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Comparing the Added Value of Blended Science and Literacy Curricula to Inquiry-Based Science Curricula in Two 2nd-Grade Classrooms

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Abstract

In response to pressures to integrate literacy and science learning, an observational, comparative analysis was conducted exploring the added value of blended science and literacy curricula over inquiry-oriented science curricula in two 2nd-grade classrooms (ages seven to eight). Data were collected over ten weeks by the research team, and statistically significant differences were found in favor of the blended curricula on measures of identity and student understanding of the nature of science (NOS) as well as conceptual understanding. Analyses of the reading, writing, and language use in both classrooms suggests several factors that may have contributed to these important differences in outcome.

The Science and Literacy Connection

As pressures for an emphasis on early literacy instruction continue, other subjects risk being squeezed out of elementary classrooms (Asimov, 2007; Gaskins & Guthrie, 1994; Glynn & Muth, 1994; Hand et al., 2003). Educators face a growing call for scientific literacy while facing decreasing instructional time and curricular resources for the teaching of science in elementary classrooms (American Association for the Advancement of Science [AAAS], 1989). Simultaneously, many elementary teachers lack confidence and proficiency in teaching science because much of their preparation was in the area of early literacy (Koballa & Crawley, 1985; Ramey-Gassert & Shroyer, 1992). In reaction to these tensions, science and literacy educators are partnering with unprecedented frequency to integrate these curricular areas (Baker & Saul, 1994; Hand et al., 2003). Thus, the science and literacy connection is a growing area of theoretical development, curricula design, and research (Keys, 1999; Peacock, 2001; Peacock & Weedon, 2002; Shepardson & Britsch, 2001).

This growing body of research has articulated clearly the shared cognitive processes embedded in science and literacy (Padilla, Muth, & Padilla, 1991), as well as the metacognitive processes required to do either well (e.g., sequencing, making inferences, and analysis) (Baker, 1991). Further, Guthrie and Ozgungor (2002) and Palinscar and Magnusson (2001) connect the two curricular areas through a shared approach to investigation (i.e., investigating textual meaning versus investigations of the world), while others connect science and literacy by their similarities in applying knowledge to new situations (Romance & Vitale, 1992). In bringing these conceptions together, Hapgood and Palinscar (2007) argue that a natural connection exists between inquiry-based science and literacy learning. They offer an extensive list of ways to connect literacy with inquiry practices in elementary science classrooms by utilizing the discursive processes of reading, writing, and oral language. In addition, the need for more exposure to informational texts in elementary literacy classrooms has been well-documented (Duke, 2000), and research is emerging supporting content-oriented instruction over strategy-oriented instruction in reading gains (Vitale & Romance, 2007).

As with literacy, science can be viewed as a discursive process requiring the making of meaning through language, text, signs, and symbols (Lemke, 1990). Scientists operate within communities of practice, adhering to particular ways of talking, acting, writing, and thinking (Latour & Woolgar, 1986; Lave, 1988; Lemke, 2001). Understanding these community norms is essential for science learning, and understanding how science teaching guides children's comprehension of these norms is essential (Roth, McRobbie, Lucas, & Boutonné, 1997; Roth & McGinn, 1998). Through the discursive connections between literacy and science and their shared cognitive processes, it seems logical and imperative to explore curricular materials emphasizing each.

Situative and sociocultural perspectives suggest that entering a community of practice (i.e., the discursive practices of science) provides motivation and engagement that supports learning and identity development (Eckert, 1989; Greeno, Collins, & Resnick, 1996; Lampert, 1990; Lave & Wenger, 1991; Smith, 1988). From this, we might expect that children wanting to enter the discursive science community may be influenced by the degree to which they are already interested in science and their existing identity structures. For example, one student in the study that follows articulated a strong pre-existing commitment to becoming a scientist (as assessed by identity and interest measures). From a situative, discursive perspective, this student might be hypothesized to gain more from a curriculum that attends to these pre-existing notions.

The purpose of this study was to investigate the impact of a discursive linkage between science and literacy by examining student interest in science and science identity as well as students' conceptual understanding. In addition to analyses of each of these three constructs, the research reported here also sought to explore student self-efficacy beliefs as these are often closely associated with identity (Bandura, 1986). Finally, because interest is often confounded with affect (e.g., "I'm interested in science because I like science.") (Brophy, 2004; Reeve, 1996), the decision was made to distinguish between interest in science and affect toward science and peruse data around each construct independently. A review of the constructs of interest will be provided in the "Research Questions" section.

The Curricula

Seeds: Experimental Science and Literacy Blended Unit

The experimental curriculum was a hands-on, inquiry-oriented, blended science and literacy unit developed at Lawrence Hall of Science at the University of California in Berkeley with support from the National Science Foundation under a grant titled, "Seeds of Science: Roots of Reading" (Seeds of Science/Roots of Reading, 2006). The science materials positioned learners to think, write, read, draw, talk, and generally act in ways similar to scientists. Specifically, the Seeds curriculum was designed with these goals in mind:

- To develop good inquiry and comprehension abilities
- To make explanations grounded in evidence
- To engage in the discourses of science
- To understand and use scientific and academic language

The Seeds unit was developed on the premise that science and literacy share common underlying processes like the ones listed previously and, therefore, the embedded teaching activities were designed to support each simultaneously. The Seeds unit included a series of readers mapped to unit content that included informational text, reference materials, fictional materials, text modeling processes of inquiry, and text that illustrated the lives and activities of scientists. Students and teacher frequently discussed science-related career pathways and imagined together what their lives might be like as scientists while using the readers. Without question, use of the readers supported the development of literacy and science learning with an emphasis on the discursive practices of science. A teacher's guide described suggested activities as well as the scope and sequence of the curriculum.

GEMS: Hands-on, Inquiry-Based Comparison Curriculum

The comparison curriculum was Great Explorations in Math and Science (GEMS) (2005), also developed at Lawrence Hall of Science, which served as the foundation materials for the experimental Seeds materials. Indeed, the comparison GEMS unit maintained the same curricular focus as the blended Seeds unit but without the literacy components. In terms of design features, "GEMS activities engage students in direct experience and experimentation to introduce essential, standards-based principles and concepts." In addition, GEMS strives to engage all learners and maximize interest and participation in science. In this research, the comparison GEMS unit was hands-on, inquiry-oriented, and activities-based, and was designed to model the processes of science. These processes include collecting data, analyzing information, developing and testing hypotheses, and basing conclusions on evidence. Class time also included time for individual storytelling, the sharing of personal experiences related to class content, the pursuit of individual and group inquiry, and having fun. It should be noted that GEMS has a long history of wide-scale use across the U.S. and abroad, indicating some degree of face validity with curriculum specialists and teachers.

In summary, this research sought to compare two innovative and high-quality curricular programs. Though both focused on inquiry and science processes, the experimental Seeds materials also included a literacy component.

Methods

Research Questions

Based on the theoretical framework, we hypothesized that an effective blending of science and literacy curricula—one that tapped the science and literacy connection—would have a greater impact on several cognitive and affective factors. Specifically, we asked the following research questions: Compared to students taught with the GEMS curricula, do students taught using the experimental Seeds curricula demonstrate statistically significant degrees of

- affect toward science, interest in science, efficacy beliefs about themselves as science learners, and identity affiliations about themselves as science learners?
- understanding of the nature of science (NOS)?
- conceptual understanding?

In addition, careful observations were made documenting how reading, writing, and language were used differently in each of the classrooms. These observations were brought to bear in analysis of the research questions above and will be treated as a separate analytic task.

Setting

In an effort to evaluate these two curricula according to the cited research questions, an elementary school (Grades K through 5; N = 450) in a small town in the northwestern U.S. was selected, which included a willing principal and two interested teachers who were eager to participate. The surrounding community is overwhelmingly Caucasian, working class, and conservative in politics and values. As an illustration of this, the district provides release time for interested students each Wednesday morning in all grades for structured *Bible* study. About 75% of all students attend these 60-minute sessions held at various off-campus sites within walking distance of the school.

As the two teachers comprised the entire 2nd-grade faculty, all 2nd graders in this elementary school were, by default, participants in the research study. The student population in these classrooms reflected the demographics of the larger community: largely Caucasian and working class families. Appropriate informed consent was obtained from both students and their parents or guardians, and this evaluation study was approved by the Institutional Review Board (IRB) of the university of the lead researcher.

Each teacher participant had taught 2nd graders in this building for several years. In that regard, they represented a fairly close-knit instructional team and were eager to collectively join this evaluation study. After an introductory meeting in which the role of the research team (author and graduate assistant) and the variations across the instructional programs were explained, the participant teachers identified by coin toss who would deliver the Seeds curriculum.

Variations in curricula, time in study, student demographics, and other classroom level variations are presented in Table 1. The left-hand column lists the categories for which comparisons are made between the various pedagogical treatments. The two classes were similar in size, gender distribution, and the lack of student ethnic diversity.

Table 1. Setting Variations for Each 2nd-Grade Class

Setting Variable	Seeds Experimental Class	GEMS Comparison Class
Characterization of curriculum/pedagogy	Blended science and literacy	Hands-on, inquiry oriented
Science curriculum unit	Terrariums/habitats	Terrariums/habitats
Frequency of science instruction	4 days/week, 45-60 minutes/day, 200 minutes/week	3 days/week, 45-60 minutes/day, 150 minutes/week
Frequency of literacy instruction	3 days/week, 45-60 minutes/day, 150 minutes/week	4 days/week, 45-60 minutes/day, 200 minutes/week
Total science and literacy minutes per week	350 minutes/week	350 minutes/week
Total science unit duration	10 weeks	8 weeks
Student ethnicity by gender	1 Asian girl 1 African-American girl 1 African-American boy 10 Caucasian girls 13 Caucasian boys	1 Hispanic boy 14 Caucasian girls 12 Caucasian boys
Teacher ethnicity, gender, and experience	Caucasian female; 16 years teaching	Caucasian female; 12 years teaching

Curricular Administrations

The major difference occurred in the frequency and duration of instruction between the two classrooms. Though the experimental Seeds classroom spent more time in science instruction (although blended with literacy) than the comparison classroom, minutes spent in supplemental literacy instruction was less than in the comparison classroom. Total minutes per week spent in both science and literacy instruction were equivalent. Although the nature of this supplemental literacy instruction is important, this was, unfortunately, not detailed.

Observation Schedule

To increase fidelity of implementation, the research team visited each classroom on a schedule to observe, interact with students, and take extensive field notes in an effort to characterize the nature of the instructional program as well as details about the teaching and learning that took place. Table 2 provides a brief synopsis of the differences in the instructional strategies between the two classrooms. It is clear that the types of instructional strategies employed were quite similar.

Table 2. Showing Percentage of Time in Various Instructional Strategies

Setting Variable	Seeds Experimental Class	GEMS Comparison Class
Teacher lecture/demonstration	10%	13%
Teacher-led discussion	19%	15%
Independent seat work	14%	9%
Collaborative activity	42%	52%
Assessment	15%	11%

Measures

The Feelings Toward Science Inventory

This measure is an amalgam of four factors and associated items taken from several sources and is intended to measure affect, interest, efficacy, and identity. The inventory has been used effectively in several evaluation studies of elementary science learning and exhibits high reliability ratings for each of the factors (Girod, 2001). Specifically, the four factors measured by the inventory are (1) student affect toward science—that is, the emotion directed toward science and the science class; (2) student interest in learning science, which may be considered affect coupled with a cognitive component; (3) student efficacy beliefs about themselves as science learners; and (4) student identity affiliations toward science or a rating of themselves as a "science type person." Table 3 examines the origin of the factors and the individual items that comprise it.

Table 3. Origin and Exemplars for the Feelings Toward Science Inventory

Factor	Original Source	Exemplars
Affect and Interest	Taken from the Attitude toward Science in School Assessment (Germann, 1988) but divided into separate constructs after exploratory factor analysis.	Affect: "I have a good feeling toward science" and "Science is fun." Interest: "I enjoy learning science" and "Science is interesting to me."
Efficacy	Items taken as a factor from a measure of motivational and self-regulated learning of classroom academic performance (Pintrich & DeGroot, 1990).	"I believe I will do well in science" and "I think I am capable of learning science."
Identity	Items taken from several scales	"I am a science-type person" and "I can imagine myself as a scientist."

All items were measured on a five-point, Likert-type scale and reliability statistics indicated that the measure performed reasonably well with Cronbach's alpha statistics, ranging from a low of 0.82 on the identity factor at pretest to a high of 0.90 for the interest factor at posttest. (The full measure is included in Appendix A.)

NOS

Though explorations of student understanding of the NOS is a popular and well-explored area of research in science education, a dearth of research exists in regards to student understanding of the NOS with children as young as 2nd grade. For this reason, it was not possible to borrow an existing measure with previously established levels of reliability and validity; thus, it became necessary to develop a suitable instrument.

After exploration of the scholarly literature around NOS (Lederman, 1992; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Meichtry, 1993; Solomon, Scott, & Duveen, 1996), seven key elements were identified. These seven key elements match nicely with the definition of NOS provided by AAAS (1989):

1. Science has method(s).
2. It is based on method and data.
3. It uses observation, tools, and data.
4. People do science and work together.
5. It requires tentative nature of science knowledge.
6. Methods mean science is "portable."
7. Imagination and creativity are used.

Rather than develop a lengthy and possibly unwieldy paper-and-pencil measure of these constructs, an interview protocol was designed to encourage children to talk about their thoughts on each of these. Both prior to and following administration of the curricular units, participants were interviewed in an effort to judge understanding of the NOS. All interviews were conducted by the author with individual students and ranged from ten to 30 minutes in length. All interviews were recorded and transcribed verbatim. The research team then rated the interview protocols, blind for students, class, and time of administration. Responses were scored based on both the sophistication of the student response and the number of examples and supporting evidence provided by the student. Initial rater agreement exceeded 85%, but all disagreements were discussed and an agreed-upon score was entered. (The questions and rating scale for the student NOS interview is included in Appendix B.)

Tests of Conceptual Understanding

Both pre- and posttests of conceptual understanding consisted of ten short-answer questions designed by project staff at Lawrence Hall of Science. The measure of conceptual understanding was modified to include a question measuring student's ability to design an inquiry as this is a required benchmark for students of this age in the state where the research occurred. This addition was designed and included upon the request of the participating classroom teachers. As with the Feelings Toward Science Inventory, pre- and posttests of conceptual understanding were scored twice, once by each member of the research team, blind to student identity, time of administration, and curricular condition. All scoring discrepancies were discussed and resolved during determination of total scores, though initial rater agreement exceeded 90%. (The final measure and associated scoring parameters are included in Appendix C.)

Summary of Design

Given the differences between the curricula described earlier and the research questions above, a quasi-experimental, pre-/poststudy was employed where students, prior to and following instruction, responded to scales for affect, interest, efficacy, and identity; measures of understanding of the NOS; and conceptual understanding. All tests were identical for each classroom and for time of administration. In all cases, student data were catalogued and scored blind by the research team.

Results

Research Question #1: Effect on Student Feelings Toward Science

Students in both classes responded to the Feelings Toward Science Inventory before science instruction had begun and again at the conclusion of the science units. The inventory was completed individually, and the regular classroom teacher circulated among the students, assisting with the few reading difficulties that did occur. Likert responses were converted to a numeric value, and items written in reverse were switched to allow for the aggregation of total factor scores. Possible scores for each factor ranged from a low of four (one point for each of the four items) to a high of 20 (five points for each item). Descriptive statistics for the Feelings Toward Science Inventory for both classes is found in Table 4.

Table 4. Descriptive Statistics for the Feelings Toward Science Inventory

	Seeds Experimental Class		GEMS Comparison Class	
Factor	Pretest	Posttest	Pretest	Posttest
Affect				
Mean	17.26	17.65	16.48	18.00
SD	2.63	2.11	2.77	2.97
Interest				
Mean	17.11	17.96	16.77	17.77
SD	2.59	1.84	2.56	2.65
Efficacy				
Mean	17.11	18.38	16.55	17.11
SD	2.26	1.57	3.32	2.26
Identity				
Mean	14.57	17.46*	14.92	15.11
SD	2.80	1.77	3.35	3.47

Pre-/postgain comparisons: *$p < 0.01$

Analysis of Table 4 reveals that across each of the four factors, differences in pretest scores between the experimental Seeds classroom and the comparison GEMS classroom were small. Independent samples of *t*-tests were used to explore the size of these pretest differences, and no statistically significant differences were found. Due to these small pretest differences, no efforts were taken to control for pretest differences on investigations of posttest differences. In other words, pretest scores were not used as a covariate in modeling the effect on posttest scores. As a precaution against increased chance of type I error, the probability level was adjusted to less than 0.025 for rejection of the null hypothesis and for findings to be considered statistically significant. This seemed an appropriately conservative approach given small sample sizes and acknowledging that, indeed, small pretest differences did exist. This technique is repeated throughout analyses (Gay & Airasian, 2003).

Given this, independent samples of *t*-tests were used to explore differences at posttest between the two classes. Nonsignificant differences were found for affect ($t = -0.49$, df = 51, $p = 0.63$), interest ($t = 0.29$, df = 51, $p = 0.77$), and efficacy ($t = 2.08$, df = 51, $p < 0.05$). A significant difference was found for the identity factor in favor of the experimental science and literacy unit ($t = 3.08$, df = 51, $p < 0.01$).

Research Question #2: Effect on Student Understanding of the NOS

The scoring procedures described previously yielded the results found in Table 5.

Table 5. Individual NOS Items by Class and Time of Administration

	Seeds Experimental Class		GEMS Comparison Class	
NOS Protocol Item	**Pre-Mean**	**Post-Mean**	**Pre-Mean**	**Post-Mean**
What does a scientist do?	1.15	2.04	1.44	1.55
How does a scientist try to learn about things?	1.23	2.34	1.11	1.29
If a scientist wanted to claim that something was true, what proof would he or she provide to convince others?	1.11	2.15	0.92	1.51
Once a scientist has learned something, what does he or she do with that knowledge?	0.84	2.15	0.70	0.96
If a scientist says something is true, is it? Is it true forever? *Probe:* What would have to happen to make it not true later?	1.50	2.34	1.22	1.77
Do scientists use their imaginations? *Probe:* If so, when? If not, why not?	1.65	2.79	1.67	2.22
Would scientists who live in different parts of the world—who might speak different languages and use different tools—agree on new science ideas?	1.15	2.11	0.96	1.66
Total NOS	8.65	15.92*	8.04	11.00
SD	(2.07)	(1.92)	(1.93)	(2.76)

$^{*}p < 0.001$

As with analysis of affect, interest, efficacy, and identity, mean pretest differences between classes were explored using independent samples of *t*-tests, which returned very small, nonsignificant differences. In other words, students' initial understanding of the NOS was very similar between treatment and comparison classrooms. Comparisons of the *t*-test between class means for the posttest of NOS revealed a statistically significant difference in favor of the experimental Seeds curriculum, where $t = 7.52$, df = 51, and $p < 0.001$ with a mean difference of 4.92 between classes.

Research Question #3: Effect on Student Conceptual Understanding

Table 6 contains the descriptive statistics for pre- and posttest administrations for conceptual understanding in both classes. A total of 36 points was possible on both pre- and posttests.

Table 6. Descriptive Statistics for Tests of Conceptual Understanding

	Seeds Experimental Class		GEMS Comparison Class	
Factor	**Mean**	**SD**	**Mean**	**SD**
Pretest	7.73	4.55	7.40	3.46
Posttest	27.81*	2.46	22.85	4.26

*$p < 0.001$

Again, the technique of comparing pretest means to determine if more advanced modeling was needed was employed, and independent samples of *t*-tests on pretests of conceptual understanding between the two classrooms revealed very small, nonsignificant differences. Independent samples of *t*-tests comparing posttest scores revealed statistically significant differences with a $t = 5.15$, df = 51, and $p < 0.001$.

Analysis of Reading, Writing, and Language Use

Detailed field notes were recorded during observations of each period of science instruction in both classes. At the conclusion of each lesson, these field notes were reviewed by both members of the research team, and weekly analytic memos were written to summarize observations and to begin speculating about the major differences between the two instructional programs in terms of reading, writing, and language use. At the conclusion of science instruction in both classrooms, all field notes and analytic memos were reviewed, and an initial coding scheme was developed to begin to differentiate empirically between the two classes. Initial themes focused on the processes being used by students (i.e., hypothesizing, analyzing, and critiquing), but these codes became overly cumbersome and difficult to distinguish and trace across time. In the end, more broad analyses of reading, writing, and language use were employed, and categories within each were identified following the constant-comparative method (Glaser, 1978; Glaser & Strauss, 1967). For example, analysis of reading activities revealed that exegesis of author meaning and fantasy text dominated the GEMS classroom while interpretation and critique were more prevalent in the Seeds classroom. These differences correspond well with the intended emphases of the curricula employed and may have contributed to the differences in student outcomes already established. More specifically, examinations of reading, writing, and language use in each classroom are provided below.

Reading During Science

Reading tasks were used in both the Seeds and GEMS classrooms, but the nature of these reading activities varied greatly. Overwhelmingly, reading in the GEMS classroom focused on fictional examples of science (i.e., storytelling) laden with content in opposition to a sophisticated understanding of the NOS in particular. Several stories that were read to students contained examples of anthropomorphism. For example, in a story about forest creatures and their environment, the following line was found describing how raindrops form: "As the drops of rain got bigger and bigger in the cloud, they began to get tired and so they fell to the ground."

Only four short opportunities were provided for students to read informational text requiring formal science language. On each of these occasions, the GEMS teacher downplayed the importance of these informational texts as "hard" and "boring."

By contrast, reading in the Seeds classroom included opportunities to review the ideas of scientists as illustrated by the following exchange recorded between the teacher and a student:

Teacher: What are the main ideas about decomposing that these scientists are trying to tell us?

Student: I found one book that says earthworms squirt out mucus when they're scared and another that says they use mucus to slide through the dirt. Which one is right?

In addition, students were encouraged to critique the nature of the text in the Seeds classroom. A student named Johnny, after being asked to discuss what he had learned from the pictures in the book, claimed, "I'm not sure what this picture is trying to tell me. Is it here to make the story interesting or is it showing me how roots look underground? I guess it could be doing both." Finally, reading in the Seeds classroom allowed for interpretation of text as opposed to exegesis in the GEMS classroom. It was common for the Seeds teacher to ask questions about the intended meaning of the author for various passages.

Writing Use During Science

Writing activities in the GEMS classroom were either highly directed data collection that lacked analysis or interpretation demands or creative writing with almost no guidelines or requirements around accurate representation of data or the NOS. In other words, writing was not an integrated component of the science unit and was used either functionally or creatively to add interest to the science unit.

By contrast, writing in the Seeds classroom emphasized several different kinds of writing that were each connected closely to the content of the instructional unit. For example, during a creative writing activity, students were asked to write a story about what might have happened that would explain the data being displayed in an accompanying graph. Students were free to invent circumstances but had to match circumstances to data.

During analytic writing activities, students were frequently asked to describe how data informed their understanding. In the most extended use of writing in the Seeds classroom, students engaged in an expository activity in which they were required to communicate the findings of individual inquiry projects to students in their 5th-grade partner classroom (both 2nd-grade classrooms had 5th-grade partner classrooms). This writing had to include both narrative text as well as a visual representation of data. The goal of the activity was explicitly defined as "to make a strong argument with data."

Language Use During Science

Language use in the GEMS class was inquiry oriented but did not often demand that students take a position and defend it with logic or data. For example, after a worm died in one of the class terrariums, the teacher posed the question, "Why might the worm have died?" Nine separate ideas were solicited from students, but many were outlandish, fanciful, and lacked any connection to available evidence (e.g., "Maybe [the worm] died of cancer."). Storytelling and experience sharing in the GEMS classroom was frequent and seemed to play an important role in student interest and enthusiasm about the unit content. However, in almost all cases, these opportunities were not used to scaffold analytic thinking, curiosity, or other elements that might correspond to an understanding of the NOS.

By contrast, language in the Seeds classroom emphasized formal and informal science literacy. It was common for the teacher to ask students how a scientist would talk about the ideas being discussed. To facilitate this, a word chart was used to identify both everyday and scientific discourse. Argumentation and problem solving were very common in the Seeds classroom as well as illustrated by the following exchange:

Teacher: Robert, do you agree with what Robin just said?

Student: Well, not really.

Teacher: Sometimes scientists disagree with each other too as they search for the right answer. So if you disagree that's ok. Can you explain why you disagree?

Student: Because I couldn't tell where the water was coming from. I'd have to set up my own experiment to tell where the water was coming from in my terrarium.

Finally, language use in the Seeds classroom focused on a variety of academic languages, including numeric systems, such as measuring and data calculation, and representational systems, including frequent use of charts and graphs.

Discussion

It appears the experimental science and literacy Seeds curriculum has some advantages over the inquiry-oriented GEMS curriculum. Ratings of students' understanding of the NOS were statistically significant for the experimental group. Student conceptual understanding of the objectives of the terrarium/habitats unit also appeared to have been supported more thoroughly by the blended curriculum. These are two very important findings that warrant more thorough examinations of connections between science and literacy. In addition, however, nonsignificant differences were found on measures of interest and affect between the two units of instruction. A close examination of mean scores reveals that more growth on these constructs occurred in the GEMS classroom. Perhaps this is also a trend that should be explored further. It could be, for example, that a hands-on curriculum contributes to student interest and affect above and beyond that of a blended science and literacy inquiry-oriented curriculum. Curriculum developers need to understand these issues thoroughly.

A statistically significant difference was found in favor of the blended unit on the identity factor. In addition, differences on the efficacy factor would have proven to be statistically significant, but the probability level was lowered from less than 0.05 to less than 0.025 to guard against type I error from small pretest differences. It has been demonstrated that measures of identity and efficacy are linked (Bandura, 1986), so this result is cross-validated. What is important to consider is the role this blended science and literacy curriculum appears to have on students' development of self. We could speculate that reading, writing, and talking like a scientist allowed children to grow in these areas more than just acting as one, as was done in the inquiry-oriented GEMS curriculum.

Examinations of reading, writing, and language use in the two classrooms reveal clear and potentially powerful differences. It is unclear just what role these differences play in terms of the other outcome measures or in the development of literacy goals, but data seem to support that these differences do indeed matter. More detailed analyses of this aspect of the literacy components is critical for a thorough understanding of these issues.

Though the data suggest efficacy for the experimental Seeds curricula, it is inconclusive what role, precisely, the nature of the blended science and literacy curricula played to cause these differences. Classroom research, especially in the primary grades, is a very messy endeavor with an almost endless list of uncontrollable and potentially confounding variables. Much larger scale replication studies are needed to cross-validate these results. Also more fine-grained analyses on the discursive practices in classrooms are needed to explore the potential impact of the science and literacy connection and the Seeds curriculum.

Limitations

Several important threats to both internal and external validity exist. First, it is possible that the deep conservativism of the community in which this investigation was conducted confounds with students' existing and/or emerging senses of science identity affiliation. It is possible that some students were more or less inclined to believe they could become scientists principally as a result of these community values. In addition, the content of the science units taught included references to adaptations which may have been viewed as bordering on an evolutionary perspective. This too may have had an impact on these overwhelmingly religiously conservative students. Though these concerns may have little effect on such young children, it does raise questions about determining the effect of this curriculum with older students.

Second, as with much research attempting to explore differences in curricular impact, this study confounds curricula with the teacher. It is possible that there could be several important teacher-level characteristics that lend themselves to the strengths and weaknesses of the instructional program independent of the curricula itself. For example, if one teacher connected uniquely well with students or communicated more effectively than the other, these factors could threaten the internal validity of the research assertions. It is the opinion of the research team that this was likely a minor concern with these two teachers, but less observable teacher-level qualities could have been in effect.

Third, because no measure of literacy learning was applied during these time periods, we have no way of knowing if one curricular program was more or less effective than the other in terms of literacy-focused outcomes. Though we have some rough accounting of how reading, writing, and language were used, we have no way of knowing how successfully literacy learning occurred. More analytic work is needed on these important issues. For example, what is the effect on vocabulary learning, reading comprehension, and fluency when integrating science and literacy? These are important questions and warrant further inquiry.

Fourth, analyses of reading, writing, and language use were conducted such that the researchers were not blind to the treatment condition. In other words, it could be that a researcher bias was present in the analysis of classroom activities. This may have had a leading effect on findings, but it is unknown at this time.

Despite these and other validity threats, it seems both logically and empirically possible to continue to pursue investigations of attempts to integrate science and literacy instruction in the everyday spaces of classroom practice. The diminishing prevalence of science-specific instruction in U.S. elementary classrooms, exacerbated by the assessment-driven pressures of our current accountability systems, threatens to leave us with a generation of science-illiterate children. Efforts such as the experimental Seeds curricula explored here must be sustained, expanded, and evaluated in an effort to hold a position in the elementary curricula.

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Appendix A: Feelings Toward Science Inventory

Please circle the response that matches best with how you feel about the statement. This will have absolutely no impact on your grade, so please be as honest as you can.

1. Mastering science ideas is hard for me.
YES!! yes not sure no NO!!

2. I can imagine myself as a scientist.
YES!! yes not sure no NO!!

3. I would like to learn more about science.
YES!! yes not sure no NO!!

4. Science is fun.
YES!! yes not sure no NO!!

5. I feel comfortable with science, and I like it very much.
YES!! yes not sure no NO!!

6. I have a good feeling toward science.
YES!! yes not sure no NO!!

7. Science is boring.
YES!! yes not sure no NO!!

8. Science is interesting to me.
YES!! yes not sure no NO!!

9. I think I am capable of learning science.
YES!! yes not sure no NO!!

10 I believe I will do well in science.
YES!! yes not sure no NO!!

11. I have a hard time understanding science.
YES!! yes not sure no NO!!

12. Science just isn’t for me.
YES!! yes not sure no NO!!

13. I am a science-type person.
YES!! yes not sure no NO!!

14. Science makes me feel uncomfortable, irritated, and bored.
YES!! yes not sure no NO!!

15. I enjoy learning science.
YES!! yes not sure no NO!!

16. Other people think of me as a science-type person.
YES!! yes not sure no NO!!

Appendix B: Scoring Rubric for NOS Interviews

Question	0 points	1 point	2 points	3 points
What does a scientist do?	No answer	Lists one action that makes some sense	Lists one to two actions that are common	Lists two to three critical actions for scientists (e.g., investigate, studies, and experiments)
How does a scientist try to learn about things?	No answer	Lists one reasonable idea	Lists one to two common ideas	Lists two to three critical ideas about scientific investigation (e.g., uses tools, gathers data, and also see above)
If a scientist wanted to claim that something was true, what proof would he or she provide to convince others?	No answer	One idea	One to two ideas with weak defensibility	Two to three ideas with a strong discussion of the defensibility of evidence
Once a scientist has learned something, what does he or she do with that knowledge?	No answer	Lists one reasonable idea	Lists one to two common ideas	Lists two to three critical ideas about the dissemination of new knowledge and scrutiny
If a scientist says something is true, is it? Is it true forever?	No answer	Yes true and true forever	One definitive and one tentative	Both tentative
Do scientists use their imaginations?	No answer	No with little justification	Yes with no logical justification	Yes with a logical justification for when scientists use their imaginations
Would scientists who live in different parts of the world—who might speak different languages and think in very different ways—agree on new science ideas?	No answer	No because the scientists are different or yes but without a logical defense	Yes because of methods of science	An answer that acknowledges the context dependence of scientific knowledge and discovery

Appendix C: Test of Conceptual Understanding

Circle the best answer for each item or write a sentence or two as appropriate.

1. How is new soil made?
   a. It is made in soil factories.
   b. New soil isn't made. It's already there.
   c. Living and nonliving things break down into tiny pieces.
   d. It is pushed to the surface during earthquakes.
   Scoring: The correct answer is C; two points if correct, and zero points if incorrect.

2. What are three clues that can tell you that a leaf is beginning to decompose or rot?
   Criteria: Accurately describing three or more indicators to tell if something is decomposing warrants full credit. Accurately describing one or two indicators of decomposition warrants partial credit.
   Scoring: Five points for full credit, three points for partial credit, and zero points for no credit.

3. Why are rotting plants helpful?
   a. They release nutrients (like vitamins) that help new plants grow.
   b. Rotting old plants are not helpful; they are bad for new plants.
   c. They smell bad and this keeps bugs away.
   d. The plants in the pile get bigger.
   Scoring: The correct answer is A; two points if correct, and zero points if incorrect.

4. Why do plants need soil?
   a. To get air and carbon dioxide
   b. To get water and nutrients
   c. To keep insects away
   d. To take in sunlight
   Scoring: The correct answer is B; two points if correct, and zero points if incorrect.

5. Why do humans need soil? List as many reasons as you can.
   Criteria: Accurately describing two or more ways that humans need soil warrants full credit. Accurately describing one way that humans need soil warrants partial credit.
   Scoring: Five points for full credit, three points for partial credit, and zero points for no credit.

6. What are three ways that soils can be different from each other?
   Criteria: Accurately describing three ways that soils can be different from each other warrants full credit. Accurately describing one or two ways that soils can be different from each other warrants partial credit.
   Scoring: Five points for full credit, three points for partial credit, and zero points for no credit.

7. How do earthworms help the soil?
    a. They eat insects that are bad for soil.
    b. They spread seeds underground.
    c. They keep the soil warm.
    d. They let air and water into the soil.

    Scoring: The correct answer is D; two points if correct, and zero points if incorrect.

8. What are two things that help earthworms live in soil?

    Criteria: For full credit, the student needs to list two things that help earthworms live in soil, including the adaptation (i.e., structure or behavior) and how it helps. For partial credit, the student needs to have one thing that helps earthworms live in soil, including the adaptation (i.e., structure or behavior) and how it helps.

    Scoring: Three points for full credit, two points for partial credit, and zero points for no credit.

9. What do you think will happen to the leaves on the ground if they are left under the tree? Tell why you think so.

    Criteria: The student should receive full credit for describing what will happen to leaves on the ground using the process of decomposition and why they know this. The student should receive partial credit for describing some other process than decomposition or for explaining decomposition and not explaining how they know this will occur.

    Scoring: Five points for full credit, three points for partial credit, and zero points for no credit.

10. We know that some frogs live in forests, others in deserts, and others in jungles. If somebody gave you a frog, how could you figure out if that frog was best suited for life in a forest or in a desert? What would you do to figure it out?

    Criteria: Full credit should be awarded when the student describes clear and complete procedures for a solution, and describes data, observations, and variables. Partial credit should be awarded when the student describes incomplete or unclear procedures or incomplete observations and assumptions.

    Scoring: Five points for full credit, three points for partial credit, zero points for no credit.

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