

Science Learning in the Terrarium Habitats Unit¹

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Seeds of Science/Roots of Reading: Effective Tools for Developing Literacy Through
Science in the Early Grades**

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Abstract

Two research studies were conducted using a pre-test/post-test design, an experimental group learning with the new Seeds curriculum (Terrarium Habitats unit), and two comparison groups including the parent GEMS unit on which the Seeds unit is based and a third, popular curriculum published by Scholastic. Both of the studies were designed to explore the efficacy of the Seeds curriculum to impact student affect, interest, efficacy, identity, understanding of the nature of science (NOS), conceptual understanding, and the degree of transfer to out-of-school contexts. The role of discourse was also explored, in particular, its effect on student understanding of NOS. A third study, exploring the demands of implementation of Seeds curriculum was also explored. Each study demonstrates a clear and compelling “value added” of the Seeds unit over the parent GEMS unit as well as over learning taking place as a result of the Scholastic unit. Though the demands of the Seeds unit are significant, they are not so great as to present legitimate hurdles in the scaling up and more wide dissemination of these materials.

Introduction

The Seeds of Science/Roots of Reading (Seeds) curriculum development project is funded by a grant from the National Science Foundation awarded to a development team at Lawrence Hall of Science on campus at the University of California, Berkeley. The Seeds project included the development of several integrated curriculum units blending science and literacy instruction. The new Seeds units would be based on the highly regarded, inquiry-based Great Explorations in Mathematics and Science (GEMS) materials, developed previously at Lawrence Hall. I was invited to submit a proposal to serve as an external reviewer of the curriculum materials and was funded on a sub-grant to the larger award to explore the efficacy of the Seeds units and the learning of, in particular, science content as one of the units is used in an appropriate classroom.

The science and literacy connection

As pressures for an emphasis on early literacy instruction continue (Gaskins & Guthrie, 1994; Glynn & Muth, 1994; Hand, Alvermann Gee, Guzzetti, Norris, Phillips, Prain, & Yore, 2003), other subject matter areas are getting squeezed out of elementary science classrooms. Science educators face a growing concern for scientific literacy (AAAS, 1989) and decreasing time, resources, and energy for the teaching of science in elementary classrooms. In reaction to this tension, science and literacy educators are partnering like never before to integrate these curricular areas (Baker & Saul, 1994; Hand et al., 2003). The science/literacy connection is a growing area of research, theoretical development, and curricular design (Keys, 1999; Peacock, 2001; Peacock & Weedon, 2002; Shepardson & Britsch, 2001).

A growing body of research is articulating clearly the shared cognitive processes embedded in science and literacy (Padilla, Muth, & Padilla, 1991). Baker (1991) connects science and reading through the metacognitive processes required to do either well. Guthrie and Ozgunor (2002) and Palinscar and Magnusson (2001) connect them through a shared approach to investigation, while others connect science and literacy by their similarities in applying knowledge to new situations (Romance & Vitale, 1992). It seems logical that one might support the other.

Science and literacy researchers believe strongly in the shared fundamental natures of reading (or more broadly, literacy) and science, especially coming to understand the nature of science. Through this hypothesized connection, I began seeking ways to explore systematically

these connections and the impact of these connections on students' affect and interest toward science, their identity and efficacy beliefs about themselves as science learners, their developing conceptual understandings, and, of course, their understanding of the nature of science. A more clear understanding of the relationships between these would defend efforts to blend these curricular areas in ways that only support, not compromise the learning of content in either domain.

Three small research studies were conducted in an effort to explore the different aspects of the efficacy of the Seeds unit, Terrarium Habitats. The three research studies include explorations of the Seeds curriculum and its effect on: (1) conceptual understanding, feelings toward science (affect, interest, efficacy, and identity), and transfer of learning to out-of-school-contexts; (2) the role of discourse and students' understanding of the nature of science, and; (3) the teacher and her pedagogical practices. The three studies were conducted simultaneously but will be described separately in the pages that follow.

Hired as an independent evaluator of the Seeds curriculum materials, I worked hard to remain open and unbiased in my opinions and explorations. Whenever possible, student data was catalogued and scored blind – without knowledge of student identity, treatment condition, or time of administration. In addition, I spent as much time as possible as a participant observer during science instruction in all three classrooms. I formed relationships with children and teachers in all settings and even, on occasion, played a small instructional role at some point in each of the classes. Despite these activities, I remained unbiased and maintained analytic distance as my role was, ultimately, as an evaluator of teaching and learning and the use of the various curricular programs. Even with these assurances, it is necessary to understand a bit about my own dispositions and inclinations as a science education researcher.

Perspectives on science and research in science education

My inclinations as a science educator and science education researcher are to view science as a discursive process (Lemke, 1990). Scientists conduct science in communities of practice, adhering to particular ways of talking, acting, writing, and thinking (Lave, 1988; Lemke, 2001). Understanding these community norms are essential for an understanding of science teaching and learning and the exploration of these through structured inquiry.

If we hold the view that science is a way of talking and participating in the world, then studying learners' identity and efficacy beliefs, their interests and attitudes, the ways in which

learning and interests transfer to out-of-school contexts all become important elements of study in addition to conceptual understanding. Through this, it is essential to design measures that investigate these ways of conceptualizing science and listen carefully to students as teaching and learning science progresses.

One strong component of the Seeds curriculum is the goal to facilitate students' understanding of the nature of science (NOS). The link between student understanding of NOS and the concepts of identity, efficacy, and transfer to out-of-school contexts is clear as one is likely to support the other. For example, as students gain a deeper understanding of the disciplinary norms and structures, they are more likely to affiliate with the science community and identify themselves a "science type person." Through this, exploration of student NOS is critical to a full analysis of the Seeds curriculum. Student understanding of NOS was explored systematically from the perspective of discursive and participatory science teaching and learning. It is through these lenses that these research studies were designed, executed, and evaluated.

General method

In searching for a research site, I explored the possibility of working with several groups of teachers, at several area elementary schools (my area being the mid-Willamette valley of Oregon). I selected an elementary school in a small town not far from my home that included a willing principal, and three interested teachers who were eager to participate in the project. The small town, in which the elementary school is located has a population of about 16,000 and the elementary school enrolls 450 children in grades kindergarten through fifth. Two other small elementary schools serve the remaining population of primary grade children. 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 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 respective school.

I was fortunate enough to build relationships quickly with three teachers who each taught second grade. As these three teachers comprise the entire second grade faculty, all second graders in this elementary school were, by default, participants in this research study. The student population in these classrooms reflects the demographics of the larger community; largely Caucasian and working class. Gender and number of students in each of the three classrooms was very evenly split.

The three teacher participants had each been teaching in this building for several years and had been teaching second graders the entire time. In that regard, they represent a fairly close-knit instructional team, which is likely one of the reasons they were eager to join me in this project. After an introductory meeting in which I explained my role as a researcher exploring the efficacy of the new Seeds materials, they identified which teacher would deliver the Seeds curriculum, the parent GEMS curriculum, and which would serve as a control environment teaching children a parallel unit using their current curricula, a hands-on program by Scholastic. Variations in curricula, time in study, student demographics, and other classroom level variations is represented below in Table 1.

Table #1: Setting variations for each 2nd grade class

<u>Setting variable</u>	<u>Seeds treatment class</u>	<u>GEMS control class</u>	<u>Control class (Scholastic)</u>
Characterization of curriculum/pedagogy	Blended science/literacy	Hands-on, inquiry oriented	Hands-on, teacher centered
Science curriculum unit	Terrariums/habitats	Terrariums/habitats	Ecosystems/living things
Frequency and duration of instruction	4-5 days a week 60-75 minutes/day 9 total weeks 40 total lessons	3-4 days a week 45-60 minutes/day 6 total weeks 22 total lessons	3 days a week 45-60 minutes/day 8 total weeks 24 total lessons
Student gender	12 girls 14 boys	14 girls 13 boys	14 girls 11 boys
Student ethnicity	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	1 Hispanic boy 1 Hispanic girl 1 African American boy 13 Caucasian girls 9 Caucasian boys
Teacher gender and experience	Female, 16 years teaching	Female, 22 years teaching	Female, 8 years teaching

The top row of Table 1 lists the three classes under study including the experimental Seeds unit (Terrarium Habitats), the parent GEMS unit also focusing on terrariums and habitats, and third

class – a more true control setting – which studied living things and ecosystems. Content in this unit roughly parallels the content of the first two classrooms, using Hands-on Life Science by Scholastic. The left-hand column of Table 1 lists the categories for which comparisons are made between the various pedagogical treatments. The three classes are amazingly similar in size, distribution of gender, and the lack of diversity in terms of student ethnicity. The major difference occurs in the frequency and duration of instruction between the experimental Seeds unit and the other two. Though this is a fairly serious threat to internal validity, one should also consider that while the GEMS and Scholastic units focus exclusively on science, the Seeds curriculum unit blends science and literacy. For this reason we should expect the duration of the unit to be longer as two curricular areas are taught in concert as opposed to only one.

I spent considerable time in each of the three classrooms observing, interacting with students, and taking extensive field notes in an effort to characterize the kind and complexity of discourse used in support of science learning as well as the general quality of teaching and learning. Table #2 provides a brief synopsis of the differences in the pedagogical program between the three classrooms.

Table #2: Showing percentage of time in various instructional strategies

<u>Setting variable</u>	<u>Seeds treatment</u>	<u>GEMS control</u>	<u>Control class</u>
	<u>class</u>	<u>class</u>	
Teacher lecture/demonstration	10%	13%	27%
Teacher-led discussion	19%	15%	23%
Independent seatwork	14%	9%	18%
Collaborative activity	42%	52%	28%
Assessing	15%	11%	4%

Interestingly, Table 2 doesn't easily reveal the differences between the three classes. Though the Seeds treatment class spent the least amount of time in teacher lecture/demonstration it also spent the most time in assessment activities. The GEMS classroom spent the most time in collaborative activity and the least in independent seatwork. The Scholastic classroom looks more stereotypical in this numeric portrayal but was actually a richly engaging room in which teacher and students talked at length about class content and completed fairly high quality seatwork

which clearly reinforced student learning. In other words, this numeric portrayal of the three pedagogical programs doesn't illuminate well what differences did exist between these three classrooms. For example, issues of identity, possible future selves (Markus and Nurius, 1986), and science as a profession dominated the discussions in the Seeds classroom. The emphasis in the GEMS classroom was on individual student stories, real-life experiences that connected to course content, and having fun. Students in the GEMS class really enjoyed the unit of study because of this. Finally, in the Scholastic classroom, student and teacher talk focused carefully on content and helping students to understand key concepts. Though the mood in the Scholastic control classroom was light, cooperative, and engaging, the emphasis on student learning was always clear. In all, each of the three classrooms were outstanding in instruction, the quality of the teacher, and the quality of the curricula and materials. It was within these contexts that the three research studies were executed. Each are described separately in the pages that follow.

Study #1: Exploring conceptual understanding, feelings toward science, and out-of-school transfer

I believe strongly that outstanding science teaching and curricula ought to have an effect on three critical factors including conceptual understanding, student feelings toward science (affect, interest, efficacy beliefs, and identity affiliations), and the transfer of science understandings and interests to out-of-school contexts. If teachers could deliver instruction that made a difference on each of these factors school learning would be significantly more powerful. In an effort to explore these critical issues the following research questions were explored:

1. Do treatment group students learn as much (or more) science than control group students?
2. Do treatment group students report similar (or more positive) interest in science, affect toward science, and identity affiliations about themselves as science learners, and efficacy beliefs about themselves as science learners than control group students?
3. Do treatment group students report similar (or more sophisticated) out-of-school transfer than control group students?

Specific method decisions for study #1

In an effort to explore the power of the Seeds curriculum above and beyond its parent GEMS unit as well as a common curricular alternative, I designed a study in which matched curricular units were delivered with parallel amounts of time in use, content and outcomes sought, and grade level of students instructed.

Given the differences between the three classes described earlier and the research questions above, the following specific methods were employed. A quasi-experimental, pre/post study was employed in which all students responded to pre-tests including the Feelings Toward Science Inventory and a series of short questions were asked in an interview setting to determine levels of out-of-school transfer. Only the Seeds and GEMS classrooms responded to pre and post-tests of conceptual understanding. These tests were identical for time of administration and student population. Tests of conceptual understanding were not collected in the Scholastic class as although this content was parallel to the Seeds and GEMS content, it was not identical and would not have provided valid and reliable data.

Effect on student Feelings Toward Science

The Feelings Toward Science Inventory is an amalgam of four factors and associated items taken from several sources. I have used this inventory in five previous studies of elementary science learning and it continues to achieve high reliability ratings. The four factors themselves are: (1) student affect toward science - meaning pure emotion directed toward science and 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 a science learner, and; (4) student identity affiliations toward science or a rating of themselves as a “science type person.” I believe strongly that each of these are important aspects of science learning and each are likely strong predictors of student achievement in science. Because of this, each are measured on a common inventory. Table #3 examines the origin of the factors and the individual items that comprise it.

Table #3: Factor origins for the Feelings Toward Science Inventory

<u>Factor</u>	<u>Original source</u>	<u>Exemplars</u>
Affect	Attitude toward Science in School Assessment (Germann, 1988)	“I have a good feeling toward science” “Science is fun”
Interest	Split from attitude factor in exploratory factor analysis	“I enjoy learning science” “Science is interesting to me”
Efficacy	(Pintrich & DeGroot, 1990)	“I believe I will do well in science” “I think I am capable of learning science”
Identity	Items taken from several scales	“I am a science-type person” “I can imagine myself as a scientist”

The inventory was modified to accommodate readers of a lower proficiency than I’ve explored in the past and each factor was reduced to four items making a 16-item inventory. All items are measured on a five point Likert type scale and reliability statistics indicate the measure performed reasonable well with Cronbach alpha statistics ranging from a low of .82 on the identity factor at pre-test to a high of .90 for the interest factor at post-test. The full measure is appended as A.

Students in all three classes responded to the Feelings Toward Science Inventory before science instruction had begun and again at the conclusion of the science units. I was not present

during any administration but all were administered individually and the regular classroom teacher circulated carefully between students assisting with decoding and comprehension issues. All Inventories were scored blind for student, class (Seeds, GEMS, or Scholastic), and time (pre or post) by two researchers including myself and a science education undergraduate student. Likert responses were converted to a numeric value and items written in reverse were switched to allow for the aggregation of total factor scores. Descriptive statistics for the Feelings Toward Science Inventory for all three classes is found below in Table 4.

Table #4: Descriptive statistics for the Feelings Toward Science Inventory

Factor	<u>Seeds treatment class</u>		<u>GEMS control class</u>		<u>Scholastic control class</u>	
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>
Pre-affect	17.26	2.63	16.48	2.77	16.48	4.61
Post-affect	17.65	2.11	18.00	2.97	17.08	3.77
Pre-interest	17.11	2.59	16.77	2.56	16.08	4.97
Post-interest	17.96	1.84	17.77	2.65	16.48	4.19
Pre-efficacy	17.11	2.26	16.55	3.32	15.56	4.64
Post-efficacy	18.07	1.44	17.11	2.75	16.00	3.92
Pre-identity	14.57	2.80	14.92	3.35	15.52	4.77
Post-identity	17.46	1.77	15.11	3.47	16.20	4.43

Table 4 includes a great deal of information about students Feelings Toward Science in all three classes. Rather than use post-hoc comparisons for the effect of the group and simultaneously compare the performance of students in all three groups, ANCOVA was used in three separate comparisons (Seeds vs. Gems, Seeds vs. Scholastic, and Gems vs. Scholastic). Though this does slightly elevate the risk of a type I error, the use of post-hoc comparisons and ANCOVA is controversial and unorthodox. I didn't understand this prior to preliminary analyses but it is controversial enough that the default settings in SPSS 13.0 are to preclude one from using post-hoc comparisons with ANCOVA. For this reason, multiple ANCOVA models were used to investigate differences in each of the three comparisons. Each are described below.

Seeds treatment class vs. GEMS control class

This analysis is the most critical as it seeks to understand the “value added” of the Seeds curriculum over the “parent” GEMS curriculum on each of the Feelings outcomes. As in all models, gender was explored as a covariate but was eliminated as it held no predictive value in

any model. ANCOVA analysis returned no statistically significant differences between Seeds and GEMS students on the affect factor. In analysis of the interest factor, a statistically significant difference was found in favor of the GEMS class where $p < .05$ [$F=4.08(52,1)$]. In analysis of the efficacy factor, a statistically significant difference was found in favor of the Seeds class where $p < .001$ [$F=11.82(52,1)$]. In analysis of the identity factor, a difference was also found in favor of the Seeds class where $p < .05$ [$F=4.48(52,1)$]. Statistically significant interactions existed on group*pre-test on the interest and efficacy factors but is likely only a reflection of the large gains made by all students from pre to post-test.

Seeds treatment class vs. the Scholastic control class

This secondary analysis is also critical as it explores differences between the experimental Seeds curriculum and another popular curriculum package in widespread use in elementary schools today, Hands-on Science by Scholastic. In analysis of the affect factor, a statistically significant difference was found in favor of the Scholastic control class where $p < .05$ [$F=5.25(50,1)$]. In analysis of the interest factor, a statistically significant difference was found in favor of the Seeds treatment class where $p < .001$ [$F=14.58(50,1)$]. In analysis of the efficacy factor, a statistically significant difference was found in favor of the Seeds treatment class where $p < .001$ [$F=18.76(50,1)$]. In analysis of the identity factor, a statistically significant difference was found in favor of the Seeds treatment group where $p < .001$ [$F=23.11(50,1)$]. Statistically significant interactions existed on group*pre-test score on all factors. This is likely only a reflection of the large gains made from pre to post-test for all students.

GEMS control class vs. Scholastic control class

Interestingly, ANCOVA modeling revealed no statistically significant differences between the GEMS control class and the Scholastic control class on any of the factors measured by the Feelings Toward Science Inventory.

Effect on student conceptual understanding

As mentioned previously, it seemed prudent to only compare the Seeds and GEMS classes on a test of conceptual understanding as the Scholastic control classroom did study slightly different content. In fact, the Seeds and GEMS classes responded to the exact same test of conceptual understanding both before and after instruction. The test of conceptual understanding consisted of 11 short answer questions designed by project staff at Lawrence Hall. The measure of conceptual understanding was modified to include a question measuring students

ability to design an inquiry as this is a major benchmark for students of this age in Oregon. The final measure is appended as B.

Table #5 contains the descriptive statistics for pre and post administrations of the test for conceptual understanding in both the Seeds and GEMS classes.

Table #5: Descriptive statistics for tests of conceptual understanding

Factor	Seeds treatment class		GEMS control class		Scholastic control class	
	Mean	SD	Mean	SD	Mean	SD
Pre-test	7.90	4.59	7.40	3.42	--	--
Post-test	27.20**	3.62	22.34	4.40	--	--

** p<.01

ANCOVA returns a $p < .01$ [$F=7.06(46,1)$] on the post-test of conceptual understanding indicating that, when controlling for differences in conceptual understanding at pre-test, the Seeds students achieved more learning gains as measured by the post-test, than the control class learning similar content using the GEMS curriculum materials. Table 6 below breaks scores on pre and post-tests of conceptual understanding out by gender and group.

Table #6: Descriptive by gender for conceptual understanding

Factor	Seeds treatment class				GEMS control class			
	Girls		Boys		Girls		Boys	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pre-test	4.54	2.42	10.06	4.36	7.38	3.62	7.42	3.46
Post-test	26.95	3.62	27.80	1.94	21.46	3.91	24.14	4.31

Though no statistically significant interactions were found for gender there is an obvious trend toward differential improvement for girls in the Seeds treatment class. Curiously, a much greater gap exists between pre-test scores of boys and girls in the Seeds treatment class than between boys and girls in the GEMS control class. I cannot account for this difference though the Seeds classroom teacher, upon my inquiry into this difference, did suggest that “my girls are a bit lower as a group than in previous years and yes, my boys are pretty smart!” At post-test, boys in the GEMS control class increased their slight advantage over girls while girls in the Seeds treatment class closed the gap considerably on their male counterparts. Though these differences are not statistically significant, they could suggest an additional “value added” for the Seeds treatment curriculum in terms of more effectively supporting female student conceptual understanding.

Effect on transfer to out-of-school contexts

Transfer is critical to deep, meaningful learning. As a psychological construct, transfer has been explored in great detail and means many things to many different researchers. In this case, I was most interested in participant learning that scaffolded thinking about unit content outside of class, perhaps telling others, or continuing to explore one's own ideas outside the school context. I believe strongly that science learning should change the way learners' perceive the world and shape learner action outside the walls of the classroom. I believe statements such as the following are evidence of this kind of powerful learning:

- "I was thinking about what we learned in class as I was walking home from school."
- "I told my little brother about what we are studying because I thought it was cool."
- "When I got home I looked outside for examples of what we learned in school that day."

Each are evidence of changed action – illustration of the power of science learner to creep over into one's daily life. In many regards, I believe these kinds of statements are the hallmark of powerful learning.

In an effort to explore these kinds of outcomes, I asked participants questions designed to elicit examples of transfer (of this nature) that may have occurred. Because this kind of transfer may be difficult to understand in general terms, I designed a series of short interview questions and follow-up probes rather than a survey.

Participants in all three classes were interviewed before and after instruction in an effort to explore their perceptions of the nature of science (NOS) and a short series of transfer questions were added to this interview protocol. The questions asked were:

- Did you think at all about what you've been learning in class while you were at home? If yes, probe for as many examples as possible. If not, why not?
- Did you tell anybody at home what you were learning at school in science? If yes, probe for as many examples as possible. If not, why not?
- Did you try to look for examples of any of the things you've been learning about in science class? Did you try to learn more about any of the things you've been learning about? If so, probe for as many examples as possible. If not, why not?

The full NOS interview protocol with transfer questions is appended as C.

Participants' transfer responses were coded and assigned a numeric value according to the following scale:

- Yes to thinking about science outside of class 0 – 2 points for frequency and depth
- Yes to telling others about school science 0 – 2 points for frequency and depth
- Yes to looking for examples of science ideas 0 – 2 points for frequency and depth

Student responses to the transfer questions were rated blind for participant, treatment, and time according to the guidelines above, by a research assistant and myself. Differences between assigned ratings were discussed until consensus was reached. Descriptive statistics for both pre and post-transfer scores for all three classrooms are included in table #7 below.

Table #7 Descriptive statistics for transfer in all three classes

<u>Factor</u>	<u>Seeds treatment class</u>		<u>GEMS control class</u>		<u>Scholastic class</u>	
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>
Pre transfer	.88	.60	1.12	.71	1.28	.70
Post transfer	3.28	2.42	1.58	1.49	1.44	1.20

Pre-transfer scores for the treatment class are quite a bit lower than pre-transfer scores for either the GEMS or Scholastic class students. Though analysis of variance controls for these discrepancies in initially lower scores, it seems as though some mitigating factor might also have played a role in differences between the three groups on pre-transfer scores. Post-transfer scores, however, reveal an equally large gap between the Seeds group and the other two, though this time in a more positive, affirming direction. ANCOVA returns a $p < .001$ [$F=28.88(52,5)$] for the effect of the class when comparing the Seeds class transfer scores and the GEMS class transfer scores. This difference was also statistically significant when comparing transfer between the Seeds participants and the Scholastic participants returning a $p < .001$ [$F=14.22(51,5)$]. In both models, the interaction between class and pre-transfer was significant but is likely explained by the very low pre-test scores in the Seeds class rather than some differential effectiveness for participants with lower initial levels of transfer. No statistically significant differences were found between the GEMS and Scholastic participants rates of transfer.

Discussion

Data from this study are powerful and offer compelling support for the Seeds curriculum. For the Seeds curriculum to facilitate student conceptual understanding that outpaces the already well-established and successful GEMS materials is an important result. When coupled with differences found in terms of student Feelings Toward Science – particularly efficacy and identity affiliations, the results are particularly encouraging. In my opinion, the emphasis on

structured scientific inquiry coupled with high quality science content and instruction supported through literacy all contributed powerfully on the identity dimension. Seeds class participants may have begun to see themselves as young scientists working carefully toward important problems and understandings about the world. Though affect and interest seem to fall in favor of the GEMS or the Scholastic curriculum, I believe the power of these new-found identity affiliations contributed to conceptual understanding and more examples of transfer to out-of-school settings.

Study #2: Investigating the role of discourse in the Seeds curriculum in supporting student understanding of the Nature of Science (NOS).

Because of the clear emphasis on NOS in the Seeds curriculum, it is necessary to explore the effect of the Seeds unit on NOS. More than this though, I am interested in how, specifically, student understanding of the nature of science is supported through classroom discourse. Given this, the following research questions were explored:

1. Do treatment group students report similar (or more sophisticated) understanding of the nature of science (NOS) than control group students?
2. How does discourse occurring in the context of the Seeds curriculum serve to scaffold (or not) student Feelings Toward Science, learning of science content, nature of science, and out-of-school- transfer?
3. What kinds of activities, prompts, and expectations are used to support discourse and its role in facilitating learning (all variables of interest).

Specific method decisions for study #2

Though explorations of student understanding of the nature of science is a popular and well explored area of research in science education, a dearth of research exists exploring student understanding of the nature of science with children as young as second grade. For this reason, I could not simply borrow an existing measure with previously established levels of reliability and validity.

After exploration of the field of nature of science (NOS) (Lederman, 1992; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), I established seven key elements of a definition of NOS. These seven key elements match nicely with a definition of NOS provided by AAAS and include:

1. Science has method(s)
2. Based on method and data
3. Uses observation, tools, and data
4. People do science and work together
5. Tentative nature of science knowledge
6. Methods means science is “portable”
7. Imagination and creativity are used

Rather than develop a paper-and-pencil measure of these constructs, an interview protocol was designed to encourage children to talk about their thoughts on each of these. The full protocol is appended as C.

Students were interviewed both before and after instruction and student responses were dictated, word-for-word by myself. As with the tests of conceptual understanding these interview protocols were then rated blind for students, class, and time of administration by myself and an undergraduate research assistant. Responses were scored based on both the sophistication of the student response and the number of examples and supporting evidence provided by the student. All mis-matches in ratings were discussed and resolved between the two researchers. The evaluation scale for the student NOS interview is appended as D.

What follows, in table 8, is a numerical representation of the content of the NOS interviews.

Table #8: Descriptive statistics for NOS

<u>Factor</u>	<u>Seeds treatment class</u>		<u>GEMS control class</u>		<u>Scholastic class</u>	
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>
Pre NOS	8.65	2.07	8.04	1.93	8.40	2.36
Post NOS	15.92	1.92	11.00	2.76	10.40	2.12

As with analysis of the Feelings Toward Science Inventory, ANCOVA was used to explore differences between groups for students scores on the Nature of Science measure. The only statistically significant differences returned were those involving the Seeds treatment class including a difference for Seeds treatment vs. GEMS control where $p < .001$ [$F=16.46(51,1)$] and Seeds treatment vs. Scholastic control where $p < .01$ [$F=8.58(50,1)$]. A statistically significant interaction between class and pre-test score was found when comparing the Seeds treatment class against the GEMS control class but again, this is likely only an artifact the large gains from pre to post rather than some differential effect for initially low scoring students in the Seeds treatment class.

Closer analysis of the variance in scores across items of the NOS protocol is included below in Table 9.

Table #9: Individual NOS items by class

<u>NOS protocol item</u>	<u>Seeds class</u>		<u>Gems class</u>		<u>Scholastic class</u>	
	<u>Pre Mean</u>	<u>Post Mean</u>	<u>Pre Mean</u>	<u>Post Mean</u>	<u>Pre Mean</u>	<u>Post Mean</u>
What does a scientist do?	1.15	2.04	1.44	1.55	1.36	1.32
How does a scientist try to learn about things?	1.23	2.34	1.11	1.29	1.20	1.16
If a scientist wanted to claim that something was true what proof would he or she provide to convince others?	1.11	2.15	.92	1.51	1.04	8.40
Once a scientist has learned something what does he or she do with that knowledge?	.84	2.15	.70	.96	1.00	1.60
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	1.36	1.96
Do scientists use their imaginations? Probe: If so, when? If not, why not?	1.65	2.79	1.67	2.22	1.44	1.52
Would scientists who live in different parts of the world – who might speak different languages and use different tools – would they agree on new science ideas?	1.15	2.11	.96	1.66	1.02	1.48
Total NOS	8.65	15.92	8.04	11.00	8.40	10.40

Visual inspection of Table 9 reveals that differences at pre-test on any particular NOS item are spread reasonably evenly across groups. In other words, it doesn't appear that any one item carried much greater statistical power in contributing to the statistically significant differences between Seeds treatment class students and either of the control class groups.

In an effort to explore more carefully the role that language and discourse patterns may have contributed to student understanding of the nature of science (NOS) in each of the three groups, extensive fieldnotes were taken during observations in each classroom. The total number of lessons in the Seeds treatment class was 40 and I observed and recorded field notes in 31 of

them (78%). Comparatively, total GEMS lessons equaled 22 and I observed 16 of them (72%) and total Scholastic lessons equaled 24 and I observed 18 of them (75%). In each of these I recorded detailed fieldnotes focusing most carefully on the role of discourse in the classroom. At first, I tried to record interesting interactions between teacher and student and between student and student. After several weeks of observing in the Seeds treatment classroom, however, I began to narrow my focus to analysis of discourse that supported student understanding of NOS. It became more and more clear to me that NOS is an essential element of science learning and that students in the Seeds classroom were gaining much greater skillfulness in this area. As my observations grew increasingly refined, I focused on (1) use of language in support of NOS, (2) use of writing in support of NOS and, (3) the use of reading in support of NOS. It is clear that these are essential elements of literacy and each were employed differently in the service of science learning in each of the three classrooms.

Each of the next small sections are illustrative of these analyses of literacy in support of NOS.

Literacy and NOS, language use

Language use in the Scholastic class:

- Informal language dominated the control classroom discourse unless bold-faced words or other conceptual “markers” oriented conversations toward them. Formal language was most often introduced and/or reinforced during independent seatwork.

Ex: T: “Where else do you find dirt?”

Ex: T: “What happens after things die? That’s right, things rot.”

- Argumentation seemed to be avoided in the control classroom as the teacher worked hard to support students’ ideas, free-thinking, and creativity. Too often, however, students’ ideas were neither supported by logic or data.

Language use in the Gems class:

- 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. These instances were infrequent compared to the Seeds class.

Ex: T: “Interesting idea TJ. Who else has an idea about that?” – in this one instance, 8 separate ideas were solicited from students about why a worm had died in a terrarium. Most were outlandish or fantastic and lacked any connection to available evidence.

- Storytelling was frequent and seemed to play an important role in student interest and enthusiasm about content.
Ex: T: “Who else has a story about hunting for sow bugs?”
- Data was frequently gathered in the Gems class but students were rarely asked to speak about it or interpret it.

Language use in the Seeds class:

<u>Example</u>	<u>Seeds class</u>
Formal and informal literacy (Gee, 2000)	T: “Great, but how would a scientist say that same thing?” T: “Check the word chart for the everyday and the science way of saying that.”
Argumentation and problem solving (Lemke, 1990)	T: “Robert, do you agree with what Robin just said?” S: “Well, not really.” T: “Sometimes scientists disagree with each other as they search for the right answer. So if you disagree that’s ok – can you explain why you disagree?” S: “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.”
Use of a variety of academic languages (Gee, 2000)	S: “I can tell from looking at the chart that the grass is growing faster than the flower.” T: “Somebody show the class how to use this ruler to measure the distance the earthworm crawled. How could we record this information in a data table?”

Literacy and NOS, reading

Reading in the Scholastic class:

- Reading in the Scholastic class was almost exclusively teacher-led using informational texts that accompanied the science unit. The goal of this reading was always to understand exactly what the author meant to say. The text had ultimate authority.
Ex: T: “I know you may have seen a raccoon during the day but do you remember what the book said? The book said raccoons are nocturnal. Do you remember what that means?”
- No examples of conversations about the nature of text were found nor were examples of alternate interpretations or critique of text.

Reading in the Gems class:

- Reading in the Gems class was almost exclusively fictional with occasional examples of formal science language. These texts were laden with content that ran contrary to a sophisticated understanding of the nature of science including fantasy and inanimate objects demonstrating agency.

Ex: T reading a story: “As the drops of rain got bigger and bigger in the cloud they began to get tired and so they fell to the ground.”

Reading in the Seeds class:

<u>Example</u>	<u>Seeds class</u>
Reviewing ideas of scientists (Norris & Phillips, 2003)	T: “What are the main ideas about decomposing that these scientists are trying to tell us?” S: “I found one book that says earthworms squirt out mucus when they’re scared and another one that says they use mucus to slide through the dirt. Which one is right?”
Critiquing the nature of the text (Norris & Phillips, 2003)	T: “Is this just a story about a boy doing science? What can we learn by reading this boy’s story?” S: “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?”
Allowing for interpretation of text (Norris & Phillips, 2003)	T: “What do you think the author meant when she wrote that?”

Literacy and NOS, writing

Writing in the Scholastic class:

- Writing in the Scholastic class was limited to fill-in-the-blank and short answer responses prompted from worksheets and an assessment. No examples of creative, expository, or analytic writing were found.

Writing in the Gems class:

- Writing in the Gems classroom was either highly directed data collection that lacked analysis or interpretation demands or creative writing with no guidelines or requirements around accurate representation of data or the nature of science.

Writing in the Seeds class:

<u>Example</u>	<u>Seeds class</u>
Creative writing	<p>T: “Look at this chart showing the data the boy collected. Can you write a story about what might have happened in this area that would fit this data?”</p> <p>T: “Your job is to write a short story from the perspective of a decomposer living in your terrarium. Be sure to use science words accurately in your story!”</p>
Expository writing	<p>As part of the cumulative project for the Seeds unit, students were asked to communicate the findings from their inquiry projects to students in their partner 5th grade classroom. This writing had to include both narrative text as well as a visual representation – commonly a data table or diagram. The explicit goal was to be provocative and challenging with evidence.</p>
Analytic writing	<p>T: “Using the data you’ve collected, write a sentence describing what it tells you about your question.”</p> <p>T: “Summarize by writing down the main idea of what your partner just told you.”</p>

Discussion

Each of these sections highlight components of literacy (reading, writing, and language use) and illustrate the increasingly explicit instruction around understanding of the nature of science. Participants in the Seeds classroom were simply using language more systematically and explicitly to scaffold understanding of NOS. Literacy activities in the GEMS and Scholastic classrooms were tangentially connected to science learning or simply not significant in the support of learning. In other words, the systematic attention to literacy integration, in support of science learning, was obviously apparent in the Seeds classroom and served to supplement well student emerging understanding of NOS.

Study #3: Investigating the particular science demands of the Seeds curriculum on the teacher

Specific research questions include:

1. What specific kinds of science knowledge does a teacher need to effectively implement the Seeds curriculum? Consider specific content knowledge, dispositions toward science, and understanding of the nature of science.
2. What specific pedagogical models, principles, resources, or skills does a teacher need to effectively implement the Seeds curriculum?
3. How is the Seeds curriculum similar to and different from what the teacher has used previously? Again, the emphasis here will be in terms of science but I suspect it will be challenging to separate science from literacy issues.
4. What unique opportunities does the Seeds curriculum afford, particularly in terms of content, instruction, and assessment that helps (or hinders) the teacher's ability to connect teaching and learning.

Specific method decisions for research study #3

In an effort to explore how the act of teaching was affected by the Seeds units and, in particular, the Terrarium Habitats unit, I explored issues such as teacher prior knowledge, teacher learning, and the challenges of instantiation of the Seeds unit in a real classroom. These questions were pursued through a series of extensive interviews conducted with the Seeds teacher (Gwen, a pseudonym) at the conclusion of the Terrarium Habitats unit. The interview protocol consisted of 21 total questions organized into seven different themes or strands and is appended as E.

The interview was conducted across two consecutive days, immediately following the end of the school day. The interviews lasted 45 minutes the first day and 60 minutes the next day. Extensive notes were taken to capture the thoughts, opinions, and attitudes of the Seeds teacher. Data was examined carefully for themes and a grounded theory approach (Glaser & Strauss, 1967) was used to generate categories of teacher feedback, collapse, refine, clarify, and reduce data to several key points. These key points might be considered overall "lessons learned" by this teacher and this researcher about the use of the Seeds curriculum.

Lessons learned

Lesson #1: Quality integrated curricula is possible

As the Lawrence Hall developers worked hard to “lead with science,” I was worried that perhaps Gwen would have found that the materials were not a very well integrated mix of science and literacy materials. On the contrary, Gwen believed that the level of integration was appropriate and in fact, the nature of the integration supported each content area nicely.

In discussing her past experiences teaching integrated units Gwen stated “In elementary classrooms we integrate different content areas all the time. I try to have my students write about issues we’re studying in social studies, in science, and even in art – and that’s clearly a form of integration. Never though, have I had the opportunity to use curriculum materials in which the integration was so complete and so supportive of each content area.” Gwen’s prior experiences seemed to have been about more loosely integrated lessons where ideas or content areas were referenced but she had had few experiences where different content areas so effectively supported one another. In speaking to this issue Gwen said “The heavy emphasis on student inquiry, exploration, data gathering, investigation really supported my students attempts to begin to use text for purposes other than decoding. In this regard the inquiry in science was supported and extended by the inquiry skills they are developing in my literacy program. “It was wonderful to have high quality non-fiction materials for my kiddos.” The informational readers were one of Gwen’s favorite and most heavily relied upon features of the Seeds curriculum.

Effective integrated curricula are often not only inter-disciplinary but also work to integrate across skills, knowledge, and dispositions. The Seeds curriculum is highly effective in this regard as students were consistently asked to apply knowledge, use the tools of science, and share their thoughts and feelings about what they were learning. It is clear that as a model for integration, the Seeds curriculum was very successful.

Lesson #2: Successful curriculum supports the learning of all students

It is obvious even to a dull observer that Gwen cares deeply for the learning needs of each child in her classroom. In asking her about her values in this regard Gwen spoke frankly, “I think teachers should be fired who can’t work effectively with children with varying learning needs. I realize that this is hard work but this is one piece of the No Child Left Behind legislation that I really believe in – schools should work hard to make sure all kids get a fair shake.”

In asking Gwen about her thoughts and opinions on the ability for the Seeds curriculum to effectively support the needs of diverse learners she stated, “I believe in the role of assessment in assuring that each child learns. I work hard to constantly and systematically gather data that helps me understand how each of my students is learning – what they’re struggling with and so on. The Seeds curricula had many more opportunities for formal assessment than I made use of but it also had lots of opportunities built in for informal assessment, observational kinds of checks, and other little features that helped me keep close tabs on how my babies were learning.” The recursive nature of the Seeds curriculum, and its emphasis on inquiry and exploration, seemed to support the on-going development of skills like observation, question asking, position taking, using data and so forth. “As I became more aware of the re-visiting of these skills that was going on throughout the Seeds unit, I was better able to point this out to students and began to help them see where they were in their development of these skills. It helped knowing that we were never very far from an opportunity to try out these skills again and further their development.”

I heard Eliot Eisner speak a few years ago about the goal of schooling and our efforts to understand student achievement. He spoke at length about helping all students learn to the very best of their ability and captured this sentiment in this phrase, “Schools should seek to elevate the mean and increase the standard deviation.” By this, Eisner meant that schools should help make all kids smarter but should certainly not hold back the gifted children from learning above and beyond what they might normally learn. This analogy is useful in examination of the Seeds curriculum. Gwen elaborates, “There is enough variation in what’s happening in the Seeds unit that my smartest students could really take off and ask different questions, design different methods for answering their questions, refine and extend their understanding of key ideas in ways that I didn’t have to expect from all my kiddos.” Because inquiry drove much of what happened during the unit, many children were able to proceed as their interests and abilities dictated which allowed Gwen opportunities to work more closely with students who required more support.

Lesson #3: Familiarity with inquiry teaching matters

It became obvious as the Seeds unit unfolded that managing inquiry-based instruction was something new to Gwen. Though she is an incredibly skillful teacher, she had only minimal prior experience using inquiry-based teaching methods. In recognition of this fact, Gwen stated,

“I’ve read about inquiry-based teaching and I’ve experimented with little assignments where students followed their own ideas but the Seeds unit was a full-blown, inquiry driven curriculum and I found myself a bit flummoxed now and then as to how to guide things.” In asking more about this issue Gwen was quick to credit the Seeds curriculum for providing lots of insight into how inquiry is best used in classrooms and basically chose to follow very closely the lessons and activities as provided. However, Gwen did give examples of having to think quickly and carefully about how to best scaffold student thinking about inquiry, design good questions to pursue, design good learning prompts that could be used to drive inquiry, and how to push students to new levels of insight around their own inquiry projects. “I’m not a scientist and have, in fact, taken very few science courses so when it came time to help my kiddos think about questions of their own to investigate I had to think carefully about the availability of the materials necessary to support their inquiry, whether or not the procedures they designed would provide them data that they could use to answer their question, and then how to help them organize and represent their findings. Though these were all fabulous learning experiences for my students, I was learning right along with them.”

One of my early hypotheses was that working with the Seeds curriculum would help teachers think different about issues of the nature of science (NOS). I asked Gwen several questions related to her own understanding of NOS and, though she openly admitted there was much about science she didn’t understand, a shallow understanding of NOS didn’t seem to present significant challenges for her in the same way that having only a limited familiarity with inquiry-based teaching did.

Lesson #4: Effective classroom structures are critical

After several days spent in careful observation of teaching and learning using the Seeds classroom, I wrote a list of all the routines and expectations that Gwen had already established that facilitated the effective implementation of the Terrarium Habitats unit. Needless to say, the list was extensive and included things like making sure students knew where to turn in their papers, where to get supplies, what to expect in the daily schedule, even how to walk down the hall, and participate effectively in a discussion. Each of these are routines and expectations that good teachers work to establish in their classrooms but I think they became even more critical as the Seeds curriculum was implemented because students (and/or student groups) were often working independently or on different aspects of projects. So much was going on, differentiated

for ability and interest, that Gwen would simply have had a terrible time managing had she not already established these frameworks. On this topic, Gwen stated “My kiddos know where to get materials, they know how to work together in small groups, they know how to come and ask me questions, and they have a clear sense of time and where the day is going. Because of this, I didn’t have to manage these kinds of details and we were able to focus on science and inquiry.”

Discussion

Of the three studies, the interview with Gwen was, in my opinion, the least informative as to the effectiveness of the Seeds curriculum. Though Gwen had very positive things to say in general such as, “This [the seeds curriculum] really is top-notch stuff. I’d use it again – absolutely.” Drawing out from her what, precisely, made the materials effective or valuable was more challenging. I think the four lessons above suggest a few critical ideas about implementation including: (1) helping teachers see the vision for how the integration of science and literacy was accomplished in the Seeds units; (2) helping teachers to see the value of the Seeds unit in terms of its utility to support learning of all children, despite differences in interests and ability; (3) helping build teachers facility and confidence in using inquiry-based teaching methods, and; (4) helping them to implement the Seeds materials in classrooms with existing structures and routines that will facilitate success. These are likely guidelines to consider when preparing professional development activities and marketing strategies for the Seeds materials.

Conclusions

This report summarizes findings from three mini-studies designed to explore the efficacy and challenges of implementation of the innovative new Seeds curriculum. Each study reports clear evidence as to the effectiveness of the curriculum, in particular, as it relates to maximizing student conceptual understanding, efficacy beliefs and identity affiliations, understanding of the nature of science and student transfer of learning to out-of-school settings. Each of these, in and of itself, would be a powerful indication of the effectiveness of the Seeds curriculum. Together they speak quite loudly that the Terrarium Habitats unit, one of the Seeds units, was used very effectively and much to the advantage of children in the treatment classroom. I applaud the developers at Lawrence Hall and am eager to see further development and dissemination of project materials and wisdom.

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Appendix A: Feelings Toward Science Inventory

Name:

Please answer each question as honestly as you can by circling the answer that fits best for you.

1. Science is interesting to me.

YES!! yes not sure no NO!!

2. I would like to learn more about science.

YES!! yes not sure no NO!!

3. I enjoy learning 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 makes me feel uncomfortable, irritated, and bored.

YES!! yes not sure no NO!!

8. Science is boring.

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. Mastering science ideas is hard for me.

YES!! yes not sure no NO!!

12. I have a hard time understanding science.

YES!! yes not sure no NO!!

13. Science just isn't for me.

YES!! yes not sure no NO!!

14. I am a science-type person.

YES!! yes not sure no NO!!

15. Other people think of me as a science-type person.

YES!! yes not sure no NO!!

16. I can imagine myself as a scientist.

YES!! yes not sure no NO!!

Appendix B: Test of Conceptual Understanding

Name: _____

Circle the best answer.

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.

2. What are 3 clues that can tell you that a leaf is beginning to decompose or rot?

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.

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

5. Why do humans need soil? List as many reasons as you can.

6. What are three ways that soils can be different from each other?

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.

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

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.

Appendix C: NOS Interview Protocol

Name: _____

1. What does a scientist do? Probe as appropriate. Looking for an image of a scientist.
2. How does a scientist try to learn about things? Do they use tools or other resources? Probe as appropriate.
3. If a scientist wanted to claim that something was true, what proof would he or she need to convince others? Probe as appropriate.
4. Once a scientist has learned something, what does he or she do with that knowledge? Probe as appropriate.
5. If a scientist says something is true, is it? Is it true forever? Probe as appropriate.
6. Do scientists use their imaginations? If not, why not? If so, in what ways?
7. Would scientists who live in different parts of the world – who might speak different languages and think in very different ways – would they agree on new science ideas?

Inquiry questions added to test of conceptual understanding:

8. 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 lived better in a forest or in a desert? What would you do to figure that out? Observations? Data? Questions? Actions/experiments? Interpretation of data?

Transfer questions scored separately:

9. Did you think at all about what you've been learning in class while you were at home? If yes, probe for as many examples as possible. If not, why not?
10. Did you tell anybody at home what you were learning at school in science? If yes, probe for as many examples as possible. If not, why not?
11. Did you try to look for examples of any of the things you've been learning about in science class? Did you try to learn more about any of the things you've been learning about? If so, probe for as many examples as possible. If not, why not?

Appendix D: NOS Scoring Rubric

Question	0 points	1 point	2 points	3 points
What does a scientist do?	No answer	Lists one action that makes some sense.	Lists 1-2 actions that are common.	Lists 2-3 critical actions for scientists (investigate, studies, experiments...)
How does a scientist try to learn about things?	No answer	Lists one reasonable idea.	Lists 1-2 common ideas.	Lists 2-3 critical ideas about scientific investigation. (uses tools, gathers data, 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	Lists one reasonable idea.	1-2 ideas with weak defensibility.	2-3 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	List one reasonable idea.	Lists 1-2 common ideas.	Lists 2-3 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 – would they 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 discover.

Appendix E: Teacher Interview Protocol

Research focus: What can be said about the instructional demands of the Terrarium Habitats curriculum?

1. Have you ever taught an integrated unit like the Terrarium Habitats unit before? Have you ever taught science and literacy integrated units?
 - 1.1. How similar/different have your experiences in integrating science and literacy been to the Terrarium Habitats curriculum?
 - 1.2. How effective do you believe the integration is in the Terrarium Habitats unit? Do you think they support each other or not? What evidence would you point to either way?
 - 1.3. What other kinds of features would you like to see in the Terrarium Habitats unit to further support the science and literacy integration and the learning of each?
2. How is the Terrarium Habitats curriculum similar to and different from science curriculum materials you have used previously?
 - 2.1. What kinds of science units have you done in the past? What were the major learning goals for these units? What were the major projects or activities? How similar or different are these from the Terrarium Habitats unit? Consider emphasis on inquiry, using evidence, and the language of science.
 - 2.2. When compared against science materials you've used in the past, how effective do you believe the Terrarium Habitats curriculum is in helping all students learn science?
3. What unique opportunities does the Terrarium Habitats curriculum afford, particularly in terms of content, instruction, and assessment that helps (or hinders) the teacher's ability to connect teaching and learning?
 - 3.1. One way to think about assessment is that it should be used to provide feedback to students on their emerging understanding and used to guide future instruction. How effective do you believe the Terrarium Habitats curriculum is in using assessment for learning rather than just at the end of the unit?
 - 3.2. How successful was the Terrarium Habitats curriculum in allowing for all students to be successful? In other words, did the materials lend themselves well to adaptations or modifications that allowed all children to learn to the best of their ability?

4. What prior knowledge, skills, and dispositions does the teacher believe students need to effectively learn using the Terrarium Habitats curriculum?
 - 4.1. What kinds of prerequisite skills, knowledge, and dispositions do you think students need before being taught using the Terrarium Habitats curriculum? Do you think your students were developmentally ready to learn this unit?
 - 4.2. Do you believe there was sufficient interest and motivation to learn effectively? Do you believe the Terrarium Habitats curriculum contributed to interest and motivation or detracted from it? What evidence would you point to in defense of your answer?
 - 4.3. What kinds of things do you believe students need to understand about the nature of science to learn effectively using the Terrarium Habitats curriculum? Do you believe your students had an appropriate level of understanding of the nature of science? How do you believe the Terrarium Habitats curriculum supported (or not) your students emerging understanding of the nature of science? Provide evidence if possible.
 - 4.4. How do you think your students could have been better situated to be successful? Consider their prior knowledge and experiences, your own understanding of science, availability of resources or anything else...
5. What specific kinds of science knowledge does a teacher need to effectively implement the Terrarium Habitats curriculum? Consider specific content knowledge, dispositions toward science, and understanding of the nature of science.
 - 5.1. How would you rate your own attitude toward science prior to teaching the Terrarium Habitats unit? Did you think of yourself as a “science-type” person? Why or why not? Has your attitude about science changed as you’ve taught this unit? If so, in what ways? Now do you think of yourself any differently as a teacher of science?
 - 5.2. Before you started the Terrarium Habitats unit, how important did you think science learning was in the primary grades? Do you think differently about this now?
 - 5.3. How would you rate your understanding of science concepts such as habitats, nutrient cycling, and adaptations before beginning to teach the Terrarium Habitats unit? How has your understanding of these things changed across the course of the unit? What would you have liked to know more about before teaching this unit? What do you think differently about (in terms of content) as a result of teaching this unit?
 - 5.4. Did teaching the Terrarium Habitats unit help you think differently about issues related to the nature of science – particularly how scientists use evidence,

conduct inquiry, and make progress in the field? What do you think differently about, in terms of nature of science, as a result of teaching this unit?

6. What specific pedagogical models, principles, resources, or skills does a teacher need to effectively implement the Terrarium Habitats curriculum?
 - 6.1. How has your personal teaching style (in terms of instructional models, curriculum organization, and delivery of instruction in particular) matched with the Terrarium Habitats unit teaching style? Has it been a good match between what you would normally do and what the Terrarium Habitats unit has asked you to do? Provide examples of both matching and non-matching instructional styles.
 - 6.2. What kinds of instructional styles do you believe a teacher needs to have to implement the Terrarium Habitats unit well? What might be the consequences of a mis-match?
 - 6.3. What do you believe a teacher ought to be good at before trying to use the Terrarium Habitats curriculum? What resources should the teacher have available to more effectively implement the Terrarium Habitats curriculum?
7. How effective was the Terrarium Habitats unit?
 - 7.1. How would you rate the effectiveness of the Terrarium Habitats unit to help all students learn science? What would you point to as evidence of your judgment in this regard?
 - 7.2. How would you rate the effectiveness of the Terrarium Habitats unit to help all students improve their literacy skills? What would you point to as evidence of your judgment in this regard?
 - 7.3. How would you rate the effectiveness of the Terrarium Habitats unit in terms of motivation and engagement in science and literacy? What would you point to as evidence of your judgment in this regard?