Evaluating the *Authentic Literacy and Language (ALL) for Science* Curriculum Development Framework Effectiveness in Developing Young Children's Science-Specific Disciplinary Literacy and Science Content Knowledge

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Abstract

Despite natural linkages across subject areas, instruction in science and English language arts is typically compartmentalized, providing students in the United States few opportunities to engage in sense-making while using text, media and verbal communications in ways that are similar to those of practicing scientists. Further, most science teaching relies on teacher-centric approaches focused on skills or content knowledge development while bypassing learner-centered strategies that help students engage in the culture of science and participate as members of a scientific community, though such interactions contribute to student learning and identity development in ways that may influence eventual career paths. The Authentic Literacy and Language (ALL) for Science program aims to address both challenges by providing opportunities for students to: 1) develop science-specific disciplinary literacies in the context of firsthand science investigations and text-based inquiry; and 2) share experiences within a community of scientific and related literacy practices. This study describes the evaluation of a unit created using the program's curriculum development framework. Outcomes of the matched triad, random assignment field test indicate that students participating in the full implementation of the materials, despite lower pre-assessment scores, outgained peers participating in inquiry-based science lessons without literacy integration or standard practices for science and ELA instruction, suggesting that the model may have the ability to close knowledge gaps for grade 2 children.

Introduction

The majority of United States students in grades K–12 have few opportunities to engage in scientific sense-making while using text, media and verbal communications in ways that are similar to those of practicing scientists. The teaching of science and English language arts (ELA) continues to be compartmentalized in most cases, despite more than thirty years of attention to the natural linkages across these subject areas at all grade levels (Flick & Lederman, 2002: Glynn & Muth, 1994; Holiday et al, 1994; Romance & Vitale, 1992; Yore & Shymansky, 1991). Both the Next Generation Science Standards and the Common Core for ELA Standards provide guidance for developing students' skills in areas that bridge both subject areas, such as the process of inquiry, disciplined reasoning and explanations or argumentation from evidence (NGSS, 2013; NRC, 2014). However, literacy in the context of science as a discipline and professional endeavor, in other words, science-specific disciplinary literacy, rarely plays an explicit role in science teaching and learning, particularly in the elementary grades (Bransford & Donovan, 2005; Pearson et al., 2010).

Similarly, over the past three decades, considerable efforts have gone into developing curricular and programmatic ways to engage and prepare students from diverse backgrounds for advanced studies or careers in science and all of the STEM (science, technology, engineering and mathematics) fields (George et al., 2001; Loucks Horsley et al., 1990; NRC, 1996; NSRC, 1997). Challenging and relevant curricula, problems related to students' real-world experiences, and a collaborative and supportive environment all have been found to contribute to motivating students' learning and choices (Elias & Hayes, 2008; Osborne et al. 2003; Schernoff et al. 2017). Among these factors, culture and social interactions now are recognized as key contributors to students' learning, their educational pathways, and career preferences, choices and attainment (Thoman et al. 2017). However, despite substantial supporting evidence regarding the important roles of community building and culture, most science teaching continues to rely on teacher-centric approaches with a focus on skills or content knowledge development while bypassing learner-centered strategies that help students engage in the culture of science and participate as members of a scientific community (Hatch, 2018; Duschl et al., 2007).

With the Authentic Literacy and Language (ALL) for Science framework for curriculum development, we aimed to address both of these challenges by providing opportunities for students to: 1) develop science-specific disciplinary literacies in the context of firsthand science investigations and text-based inquiry; and 2) share experiences within a community of scientific and related literacy practices.

Science and Literacy Integration in Elementary Grades. As noted by Pearson et al., (2010), typical science sense-making strategies and tools align with those of general literacy. Recommendations of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) are consistent with those with those for the teaching of English language arts (ELA) in the Common Core for ELA Standards. A workshop of the National Research Council (NRC, 2014 p. 9), identified areas of intersection or overlap between the two areas and organized them using language from the Common Core. The areas include: following complex processes and procedures, conducting research, using textual evidence and attending to detail, synthesizing complex information, explaining concepts, processes and procedures, making argument, assessing arguments, gathering relevant evidence and translating information from one form to another. For grades K–2, the NGSS include a number of practices that bridge science and ELA as disciplines. Examples include: recording information, using and sharing drawings or writings, using information to construct an evidence-based account, engaging in argument from evidence, listening actively to argument, constructing an argument from evidence to support a claim, reading grade-appropriate texts or other media to obtain scientific and/or technical information, communication information in oral and/or written forms (NGSS Lead States, 2013).

Students' learning of science and language arts benefits from integration of ELA and science teaching in the elementary grades. Several different approaches to integration have demonstrated positive student learning and attitudinal outcomes (Bradbury, 2014). For example, the Seeds of Science, Roots of Reading (Seeds/Roots) employs a Do-It, Talk-it, Read-it, Write-it approach to situate reading, writing and language within inquiry science, thus explicitly linking inquiry-based science and literacy learning. Cervetti, et al. (2012, p 655), conclude that, "there is sufficient evidence to suggest that literacy and firsthand experiences in science are best positioned as tools for inquiring about the natural world." With the ALL for Science framework, we incorporate inquiry even more deeply into integrated science and ELA instruction—through firsthand scientific inquiry by students following a learning cycle approach and text-based research using appropriate transcendent (i.e., generic) and science-specific reading and writing strategies. Students put these strategies into practice by working in small groups, with the intent of enabling legitimate student participation in an incipient community of practice guided by their teacher.

Science Communities of Practice and Identity. Communities of practice can be viewed as social learning systems, in which members interact productively with other members of the community. A community of practice consists of three fundamental components: a domain of knowledge; a community of people who care about the domain; and the shared practice, or set of frameworks, ideas, tools, information, language and specific knowledge (Wenger, McDermott & Snyder, 2002). In this context, conceptualized learning becomes a pathway into a community. Newcomers gradually become established members (i.e., old timers) as they internalize the shared knowledge and practices of the group (Mercieca, 2016). Importantly, community membership is related to personal identity. Wenger (1998, p. 45) defines identity as a negotiated experience within a community, where "we define who we are by the ways we experience ourselves through participation." With the ALL for Science curriculum framework, we aim to support students' identities as science students or even scientists. Consistent with use of the communities-of-practice framework, we consider identity to refer to an understanding of oneself in relation both to past and future performances and participation (Brickhouse & Potter, 2001; Lave & Wenger, 1991). In other words, identity should be considered "not only as who one is but who one wants to become" (Shanahan, 2009). In addition, learning can be interpreted as an outcome of the transformation of identity (Tan & Calabrese Barton, et al., 2008).

Literacy and language practices play critical roles in communities. Thus, in considering how best to integrate firsthand science investigations and literacy strategies, while also supporting young students' identity formation as members of the science community (as students, scientists or citizens), we decided to provide a structure that would incorporate elements of a community of practice. Clearly, it is unlikely that a community of science practitioners already would exist in a classroom of students in the primary grades (1–3). Thus, we envisioned a curriculum framework in which the teacher would act as the established community member to guide students as they learned the shared set of ideas, tools, language, etc. that is typical of science—and in the process, provide them with a pathway into full membership in the community of practice.

The ALL for Science Framework. The overall aim of the curriculum framework is to support elementary students' acquisition of science knowledge (core concepts and crosscutting ideas) and engagement in science practices leading to development of an identity predisposed toward science. To achieve this aim, the ALL for Science curriculum framework combines small group firsthand science inquiry with ELA-aligned, text-based research using existing expository text resources. Our hypothesized theory of change is described in the steps below.

1. If students engage in their own firsthand investigations of a real-world system; extend their learning through inquiry using text-based resources and other media; and expand their repertoire of science specific and transcendent literacies;
2. Then, they will learn science ideas and concepts, acquire and apply strategies or skills associated with science-specific literacy and scientific practices and sensemaking, and come to be members of a community of science practitioners.
3. Consequently, by virtue of their membership in the science community of practice, students will develop, strengthen and affirm their individual identities as science students or scientists.

To initially evaluate the framework, we built a four-week instructional unit, *Heredity and Life Cycles,* developed using a backwards design process by an interdisciplinary curriculum development team comprised of K-3 teachers, STEM and English language arts (ELA) specialists, school administrators, instructional designers, and geneticists. The team identified ideal Grade 2 ELA and science standards for integrated curriculum, and then aligned them to ensure that explicit connections could be made between the daily activities. Students following the curriculum would participate daily in a whole group Science Investigation, a Literacy Mini-lesson, and a small group Inquiry Circle designed to engage them in collaborative text-based inquiry (Fig 1). *Heredity and Life Cycles* was piloted in 18 second grade classrooms with 350 students in spring 2018. Children demonstrated gains in content knowledge related to the themes of the unit (Moreno et al., 2020), and their pilot data, as well as teacher feedback, were used to revise the materials.

In the current project, we describe the next phase in our development and evaluation of the ALL for Science curriculum framework and related teaching resources. Specifically, we sought to evaluate the effectiveness of the framework as implemented in the revised *Heredity and Life Cycles* unit in increasing students' knowledge and skills as related to step 2 in the theory of change above (i.e., acquisition of science concepts and ideas, acquisition and application of skills and strategies associated with science-specific literacy and scientific practices and sensemaking). To do so, we conducted a three-group field test study to investigate the added value of the ALL for Science framework components as compared to a unit with firsthand science inquiry without literacy integration, and to standard classroom practices for science teaching.

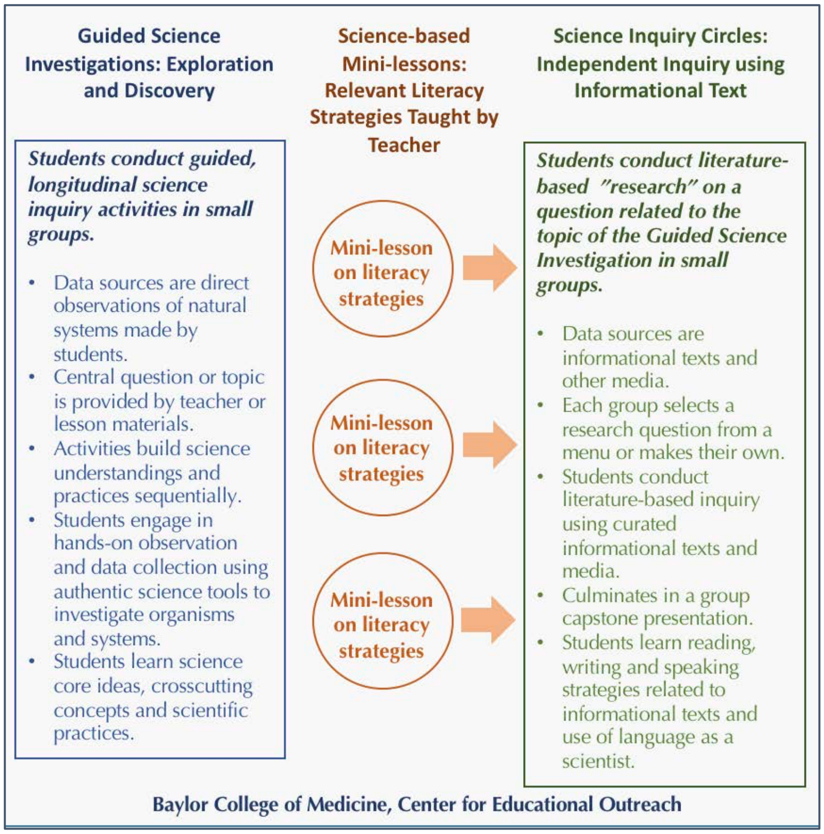

Figure 1. ALL for Science Framework Overview (Moreno et al., 2020)

Methods

Recruitment and Group Assignment. We recruited 105 second grade, self-contained classroom teachers from a large, urban area to participate in the three-group study and matched them into triads according to their self-reported demographic data on the pre-survey – the percentage of their students' performing at grade level in reading and science achievement based on district tests, and teachers' years of experience in both science and ELA. Each triad member was then randomly assigned to one of three treatment groups: 1) Full Implementation (FI), 2) Science Investigations Only (SIO); or 3) Business-as-Usual (BAU) group. There was a nonzero probability for each teacher being assigned to a treatment group. Following assignment, we controlled for contamination within schools by identifying teachers in the same school implementing different ALL for Science lessons (i.e., FI and SIO), and swapping their treatment group with the next closest matched teacher assigned to the BAU group. Although there were 35 teachers in each group prior to orientation, only 99 attended the orientation session (FI-34, SIO-32, BAU-33). Three additional teachers participated in a make-up orientation after assignments were set, and replaced the closest matched FI group teacher who did not complete orientation. A total of 23 teachers opted not to participate following orientation, thus a total of 79 teachers completed all steps required to participate in the study. Ultimately, 69 teachers submitted data related to the study.

Participants. The group composition differed despite the matching and assignment procedures, with FI teachers reporting greater mean teaching experience – total and in both science and ELA – as compared to the teachers in the other two treatment groups, and the FI teachers having the least experience of all (Table 1). A greater percentage of FI teachers had advanced degrees, however, and reported a higher number of science professional development hours over the previous 12 months as compared to teachers in the SIO and BAU groups.

Table 1. Demographics of Teachers

Science and ELA Experience and Background	Group					
	FI (N=26)		SIO (N=21)		BAU (N=22)	
	M	SD	M	SD	M	SD
Years of teaching experience						
Years of total teaching experience	9.15	7.11	10.67	8.72	12.95	9.74
Years of teaching science	7.54	6.22	9.33	8.87	10.91	7.99
Years of teaching reading	7.81	7.26	10.10	8.84	11.59	9.62
Degrees						
Education Degree (any level)	62%		81%		55%	
Advanced Degree (e.g., Master's)	35%		19%		18%	
STEM-related Degree (any level)	15%		10%		18%	
Teaching roles						
Self-contained classroom	100%		95%		95%	
Science lab teacher for one grade	0%		0%		5%	
Science lab teacher for multiple grades	0%		0%		0%	
Science department chair	8%		0%		0%	
Learners labeled as English as a Second Language	35%		43%		32%	
Learners labeled as Learning Disability	15%		33%		9%	
Learners labeled as Gifted and Talented	19%		38%		18%	
Professional Development in prior 12 months						
Science	13.35	28.85	5.86	5.03	8.62	15.89
ELA	28.08	28.16	21.81	16.48	31.96	47.85

Teachers were also asked to report on the characteristics of the children in their Grade 2 classrooms. Although the majority of children across the three treatment groups were from populations underrepresented in STEM fields, the FI classrooms had a higher percentage of Hispanic and African American children and a lower percentage of White children as compared to the other two treatment groups (Table 2). Approximately 80% of children across all groups completed both the pre- and post-assessment for the unit.

Table 2. Demographics of participating learners by treatment group

Student demographic characteristics	Group Full Implementation (N=555)	Science Only (N=416)	Business As Usual* (N=417)
Grade Level			
1st Grade	0%	4%	0%
2nd Grade	100%	96%	95%
Race/Ethnicity			
Asian	4%	4%	4%
African-American	20%	18%	16%
Hispanic	65%	51%	55%
White	9%	21%	20%
Other	2%	6%	1%
Gender			
Male	48%	52%	47%
Female	52%	48%	48%
English Language Learners	48%	34%	43%
Completion of Field Test assessments			
Pre	92%	87%	92%
Post	90%	90%	86%
Both	84%	83%	80%

*NOTE: One teacher with 19 students did not complete the demographic information, thus characteristics of those students are unknown and the values do not add up to 100%

Implementation. All participating teachers were asked to attend the orientation session, during which they received instructions and materials to implement the lessons and collect data for their specific treatment group. SI and FIO group teachers were asked to implement the science or science and disciplinary literacy lesson, respectively, over 20 consecutive classroom days. Teachers in the BAU treatment were asked to select a 20-day period during the field test to use as their data collection period, preferably one in which they would normally provide instruction related to life cycles. Daily lessons for the FI group were expected to take approximately 90 minutes, and they were encouraged to use their scheduled ELA and Science blocks for implementation. The SIO group lessons – the same Science Investigations taught in FI group classrooms – were approximately 45 minutes long each day.

Measures and Data Collection. To capture students' content knowledge before and after implementation of the materials, the curriculum development team worked with assessment and evaluation experts to develop a test aligned with the science and ELA standards in the unit, as well as the science-specific disciplinary literacies addressed in the FI group lessons. The assessment, administered by teachers prior to beginning and again following the completion of activities or the 20-day field testing period for the BAU group, consisted of six vocabulary matching items and 11 multiple choice items.

To capture teacher practices and perceptions, teachers were asked to complete short daily log surveys to capture three Opportunity to Learn Indices adapted from the Science Instructional Practices Survey (SIPS) (Hayes et al., 2016) and the MyiLOGS Instrument (Kurz et al., 2014): Time on Standards, Cognitive Processes, and Instructional Practices. Time was self-reported based on the approximate number of minutes spent in science, ELA and ALL for Science materials, specifically, each day. For the other two Indices, practices from the SIPS and MyiLoGS were adapted by the curriculum design and evaluation team to align the needs of the target grade level and content area (life science), and were supplemented with practices aligned with our Community of Practice perspective to teaching science and science-specific disciplinary literacy. Ultimately, we had three groups of practices: 1) providing learning opportunities so children could think, act, write, read like a scientist – this category had four subcategories, as well; 2) providing learning opportunities so children could interact with others like a scientist; and 3) engaged in "intentional instruction" regarding the work of scientists (Table 3). At the end of the field test, teachers were asked to complete a post-evaluation to capture overall perceptions and demographic information for the children who participated in the lessons.

Analyses. For the learner pre- and post-assessments, separate principal component analyses (PCA) on the two question types were conducted. For the matching questions, this resulted in two components with eigenvalues greater than one: Component 1 (Butterfly Life Cycle vocabulary) consisted of four items and explained 47.83% of the total variance, while Component 2 (Genetic Traits vocabulary) consisted of two items and explained 17.16% of the total variance. The components explained 64.99% of the total variance. The reliabilities for each – Butterfly Lifecyle ($\alpha = .759$), and Genetic Traits ($\alpha = .713$) – were considered sufficient for further statistical analyses (Nimon et al., 2012; Thompson, 2003).

PCA results for the multiple-choice items revealed two components, however, the component with two items (i.e., 4 and 12) had pattern structure coefficients that were of opposite signs and a Cronbach's alpha that was negative and near zero ($\alpha = -.051$). The items were related to the literacy, but a review suggested that they measured different skills. One was related to comprehending information presented in a paragraph while the other item was related to understanding definitions. A follow-up PCA without items 4 and 12 resulted in one component that explained 26.43% of the total variance (Cronbach's $\alpha = .645$) retained.

In order to explore the effects of the model on science content knowledge, we investigated descriptive statistics, and subsequently used post-assessments as the outcome in a multilevel model. Only data from children who completed the baseline assessment were included in the analyses, resulting in a total sample size of 1051 Grade 2 children. Individual pre- and post-assessment scores were transformed into z-scores and averaged for the investigation of descriptive statistics and the subsequent MLM. The full model includes Y_{ij} as the post-assessment z-score for each child. Model covariates were then entered in blocks from most proximal to most distal to the learning experience: a) learner level – pre-assessment multiple choice component z-score, pretest butterfly vocabulary score, pretest genetics vocabulary score, and days of attendance, b) classroom characteristics – treatment group, proportion of small group science time and ELA time, number of intentional instruction opportunities, the proportion of students from groups traditionally underrepresented in STEM (African American and Hispanic), the proportion of the class considered to be English Language Learners and the average classroom pre-assessment z-score; and c) teacher background – hours of ELA and Science professional development in the 12 months prior to the field test, and dummy coded variables for a STEM degree at any level and a master's degree in education.

$$
\begin{aligned}
Y_{ij}(Postest\ composite\ z - score) \\
&= \beta_{0j} + \beta_{1j}(pretest\ composite\ z - score)_{ij} \\
&+ \beta_{2j}(pretest\ butterfly\ vocab)_{ij} + \beta_{3j}(pretest\ genetics\ vocab)_{ij} \\
&+ \beta_{4j}(Attendance)_{ij} + \beta_{5j}(Group)_j \\
&+ \beta_{6j}(Intentional\ Instruction\ Composite)_j \\
&+ \beta_{7j}(Mean\ proportion\ of\ class\ time\ in\ science\ small\ groups)_j \\
&+ \beta_{8j}(Mean\ proportion\ of\ class\ time\ in\ ELA\ small\ groups)_j \\
&+ \beta_{9j}(Proportion\ African\ American)_j + \beta_{10j}(Proportion\ Hispanic)_j \\
&+ \beta_{11j}(Proportion\ ELL)_j + \beta_{12j}(Teacher\ STEM\ degree)_j \\
&+ \beta_{13j}(Teacher\ MEd)_j + \beta_{14j}(Teacher\ hours\ ELA\ PD)_j \\
&+ \beta_{15j}(Teacher\ Hours\ Science\ PD)_j \\
&+ \beta_{16j}(\overline{pretest\ composite\ z - score})_j + \varepsilon_{ij}
\end{aligned}
$$

To address missing data at both levels in the dataset, we used multiple imputations by creating 20 datasets using the Multivariate Imputation by Chained Equations (MICE) package in R and created pooled model estimates from the imputed datasets using Rubin's rules (Rubin, 1987) with the MICE pool() function.

For teacher practices, mean time reported for each instructional topic area was calculated across the 20 daily logs to provide a total average daily time in minutes for each curriculum component (FI and SIO) as well as time in Science and ELA for each treatment group in different modalities – individual work, small group work and whole class instruction. Differences between FI and SIO groups were compared with independent t-tests and groups' average time in ELA and Science were compared with one-way ANOVAs with a Tukey HSD post-hoc comparison. Practices in each of the three categories were summed across field test days to create an aggregate score for each teacher on each set of practices over the 20 days. Group means were then created for each treatment group, and compared for each set of practices using a one-way ANOVAs with Tukey HSD post-hoc comparisons.

Results

Learner outcomes. The preliminary investigation of outcomes using descriptive statistics found that children in the SIO classrooms had a higher mean composite pretest z-score as compared to the children in the BAU and FI classrooms, while there were no statistically significant differences between treatment group scores on the vocabulary matching items at pre-test (Table 3).

Table 3. Descriptive Statistics and Kruskall-Wallis comparison for each pre- and post-assessment composite by group

Assessment	Group	n	M	SD	χ^2	*df*	*p*	Sig. differences
Composite Z-scores (9 items)								
Pretest	FI	435	-0.11	0.95	24.00	2	<0.001	FI-SIO <0.001
	SIO	305	0.24*	1.07				SIO-BAU <0.001
	BAU	311	-0.08	0.95				
Posttest	FI	435	0.19	0.94	126.42	2	<0.001	FI-BAU <0.001
	SIO	305	0.26	0.97				SIO-BAU <0.001
	BAU	311	-0.53*	0.92				
Change	FI	435	0.29*	1.02	97.52	2	<0.001	FI-SIO = 0.001
	SIO	305	0.02*	0.88				FI-BAU <0.001
	BAU	311	-0.42*	0.93				SIO-BAU <0.001
Genetics Vocab (2 items)								
Pretest	FI	435	0.60	0.75	1.73	2	0.422	N/A
	SIO	305	0.65	0.74				
	BAU	311	0.68	0.83				
Posttest	FI	431	1.07	0.91	20.05	2	<0.001	FI-BAU <0.001
	SIO	304	1.09	0.90				SIO-BAU <0.001
	BAU	308	0.81*	0.82				
Change	FI	431	0.47	1.14	19.29	2	<0.001	FI-BAU <0.001
	SIO	304	0.44	1.14				SIO-BAU <0.001
	BAU	308	0.13*	1.03				
Butterfly Vocab (4 items)								
Pretest	FI	435	1.89	1.38	3.05	2	0.217	N/A
	SIO	305	2.04	1.37				
	BAU	311	2.05	1.44				
Posttest	FI	430	3.06	1.30	47.60	2	<0.001	FI-BAU <0.001
	SIO	305	2.96	1.38				SIO-BAU <0.001
	BAU	308	2.45*	1.38				
Change	FI	430	1.16*	1.50	43.85	2	<0.001	FI-BAU <0.001
	SIO	305	0.92*	1.37				FI-SIO = 0.043
	BAU	308	0.40*	1.41				SIO-BAU <0.001

Post-unit, however, post hoc analyses found that children in the FI classrooms had achieved parity with the SIO children, with no statistically significant differences on the posttest. Further, FI classrooms had significantly greater gains than the children in both the SIO and BAU groups on the composite test and butterfly vocabulary items, having statistically significantly greater mean gains that the other treatment groups on both (Figure 2). Both SIO and classrooms had greater mean scores on the post-assessment composite and both types of vocabulary items as compared to the children in the BAU group. Overall, the trends in the descriptive statistics increase in the direction of the ALL for Science components, with SIO classrooms outperforming BAU classrooms and FI classrooms outperforming both partial and non-implementation classrooms.

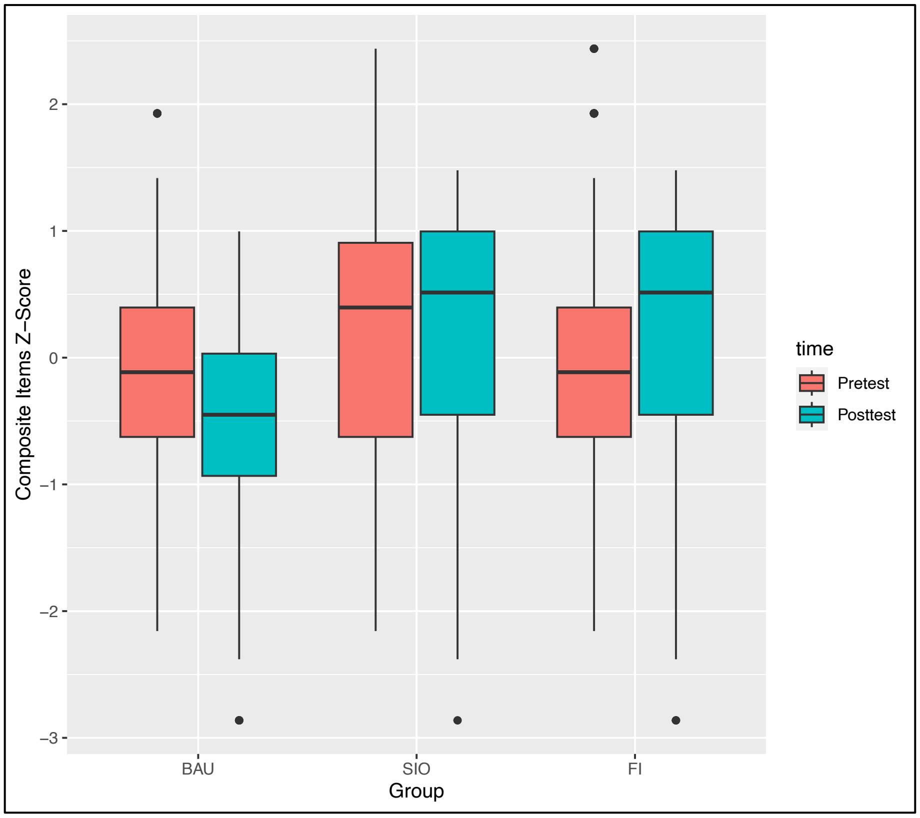

Figure 2. Boxplots of pre- and post-assessment composite z-scores for each treatment group

Of the individual, classroom and teacher characteristics used to predict children's post-assessment scores on the composite items in the multilevel model, only children's standardized composite pretest score, pretest butterfly vocabulary scores, and membership in either implementation group were statistically significant predictors of their post-assessment score (Table 4). Specifically, every 1 standardized point higher on the pretest composite was associated with .301 increase on the posttest, while for butterfly vocabulary it was associated with a 0.118 increase. For group membership, SIO classrooms had a mean score .472 higher and the FI group .549 higher on the posttest than the BAU group. A post-hoc analysis found that the difference between the FI and SIO groups was not statistically significant, however, the trend in increases were aligned with those found in the preliminary descriptive analyses, with FI having greater increases over the BAU group than the SIO group. No other variable included as a predictor was found to significantly impact children's outcomes on the composite post-assessment.

Table 4. Results from multilevel model predicting student post scores

	b	S.E.
Fixed effects		
Intercept	-0.801	1.197
Pretest Composite Z-Score	0.301***	0.032
Pretest Genetic Vocab Score	-0.016	0.040
Pretest Butterfly Vocab Score	0.118***	0.023
SIO Classrooms	0.472*	0.198
FI Classrooms	0.549***	0.184
Average Classroom Pre Z-score	0.208	0.170
Total Days of Attendance	0.000	0.054
Practices	0.000	0.000
Proportion of ELA time in Small Groups	0.036	0.357
Proportion of Science time in Small Groups	0.094	0.239
Proportion African American	-0.040	0.230
Proportion Hispanic	0.126	0.209
Proportion ELL	-0.138	0.189
Hours of Teacher Science PD	0.001	0.005
Hours of Teacher ELA PD	-0.003	0.004
Teacher MEd	-0.174	0.181
Teacher STEM degree	-0.094	0.205
Random effects		
τ_0^2	0.42	
σ^2	0.71	
-2 Log Likelihood range	(-1434) – (-1363)	
AIC range	2765 – 2909	

*p<0.05, **p<0.01, ***p<0.001

Teacher practices. Teachers reported differences across instructional time and context in both ELA and Science for the different treatment groups. BAU group teachers reported statistically significantly greater average minutes in ELA-dedicated time across all learning contexts as compared to the teachers in the SIO and FI groups. Specifically, they reported a combined ELA time almost twice that of the SIO teachers, who spent the least total time in ELA (Table 5). Between the two implementation groups, FI teachers reported statistically significantly more time in small group and whole group work than the SIO teachers.

Table 5. Descriptive statistics and zero-inflated regression analysis comparison time in minutes spent in science and ELA instruction for each group by context

Subject area and work setting	Group	M(SD)	%	df	χ^2	pseudo R2	p
ELA							
Individual work	FI	10.24 (14.34)	20%	2	533.56*	0.447	<0.001
	SIO	13.37 (20.45)	34%				
	BAU	25.68 (15.86)	35%				
Small group work	FI	23.27 (15.03)	45%	2	225.36*	0.237	<0.001
	SIO	13.00 (16.77)	33%				
	BAU	25.47 (21.69)	35%				
Whole class work	FI	17.93 (11.38)	35%	2	203.57*	0.273	<0.001
	SIO	12.99 (16.91)	33%				
	BAU	21.52 (15.36)	30%				
TOTAL	FI	51.44 (30.20)					
	SIO	39.46 (46.14)					
	BAU	72.67 (34.69)					
Science							
Individual work	FI	8.79 (9.11)	21%	2	525.88*	0.347	<0.001
	SIO	8.11 (7.47)	23%				
	BAU	13.77 (14.89)	39%				
Small group work	FI	14.62 (12.24)	34%	2	120.74*	0.168	<0.001
	SIO	13.21 (10.19)	38%				
	BAU	7.94 (10.96)	23%				
Whole class work	FI	19.02 (12.160	45%	2	350.56*	0.302	<0.001
	SIO	13.61 (8.81)	39%				
	BAU	13.36 (10.98)	38%				
TOTAL	FI	42.45 (20.20)					
	SIO	34.93 (8.98)					
	BAU	35.08 (21.98)					

Table 5 continued. Sidak Post Hoc Analysis

	Comparison	Log Estimate	SE	p
ELA				
Individual work	BAU - SIO	-12.30*	0.774	<.0001
	BAU - FI	-15.44*	0.643	<.0001
	SIO - FI	3.13*	0.769	0.0001
Small group work	BAU - SIO	-12.40*	0.964	<.0001
	BAU - FI	-2.20*	0.864	0.029
	SIO - FI	-10.20*	0.848	<.0001
Whole class work	BAU - SIO	-8.53*	0.774	<.0001
	BAU - FI	-3.59*	0.54	<.0001
	SIO - FI	-4.94*	0.71	<.0001
Science				
Individual work	BAU - SIO	-5.66*	0.585	<.0001
	BAU - FI	-4.98*	0.589	<.0001
	SIO - FI	-0.68	0.468	0.3167
Small group work	BAU - SIO	5.27*	0.625	<.0001
	BAU - FI	6.68*	0.658	<.0001
	SIO - FI	-1.41	0.618	0.0572
Whole class work	BAU - SIO	0.243	0.517	0.8851
	BAU - FI	5.68*	0.532	<.0001
	SIO - FI	-5.43*	0.405	<.0001

In comparisons on the time spent in science instruction, BAU and SIO groups reported similar total time across all instructional contexts, while the FI teachers spent an average of 7.52 more minutes of total instructional time in science as compared to the SIO group, and 7.67 more minutes than the BAU group. Both implementation groups reported similar amounts of time in individual and small group work in science, while the BAU teachers reported statistically significantly more time for individual work and less time for small group work. Finally, teachers in the FI group reported statistically significantly more average time in whole class instruction than either of the two other groups.

When teacher practices on the other two Opportunities to Learn indices were compared, a trend emerged in which the implementation groups reported a greater number of each practice than the BAU group, and the FI group reported greater mean number of instances of each practice across the classroom days as compared to the SIO and BAU groups (Table 6). The only practice in which this was not the case was group 2: "Provide learning opportunities so children could interact with others like a scientist…" in which the SIO and FI groups were almost identical. Negative binomial regression analyses and Sidak post hoc comparisons of examination of average reported practices across groups did not uncover any statistically significant differences between SIO and FI teachers in any of the practice categories despite these trends. FI teachers, did, however provide, statistically significantly more opportunities for learners to engage in scientific discussion, reasoning, and reflection, engage in the language of science, and engage in the written tools of scientists than teachers in the BAU group. Finally, despite the trend in descriptive statistics, there were no statistically significant differences between groups for the engage in intentional instruction category of practices.

Discussion

Our find findings suggest that the inclusion of the ALL for Science framework components, which were intended to develop children's science content knowledge, science-specific disciplinary literacies and provide shared experiences within a community of scientific and related literacy practices may have provided an added value to students' science learning in this population. These findings are aligned with prior work indicating the potential benefits of literacy and inquiry-based science (e.g., Cervetti, et al., 2012). In our study, specifically, we found that the FI classrooms in which the learners completed the full ALL for Science framework, while statistically significantly lower on pretest composite scores, had greater content knowledge gains were not statistically significantly different from peers in the longitudinal science investigation treatment classrooms. Thus, although both were effective for learners, the trends in our data suggest that the implementation of all components of the ALL for Science Framework may have had an impact on children's learning above and beyond the implementation of high-quality science lessons. Further, the trend in teachers' practice across the groups towards full implementation suggest that the addition of the literacy component is potentially a value added to the lessons implemented by the SIO teachers.

Conclusions

Teachers in ALL for Science classrooms acted as proxies for scientific expertise in their and, as such, folded children into the work of scientists, as evident in the instructional practices we report above. Specifically, our findings in changes in learning and teacher practice suggest that the curricular materials made scientific practice and language transparent to teachers, who, in turn, made them available to their learners, situating them as members of a classroom community of practice. Given these promising findings, future work may investigate the effectiveness of community of practice as a theory for creating pathways for young learners in STEM.

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