Exploring Disciplinary Boundaries in Early Elementary Students' Developing Practices

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Abstract: In CSCL we often refer to knowledge in terms of "practices" to highlight how knowledge is performed in context rather than abstracted from it (e.g., Greeno, 1998). One aspect of context is the notion of disciplines such as science, math, and the language arts (Sawyer, 2006). To date, however, research that explores the relationship between knowledge and disciplinary context has typically focused within a single disciplinary frame, such as science (e.g., Banks et al., 2007). This paper aims to explore the influence of disciplinary boundaries between science and language arts on students' developing practices. We present data from a mixed-age first and second grade classroom where students collaboratively engaged with a book about honeybees from either a science or a language arts frame. Analyses of students' individual written critiques reveal how they consistently adapted their criteria for what makes a good representation based upon the disciplinary framing.

Introduction

Core to CSCL and the Learning Sciences is the belief that context matters (Sawyer, 2006) and that the social, cultural, and physical environment in which students learn new content fundamentally shapes what they have learned (Greeno, 2006). For this reason, sociocultural theorists often refer to knowledge in terms of the "practices" that students know how to engage in, to highlight the situated and interactive nature of knowledge, and how knowledge is performed in context rather than abstracted from context (Greeno, 1998, 2011; Lobato, 2012).

In an effort to understand the relationship between learning and context, researchers have focused on many aspects of learning environments including whether students are working individually or in groups (e.g., Webb et al., 2009) and whether students are learning in or out of school (Kafai, Peppler, & Chapman, 2009) to name a few. However, one aspect of context, which cuts across all of these other variables and remains crucial for supporting learning, is the notion of disciplines such as science, math, and the language arts (Sawyer, 2006). To date, however, research that explores the relationship between knowledge and disciplinary context has typically focused within a single disciplinary frame, such as science, even when it explores students' developing practices within disparate social contexts such as the school and home (Banks et al., 2007). Furthermore, while there is an abundance of work examining STEM (Science, Technology, Engineering, and Math) disciplines, other disciplinary contexts such as the language arts are largely overlooked. The question then emerges, how do these disciplinary contexts influence students' practices?

Therefore, this paper aims to explore the influence of disciplinary boundaries between science and language arts on students' developing practices. We selected students early in their academic career, in first and second grade, to highlight and test whether students' awareness of disciplinary boundaries develops early in the process of schooling. Students in elementary school classrooms typically remain in the same room and work with the same teacher as they transition between disciplines, contrasted with middle and high school students who frequently move to a new classroom and work with a different teacher for each discipline. One might then assume that disciplinary boundaries are less salient at this stage of schooling, although our experiences suggest that this is not the case. Further, educators typically assume that students can learn discipline-specific practices in a variety of disciplinary contexts, and that this is likely to promote more robust understanding of the links between disciplines. For example, many of our collaborating teachers have asked students to read about the current science topic during their literacy time, assuming that the students will learn the science content and the reading practices simultaneously. However, researchers have rarely studied whether this assumption is true. By exploring disciplinary boundaries at this stage of schooling, and within a context where disciplinary boundaries might be more subtle, we aim to demonstrate how salient these boundaries actually are for students, and how they impact student learning and knowing. Our core research question is: *To what extent does explicit disciplinary framing of an activity as science or language arts affect young children's classroom practices?*

We present data from a mixed-age first and second grade classroom where students were asked to evaluate a short book about honeybees before and after extensive language arts and science instruction. This activity was chosen because it required students to make their disciplinary values explicit, allowing us to contrast the influence of the two disciplinary contexts and the practices that students engage in within those contexts.

Students were randomly assigned to one of two conditions where the honeybee book was framed as either a "science" representation or as a "language arts" representation. Students then completed several activities to give them a range of opportunities to reveal their perspective on what makes a "good" or accurate representation within the specific disciplinary context. The students in each group then completed an identical 10-week science curriculum where they learned about how honeybees collect nectar (Danish, Peppler, Phelps, & Washington, 2011) as well as standard language arts instruction on grammar, spelling, and strategies for good writing/storytelling before again critiquing storybooks about bees. Close analyses of students' written critiques reveal how they consistently adapted their criteria for what makes a good representation based upon the disciplinary framing, often overlooking errors in one disciplinary condition that were treated as crucial in the other.

Contrasting disciplinary practices using student representations

Our work is grounded in sociocultural theories of learning (Cole, 1996; Greeno, 2006, 2011). These theoretical frameworks share a common ancestry in Vygotsky (1978) and highlight the role of the social environment in learning and development. From this perspective, disciplinary knowledge includes not only specific facts but practices of engaging with content, people, and materials (Greeno, 2011), and even disciplinary ways of perceiving the world around us (Goodwin, 1994; Stevens & Hall, 1998). As such, the notion of "discipline" has emerged as crucial to structuring how we think about learning environments, and how we evaluate students' knowledge (Sawyer, 2006).

Thus, our goal in the current study is to examine students' participation within disciplinary activities in order to begin identifying the relationship between their shared and individual understandings of what the disciplinary context means, while also teasing out the role of the environment in shaping those perspectives. To ground our contrast we identified a common practice of both science and language arts—the critique, or evaluation of quality, of visual representations.

Representations as a site for disciplinary comparison

Representations, such as drawings and narrative storylines, play a role across disciplines and contexts (diSessa, 2004; Lehrer & Schauble, 2000; Schwartz & Heiser, 2006) and yet serve a different purpose within each discipline. For example, a drawing of a flower might be used as an anatomical reference in a science classroom, and need to be accurate. In contrast, a drawing of a flower in language arts might instead be a starting point for a new story. Representations are also commonplace in early elementary classrooms because they make it easy to capture, share, and relate information in powerful ways (Schwartz & Heiser, 2006; Willats, 2005). Students are frequently asked to create or work with representations as part of their daily activities.

Much of the research into students' engagement with representations, including their critiques, has focused on either the cognitive benefits or abilities of individual students (Schwartz & Heiser, 2006), or a specific disciplinary context such as science or math (Lehrer & Schauble, 2005). However, an increasing body of research has drawn upon sociocultural theories of learning to move beyond individual cognition and explore the relationship between representations and the activities in which they are created, modified, and used (Hall, 1996; Roth, 1997; Roth & McGinn, 1998). These sociocultural studies accomplish this by examining observable patterns in student behavior (practices) as they develop over time, or the immediate influence of a specific activity upon students' actions. We blend these two approaches by comparing students' practices not only across two distinct contexts, but also as they change over time. Furthermore, despite an interest in context, prior sociocultural studies continue to focus largely on representations in math and science. Our present study aims to extend this pattern by contrasting students' creation of representations in a science context with a language arts context. Language arts was chosen because because we hypothesized that it would be a distinct enough setting from science to make students' awareness of disciplinary contexts visible.

Representational critique in science and language arts

Representations play an important and unique role in science as a discipline, allowing researchers to share theories, experiments, and evidence across vast distances and different time periods (Latour, 1987, 1988; Roth & McGinn, 1998). When working with representations, one important practice shared by multiple disciplines is the ability to critique and evaluate representations, both those that others have produced as well as one's own, in an effort to improve and refine it (diSessa, 2002). This practice of critique is also instrumental in providing students with an opportunity to develop and explore their own identity with respect to the representation and the discipline (Greeno, 2011). Effective critique of a representation requires an understanding of the purpose of the representation and the context of its use. Fortunately, research shows that young children (i.e., kindergarten through second grade) are capable of critiquing representations along a number of dimensions, including the accuracy of their content (Danish & Enyedy, 2007; Danish & Phelps, 2010a). Critique can be particularly powerful as students create their own representations, allowing them to explore both the representational form and the science content referred to by the representation (Danish & Phelps, 2010b; Parnafes, 2010).

While there is significantly less existing research investigating the nature of representations within the context of language arts, we do know that language arts representations, especially storybooks, videos, and other media, play a critical role in the development of language arts skills. We looked to the Common Core standards for our initial criteria. To further identify language arts practices which are likely present when engaging with science content, we also focus on informational and technical writing skills which are relevant to all STEM fields and critical 21st century skills (Duke, 2010; Purcell-Gates, Duke, & Martineau, 2007). Building on the idea of informational writing, we then generated a grounded list of criteria that resulted in a coding scheme that emphasized technical writing, grammar (such as correct capitalization, verb form, etc.) and the construction of a clear story-arc (with a beginning, middle and end to the story), among other criteria further explored in the methods section below.

Methodology

Participants

The present study took place in a public Midwestern elementary school with 20 first and 20 second grade students (ages 6-9; 40 total) in a mixed-age classroom, with 37 of the students being present at the two time points in which data was collected and included in the present study. The majority of children were White (90%) with 17 % of the students receiving free or reduced lunch. Students were randomly divided into two conditions: science (N = 19) and language arts (N = 18).

Procedure

The activities in the two conditions (and at both time points) were identical except that the activities in one were framed by the teacher as "science" and in the other as "language arts." The mixed-age classroom is co-taught by two teachers. One of these teachers led the science condition, and the other led the language arts condition. Steps were taken to ensure that as much as possible, the sequence and the methods of the two conditions were the same by scripting the directions and questions in advance of the conversation. Within each condition, the teacher followed a predetermined sequence for the 50 minute session: 1) generate definitions for what makes a good representation in the assigned disciplinary context (i.e., science or language arts); 2) record the groups' thoughts on good representations on a whiteboard; 3) introduce a short storybook about a honeybee finding and collecting nectar; 4) ask students to write or draw on a copy of the book about what made it a good or bad representation 5) follow-up whole group discussion of individual observations and thoughts about what made the book either good or bad; 6) discuss a revised version of the book with many intentional errors removed to see if students felt it was "better" or not.

The research team created two storybooks for these activities (one for use at each time-point) representing a honeybee collecting nectar, one for use at each time point. In both cases, we intentionally violated the same number of scientific principles (e.g., the number of anatomically incorrect bees) and language arts principles (e.g., counts of missing or inaccurate punctuation) in an effort to provide approximately equivalent opportunities for students to engage in the practice of discipline-specific critique. We provided hand-drawn images and hand-written text for the students to feel more comfortable in the critique process (to appear more like a peer seeking feedback on an early draft rather than a published text). Data were collected as part of the larger BeeSign study which indicated that students in both conditions learned extensive and high-level science content over the course of the study Danish, Peppler, Phelps, & Washington, 2011; Peppler & Danish, 2012). The knowledge and understanding built during the classroom activities were largely group-based and collaborative. Here, we analyze individual measures to better understand the impact of the group and the environment on individual learning.

Analysis

To summarize and contrast students' critical practices in the different conditions, student utterances in whole-group discussion and their writings (including the drawings, text, or other marks on the photocopied storybook) were collected, transcribed, and coded to reflect the content of their critique as relating to science (e.g., accuracy, parsimony), language arts (e.g., grammar, storyline), or being non-domain-specific (e.g., aesthetic preference for color over black and white drawings). This paper reflects findings from students' written critiques. Additionally, an average percent of time spent engaging science, language arts, and other was calculated per child to account for the wide variability in writing ability at early ages. One researcher coded all of students' written comments, with a second researcher coding a randomly selected 30% of all data to establish inter-rater reliability, resulting in high agreement (language arts kappa κ=.691, science κ =.898).

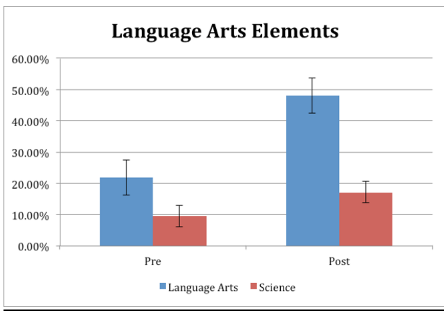
To explore the relationship between time and condition upon the mention of science or language arts content in the written critiques, a split-plot analysis of variance (ANOVA) was performed. Our hypothesis was that regardless of the disciplinary context framing students would pull from their science repertoire to create and talk about their storyboards due to their participation in the extensive science unit that targeted the same content represented in the honeybee books. A chi-square analysis was also completed to determine whether there was a significant difference in the proportion of each topic being mentioned across conditions and time-points.

Results

Across both conditions, students generally provided more discipline-specific critiques in the post-condition than the pre. This is unsurprising and likely attributable to the time spent learning the respective disciplinary practices in the intervening weeks. Below we describe the shifts in written critique practices across conditions.

Written critiques

Across both conditions, students' written critiques reflected an impact of both time point and disciplinary framing. Students were less likely than hypothesized to bring their practices of science critique into the language arts condition and vice-versa (see figure 1 and table 1). These results are discussed in further detail below.



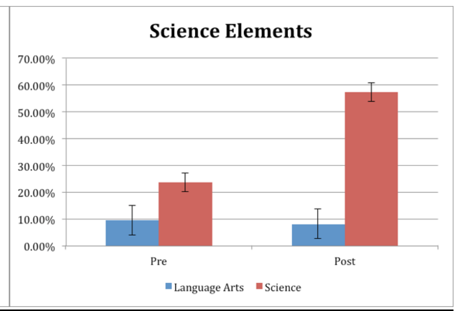


Figure 1. Percentage of written representational critique elements coded as language arts (left) and science (right). Remaining percentage refers to items coded as non-specialized or other.

Table 1: Mean number of written critique elements coded as language arts and science

		Language Arts Codes				Science Codes			
		Pre		Post		Pre		Post	
Condition	**N**	**M % (count)**	**SD**	**M % (count)**	**SD**	**M % (count)**	**SD**	**M % (count)**	**SD**
Language Arts	18	21.89% (3.83)	16.82 %	47.98% (6.06)	23.45%	9.41% (1.05)	10.55%	8.08% (0.79)	10.08%
Science	19	9.49% (1.83)	8.76%	17.09% (2.72)	14.66%	23.79% (3.05)	18.75%	57.36% (6.11)	19.81%

Language arts elements

Within the language arts group, there was an overall increase in the use of language arts elements in students' written critiques, from about 22% to about 48% of the students' written critiques. In the science group, there was also a (much smaller) increase in written critique of language arts elements, from about 9% to about 17%. (see both figure 1 and table 1). Although both groups saw their scores increase, the increase in the language arts group was proportionally more than three times the increase in the science group. This was a statistically significant interaction between time of measurement and context framing, $F(1, 35) = 21.03$, $p < .001$. The strength of this relationship, as assessed by partial $\eta 2$, was strong, with the interaction factor accounting for 37.5% of the variance in language arts elements.

Results also suggest that there was a main effect for both condition and time point such that the frequency of language arts elements including both pre and post was higher in the language arts condition compared to the science condition (32% vs. 13%) and that more language arts elements were present in the post-test than in the pre-test across both conditions (30% vs. 15%).

Taken together, these results suggest two key trends in students’ practices for written language arts critique. First, the disciplinary framing of the activity had a dramatic impact upon students’ practices, leading students to engage far more consistently on the language arts critiques during the language arts condition. Second, this effect appears to have been magnified over time. Thus the students in the science condition provided only marginally more critiques during the post-activity whereas the students in the language arts condition increased dramatically in the number of written language arts critiques they included. This increase can be attributed to continued engagement in the language arts curriculum during the intervention. Because all of the students experienced an identical classroom language arts curriculum over the 10-week period, we do not believe that these differences were due to chance but rather to the disciplinary framing of the activity. This highlights a key interaction between students’ developing practices and disciplinary framing given that students’ shift in practices related to language arts were much more evident in the language arts context.

As we turn to what this looked like for individual students in each of these conditions, Figure 2 illustrates the increase in language arts elements from the pre to post intervention written critiques. These examples are representative of the kinds of critiques the students generally provided and highlight the marked changes that occurred between the pre and post intervention in the language arts condition.

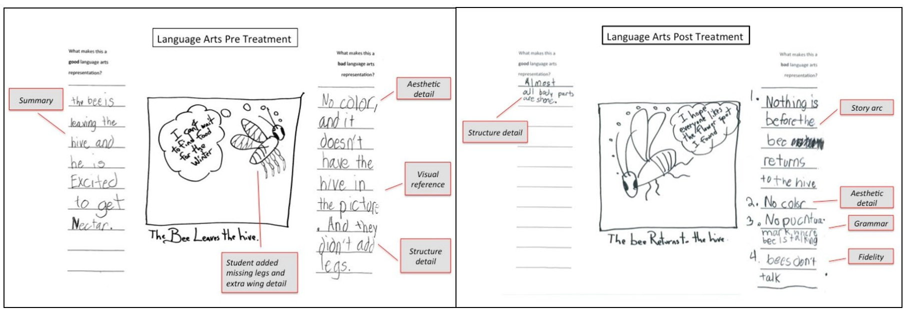


Figure 2. Sample language arts pre-intervention critique from Student 1 (left), sample language arts post-intervention critique from Student 1 (right).

In Figure 2 (left), the participant in the Language Art pre-intervention focused on general features of the image. When prompted, “what makes this a good language arts representation?” the student gave a summary response about the bee leaving the hive and being excited to get nectar, stating that “the bee is leaving the hive and he is Excited [sic] to get nectar”. This was coded as “other.” When prompted, “what makes this a bad language arts representation?” the student focused largely on the picture rather than the words, and used both the written and visual edits to identify some of the intentional errors in the structural details of the drawing of the bee. In this example, Student 1 drew on the booklet, adding the missing legs to the bee and adding details to the wings which was coded as “science” as it added greater scientific fidelity to the bee. Notably, the student has ignored other intentional grammar violations on the page, such as the uppercase ‘B’ in bee and ‘L’ in leaves as well as other intentional science and language arts violations that were included in the storyboard, including other inaccurate body parts (such as the missing thorax of the bee).

When comparing Student 1’s critique in the post-test condition after the 10-week curriculum (see Figure 2, right), several changes are apparent. There are still some general or science critiques found in the storyboard, such as reference to the fact that, “almost all of the body parts are [shown],” (coded as structure detail important to science), For example, the student critiques the story arc of the drawing because there is, “nothing before the bee returns to the hive.” The student also makes clear reference to the punctuation on the page, noting that there is, “no punctuation mark where bee is talking.” The student did not, however, pick up on the intentional violation of grammar in the text on the page with an upper case ‘R’ in the word returns.

Science elements

There was also a significant interaction between time of measurement and context framing in the prevalence of students’ written science critiques, $F(1, 35) = 13.60$, $p < .001$. The strength of the relationship, as assessed by partial $\eta 2$, was strong, with the interaction factor accounting for 27.9% of the variance in written science elements. There was a slight decrease in the mean percentage of science elements that each student included in their written critiques, from 9% to 8%, in the language arts context, and a significant increase in science elements in the science context, from an initial 23% to 57% of the written student critiques focusing on the critique of science elements (see table 1).

The frequency of science elements was also higher in the science context compared to the language arts condition (40% vs. 8% of the writings) and that more science elements were present in the post-test than in the pre-test (32% vs. 16%). This suggests that the context framing again had an impact in the type of criteria children picked to critique the storyboards, with students increasingly referring to science criteria as they learn them, particularly in the science context.Thus, the findings for students' practices of critiquing the science content of the representations appear to generally parallel those for language arts, reflecting an impact of both context and learning over time.

The case shown in figure 3 illustrates the findings from the science group before and after the 10-week curriculum. As with the language arts critique, this example was representative of the critiques of the classroom as a whole and particularly highlights the marked changes in the critique from the science condition from pre to post intervention.

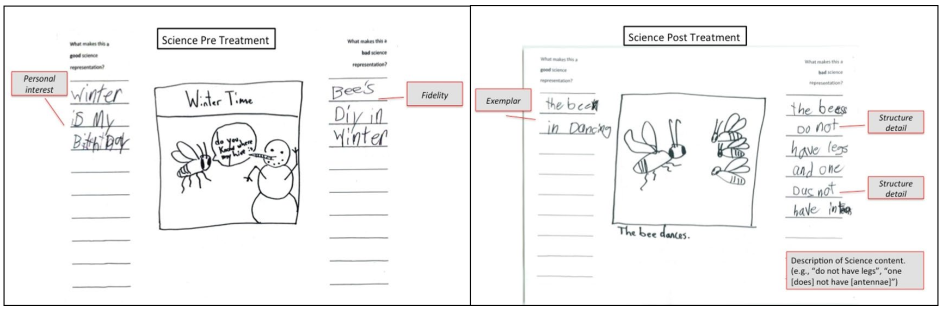


Figure 3. Sample science pre-intervention critique for Student 2 (left), sample science post-intervention critique from Student 2 (right).

In figure 3 (left), when the Student 2 was asked, "what makes this a good science representation?" the student response was simply a statement of personal interest ("Winter is my birthday") and thus was coded for "other." In response to, "what makes this a bad science representation?" the student makes reference to the fact that, "bees [die] in winter." While this is not an entirely accurate understanding of how bees survive in the winter (as many survive within the hive), it demonstrated the value that the student placed on' science fidelity that was an example of a science code.

In the post-intervention critique from the same Student 2, the student noted that this is good because it is a representation of the 'waggle dance.' This was coded as a science exemplar as the waggle dance was a central theme of the curriculum of how bees communicate. The student also showed marked improvement on recognizing missing science elements such as, "the bees do not have legs and one [does] not have [antennae]", which were both coded as structure details important to science (see figure 3, right).

Discussion

Our analyses suggest that students as young as first grade are well attuned to the particular disciplinary frame in which they work as they critique representations. In fact, they are quite likely to ignore major flaws in sample representations when evaluating it in a content domain in which those flaws are not central (e.g., students ignored grammatical errors when evaluating a representation framed as "scientific"). In short, our results indicate that disciplinary context plays a major role in shaping students' engagement with representational products, and that students' engagement in disciplinary content may at times be seen across the curriculum. While this paper focused on the students' written critiques, separate analyses of the verbal discussions suggested this trend continues when the whole group is in conversation. Given the increasing interest in cross-curricular activities designed to help students make connections throughout their learning activities, this suggests important opportunities for reflecting upon the quality and consistency of students' representational materials and activities. As the current piece does not dive into the interactional processes of learning, these findings also suggest the necessity of future research to more explicitly explore the impact of disciplinary framing upon student learning, particularly in these cross-curricular contexts. These collaborative micro-processes will continue to be of interest and importance to the CSCL community.

While these findings generally support the situative or sociocultural view that context matters in exploring cognition and learning, the details of our study offer several additional suggestions for researchers and practitioners. First, they point to some very real challenges inherent in cross-curricular activity designs. Increasingly, there is a push in early elementary education to enact interdisciplinary activities designed to help students see the connections across domains. In our work, we have found, for example, that as soon as the teachers know we are interested in teaching bees during “science time”, they identify books about bees for reading time, and have even worked with the art teacher to have students draw bees in art class. And yet, our findings suggest that these bridges are even harder to build than most educators likely anticipate. Given that the students in our experiment focused so intently upon language arts criteria as they critiqued science books within the language-arts-framed condition, it raises a question regarding what students might learn when reading about science topics in a time that is clearly designated as language arts? An important next-step in this line of research will be to examine how disciplinary framing of this nature influences student learning and other kinds of practices (e.g., creating representations rather than just critiquing them) to help address this question and effective practices to help bridge these disciplinary boundaries that seem to be so salient at even young ages.

A second and related result of this work is that there is clearly value in attending much more closely to how teachers frame activities as linked to a specific discipline, and what impact this has upon students. This is particularly relevant in early elementary classrooms where students typically work with the same teacher across content areas, as opposed to moving to new rooms and teachers as they frequently do in secondary school, and thus the shift between disciplines is marked most clearly by the teacher. In our experiment the teacher clearly framed the storybook activity as science or language arts, and then maintained this frame in follow-up questions. What is less clear is which features of the teachers’ prompts the students found salient in determining which practices to perform within the context. Future work which teases this out will be an important first step in understanding how to help students recognize the disciplinary context in which they are operation in order to promote discipline-specific practices.

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