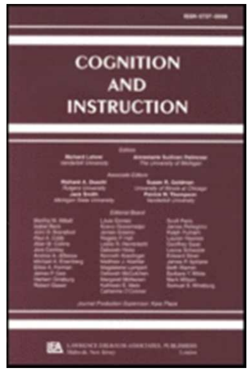

Exploring Disciplinary Boundaries in Early Elementary Students' Developing Practices

Journal:	*Cognition and Instruction*
Manuscript ID:	Draft
Manuscript Type:	Original Article
Keywords:	Social Context, Biology < Science Education, Sociocultural Theory

Exploring Disciplinary Boundaries in Early Elementary Students' Developing Practices

Core to the Learning Sciences is the belief that context matters (Sawyer, 2006) and the social, cultural, and physical environment in which students learn new content fundamentally shapes what they have learned (Greeno, 2006). The role of context does not, however, stop once students have "learned," or completed a set learning activity. Rather, students will be observed knowing information in a rich context where their knowledge is continually interacting with the context in ways that simultaneously reveals their understanding of the both the context and the appropriate ways of engaging with content within that context. 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 (Webb et al., 2009), what the composition of their groups looks like (Barron, 2003), whether they have access to technologies (Roschelle, Pea, Hoadley, Gordin, & Means, 2000), whether their home cultures align with the school culture (Lee, 2001; Moll, Amanti, Neff, & Gonzalez, 1992) 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; Bell, 2009). 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, or how this kind of knowledge manifests (or not) in the new disciplinary context. 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 in significant ways. Thus 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. A short picture book was chosen because it allowed us to represent an extended sequence, which is important in understanding both the science content (i.e., the honeybee behavior) as well as the language arts content (i.e., the narrative stories) and provided multiple opportunities for highlighting what students knew within each discipline through their critiques. 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 and verbal 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; John-Steiner & Mahn, 1996). These theoretical frameworks share a common ancestry in Vygotsky (1978) and highlight the role of the social environment in learning and development. However, a common misunderstanding is the assumption that sociocultural theories of learning ignore the individual and the information that they know. Rather, sociocultural theories focus on exploring the relationship between the individual and the social environment. As Greeno suggests:

[I]nformation is assumed to be constructed in the interactive processes of activity systems. More general structures of information, including practices of discourse and problem-solving strategy, are hypothesized to be in the common ground of participants in activity. And differences between individuals in their engagement in tasks and commitments to practices are considered as different ways in which individuals are positioned in their participation (Greeno, 2011, p. 43).

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). Thus 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 individual understanding's of what the disciplinary context means, while also teasing out the role of the environment in shaping those perspectives. In a rich activity context, however, it is challenging to know where one should begin their analysis given a theoretical account which suggests that all aspects of the environment may be relevant (Witte & Haas, 2005)[1]. This is particularly challenging when attempting to contrast disparate disciplinary contexts, which are mediated by rather distinct practices. Therefore, to ground our contrast we identified a common practice of both science and language arts—the critique 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 (John-Steiner & Mahn, 1996) 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 basic literacy practices are crucial for science learning, and because we hypothesized that it would be a distinct enough setting from science to make students awareness of disciplinary contexts visible.

When working with representations, one important practice shared by multiple disciplines is the ability to critique representations, both those that others have produced as well as one's own, in an effort to improve and refine it (Collins, 2011; diSessa, 2004). 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). Furthermore, these critiques are often a valuable opportunity for students to confront and refine their understanding of the content being represented (Danish & Phelps, 2010b; Enyedy, 2005; Parnafes, 2010). Critique is also a valuable practice from a research perspective because it challenges students to articulate their awareness of what makes for a good representation in a context-specific manner (Peppler, Warschauer, & Diazgranados, 2010).

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). Their ubiquity and variation, however, necessarily require that students develop robust practices for recognizing and working with representations of scientific concepts (NRC, 2007). In particular, students need to be able to critique and evaluate representations as part of a process of identifying the appropriate representation or representations for a given task and refining representations for use in conducting scientific inquiry (diSessa, 2004; diSessa, Hammer, Sherin, & Kolpakowski, 1991; Greeno & Hall, 1997; Lehrer & Schauble, 2006). 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 each representational form necessarily has specific criteria that one might use to critique it, such as the need to include the axis labels on a graph (diSessa et al., 1991), there is also reason to believe that students develop more general meta-representational competencies which include the ability to critique a wide range of scientific representations (diSessa, 2002). In an effort to identify what representational criteria students might employ, diSessa and colleagues began by listing of a priori categories of criteria including make-centered, use-centered, epistemic fidelity, and formal criteria. Make centered refers to challenges that might be faced when creating a representation, a category not relevant to the present study. Use-centered are those critiques related to an individual's perceived ability to use a representation to accomplish a task such as explaining new content or seeing patterns in data. Epistemic fidelity refers primarily to the inclusion and accuracy of specific scientific details such as the proboscis or tongue on a honeybee. Finally, formal criteria refers primarily to general properties of a representation such as systematicity, consistency, and simplicity which are valued across representational forms.

diSessa's data suggests that middle-school students employ all of these categories of critique in their work with representations. Danish and Enyedy (2007) found that early elementary students employed similar criteria in their evaluation of representations, particularly when they were encouraged by their teachers to evaluate representations along these lines. Thus our coding scheme for students' criteria for evaluating science representations was based upon this initial list, with minor modifications as described below to account for shared criteria across disciplines.

While there is a 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 literacy acquisition. 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 literacy skills (Duke, 2010; Purcell-Gates, Duke, & Martineau, 2007). Building on the idea of informational writing, we then generated a grounded list of criteria that The resulting coding scheme then 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 40 first and second grade students (ages 6-9) 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.” Two different instructors led the two conditions, although 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. In addition, the teachers regularly co-taught the mixed age classroom. Within both activities, the teachers followed the following sequence: 1) defining, generating a sample list of, and discussing what makes a good representation in the group’s assigned disciplinary context (i.e., science or language arts); 2) the teacher recording the groups’ thoughts on what makes a good representation on a shared whiteboard; 3) introduction of a short storybook about a honeybee finding and collecting nectar;

4) asking students to write, make notes, circle or otherwise draw on a copy of the book what they felt made it a good or bad representation (to accommodate a wide range of literacy levels); 5) follow-up whole group discussion to discuss the individual observations and to further clarify individual thoughts about what students felt made the book either good or bad; 6) discussion of a revised version of the book with many of the intentional errors removed to see if students felt it was "better" or not and thus articulate additional criteria.

The research team created the two storybooks used in these activities (one for use at each time-point) to represent a honeybee collecting nectar. 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). This data was 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 et al., 2011; Peppler & Danish, 2012), which we hypothesized would lead to increased critique of representations based on scientific accuracy in both conditions, especially considering that the storybooks displayed identical content that was taught and tested for in the BeeSign studies (i.e., honeybees seeking nectar from a complex systems perspective).

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). An individual utterance was defined as everything said by one speaker before the next speaker interjected. All units, including spoken utterances and writings, could be multiply coded for Science, Language Arts or other and 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 and spoken utterances, with a second researcher coding a randomly selected 30% of all data to establish inter-rater reliability. Agreement was high for both written comments (Language Arts kappa κ=.691, Science κ =.898) as well as for spoken utterances (Language Arts κ =.731, Science κ =.698).

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.

To ensure that any observed differences in students' practices were attributable to the context and not to differences in their engagement with the learning activities, we also tested whether the students' knowledge of the science content, as measured by a more traditional interview format, appeared similar across groups. This interview consisted of six questions about the behavior of bees such as how the waggle dance indicates where the flower with nectar is, anatomical details of the bee, and the function of these parts in the nectar collection (for additional details about the interview protocols see Danish et al., 2011). A split-plot ANOVA, with two groups as between-subjects and pre- and post-test as repeated measures, was performed to find out whether there were significant differences between students' interview responses in both Science and Language Arts contexts to determine whether the degree of science learning could account for the group differences found here. Results from the split-plot ANOVA show that there was no significant interaction between context and learning gains, $F(1,35) = 0.24$, $p = .627$; and no main effect of context framing, $F(1,35) = 0.95$, $p = .336$. However, a substantial learning gain was statistically significant regardless of the context framing, $F(1,35) = 73.89$, $p < .001$ (see Table 4). This indicates that all students, regardless of the group assignment, were equally capable of critiquing the storybooks from a science perspective. While we did not have similar pre and post measures for the Language Arts content as that was not the focus of the initial study, teacher reports indicate that all of the students engaged in similar learning activities.

Results

Across both conditions and communication formats (written and verbal), 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 the two conditions followed by a brief consideration of the verbal critique practices.

Written critiques

Across both conditions, students' written critiques reflected an impact of both time point and disciplinary framing. Contrary to what we had hypothesized, students were more likely to focus on scientific criteria in the science condition, rather than bringing their practices of science critique into the Language Arts condition and vice-versa. However, students in both developed a richer repertoire of criteria for critiquing the representations over the course of the 10-week curricula (see figures 1 and 2). These results are discussed in further detail below.

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 22% to more than 48% of the students' written critiques. By contrast in the Science group, there was a decrease in the written critique of language arts elements, from 8% to 6% of the student writings (see both figure 1 and table 1). 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 η^2, was strong, with the interaction factor accounting for 37.5% of the variance in language arts elements (see figure 1).

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 significantly higher in the Language Arts condition compared to the Science condition (35% vs. 13%), $F(1, 35) = 36.34$, $p < .001$, and that more language arts elements were present in the post-test than in the pre-test across both conditions (32% vs. 15%), $F(1, 35)= 16.14$, $p < .001$.

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 actually provided fewer critiques during the post-activity whereas the students in the Language Arts condition increased the number of their critiques 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 only evident in the Language Arts context and that the Science context might even be viewed as a degrading of skills due to the marginal decrease in critical elements.

As we turn to what this looked like for individual students in each of these conditions, Figures 3 and 4 illustrate 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. Note that all of the sample storybooks that the students critiqued had multiple pages (with one frame and short piece of text on each page) with various intentional science and language arts violations. For illustrative purposes, we have chosen a single page from Student 1[2] in the Language Arts condition and their pre and post written critiques. However, all of the pages of the storyboards were coded and analyzed for all students and summarized in the aforementioned statistics.

In Figure 3, 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.. From our classroom observations, we believe that these kinds of structural edits were learned prior to the pre-test from the non-fiction books that the teachers placed in the classroom in advance of the study, and from drawing exercises that the art teacher led in support of the curriculum. This is further amplified by the student's text stating that "they didn't add legs" (coded as *structure detail* important to science), that there is "no color" (coded as *aesthetic detail*/ non-domain-specific) and "it doesn't have a hive in the picture" as promised in the text below the image (coded as a necessary *visual reference* given the original written text in the caption and important to Language Arts). Notably, the student has ignored other intentional grammar violations on the page, such as the upper case '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 4), several changes are apparent seen. 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), that there is “no color” (coded as *aesthetic detail*/ non-domain-specific), and that “bees don’t talk” (coded as scientific *fidelity* important to science). However, the written critique demonstrates that the student was focusing on a greater number language arts elements in the post-test condition than in the pre-test condition. 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 *grammar* 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 η^2, was strong, with the interaction factor accounting for 27.9% of the variance in written science elements (see figure 2). 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 2).

The frequency of science elements was also significantly higher in the Science context compared to the Language Arts condition (40% vs. 8% of the writings), $F(1, 35) = 42.94$, $p < .001$, and that more science elements were present in the post-test than in the pre-test (32% vs. 16%), $F(1, 35) = 35.37$, $p < .001$. 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. However, there is one noticeable difference which is that students in both conditions increased their practice of critiquing the science elements although this was less dramatic in the Language Arts condition. This provides a distinct contrast with the Language Arts practices, which did not increase for both groups. We hypothesize that the variation across content areas is due to the fact that the students in the class were engaged in a standard and wide-reaching language arts curriculum, which was not explicitly targeted in our storybooks whereas the storybooks specifically targeted the same content—honeybees collecting nectar—as the science intervention. Additional studies would need to be conducted to verify this, however. Regardless, even with this difference in focus, we see that the increase was less dramatic in the Language Arts condition, further strengthening our hypothesis that the disciplinary framing of the context influenced students' practices.

The case shown in figures 4 and 5 will be used to illustrate 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.

In this example (figure 5), 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" and not coded for referring to science or language arts elements. 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, including activities simulating the waggle dance with the children. 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 6).

Verbal discussion

Since young children are not always as proficient in their writings as they are in their speech, we wanted to triangulate the written critique data presented above with an analysis of their whole group verbal discussions. The proportion of utterances pertaining to Science, Language Arts, and non-disciplinary-specific elements in students’ verbal discussion also revealed an impact of both time and context framing, similar to what was described in the results of the written critiques above (see table 3). Thus, again the disciplinary context framing elicited significantly different proportions even in the pre-test, in which students’ verbal discussions were referencing more science elements (32% vs. 11% of the utterances) in the Science context than in the Language Arts context, $\chi^2(1) = 16.03$, $p < .001$, and less non-specialized elements (12% vs. 25%), $\chi^2(1) = 5.99$, $p = .014$. In the post-test, there was an overwhelming (and highly significant) difference in science talk in favor of the Science context compared to the Language Arts context

(51% vs. 9%), $\chi^2(1) = 4.98$, $p = .026$. Last but not least, for the Science context, science elements were significantly higher after the intervention, increasing from 32% to 51%, $\chi^2(1)=4.98$, $p=.026$.We again attribute this gain to the specific focus of the intervention around the science content being represented (honeybees).

While the students did add new verbal critiques related to the content they had learned, it seems that much of their change was related to the frequency of their comments, not necessarily the content. This suggests that the shift in students' verbal practices involved a greater attention to the specific disciplinary framing, not necessarily the specific content features although we do see some changes in features in the written critiques. To illustrate these patterns, consider some general examples from the class. In the science activity, the instructor started the discussion by asking the class, "what makes a good science representation?" The following student statement typifies our findings from the science pre-intervention group discussion: "Um, well, I'm basically fired up about how the bad science representations because almost well really every single page has at least one bad science representation. Like none of the pages have color, for instance. And like maybe some of the pictures the bee didn't have a stinger." This statement did correctly identify some aspects of scientific *fidelity* that were violated such as missing body parts, but also is an example of talk that was coded as non-discipline-specific in the pre-intervention groups by focusing on that the books were black and white, rather than color.

As mentioned previously, the science post-intervention group discussions had much higher instances of science elements compared to the pre-intervention group. When asked what doesn't make sense on the papers at the end of the ten week curriculum, one student responded, "in that one I think it's weird cause bees can't stand on two legs, and they don't wear hats and they don't show the dance on a map where the flower is." In this single statement, the student correctly identified intentional violations that were not scientifically accurate and also critiqued extraneous information in the drawing like the bees wearing hats. Although, as this example indicates, many of these critiques were not necessarily grounded in the newly learned content so much as in a general focus on scientific accuracy (e.g., the students did not note the need for 6 legs in their talk though some had in their written critique).

The patterns in students' verbal practices were similar in that there was an increase in frequency not necessarily a noticeable shift in the type of content being referenced. For example, one student commented during the pre-intervention activity that the bee was asking a question, and yet there was no question mark. Similarly, in the post condition a student noted that there was a period in the middle of a sentence by saying "Well they put a period here, doesn't really make sense." In short, while we did see some changes in the content of students' written critiques, the changes we see in the verbal critiques appear to be more related to quantity than quality. This may be because it is natural to be more general in ones' talk and more specific when taking time to carefully critique a written artifact. However, additional data would need to be collected to further unpack this discrepancy, however.

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"). While this pattern is somewhat mediated by students' growing expertise in a specific content area, which resulted in a slight (but non-significant) increase in references to science criteria within the Language Arts condition. 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. 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. 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.

Our goal in this study was to explore the manner in which students as young as first and second grade are already responding to disciplinary framing as they engage in learning activities. To accomplish this we examined students' written and verbal critiques of a short book about honeybees gathering food in two conditions, which their teacher positioned as either science or language arts. To further understand the relationship between this framing and content learning, we asked students to engage in these critique activities both before and after a 10-week science unit (Danish et al., 2011) where students learned about how honeybees collect nectar, the topic of the book they were reading. We expected that while students would reveal some differences based on framing, these would be most pronounced in the pre-condition. That is, we expected that the students would all be critical of the science content in the book after spending 10 weeks learning the content, causing the differences due to disciplinary framing to fade over time as their expertise increased. The students also referred to the research team as "the bee team" and "the bee people" because of our role in supporting them in learning about bees during science time. Thus we expected that our presence would further prime students to attend to scientific facts about bees in all conditions.

Therefore, we were not surprised to see that students whose activity was framed as science were more likely to critique the book based on science criteria than language arts criteria and vice versa, and that students in both groups increased their frequency of critiquing the book based on scientific criteria over time. We were, however, somewhat surprised at the true extent of the between group differences during the post-test: the students in the language arts condition continued to focus on grammar and story errors and ignored many more of the science errors, indicating that the influence of context was even great than we anticipated. This was true despite a lack of significant difference between the two groups of students with respect to learning the content. This suggests that the disciplinary context of an activity has a powerful influence upon student actions even as early as first grade. Disciplinary framing clearly plays a key role in determining which knowledge students will bring to the fore and which will fade into the background.

From one perspective, this can be seen as an effective adaption on the part of the students who are attuned to what was being asked in the assignment. However, it does point to some very salient disciplinary boundaries where students fail to access other information that might inform the current task. For example, a good storybook might also engage high quality science content and certainly good science still needs to have high quality writing, grammar, and other pieces important to language arts. Having the students see the two as disparate may mean that they are not applying what they know in one context more generally to another and that, moreover, we need to be cautious in how we frame any activity to draw on the vast amount of information that students may know coming into the task. This seems particularly relevant as we think about non-dominant groups and the kinds of knowing and experiences they may have that they view as fundamentally disconnected from disciplinary or school-like experiences.

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 inter-disciplinary 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 teach 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.

Alternatively, it will also be valuable to understand how teachers might position content as cross disciplinary and what impact this might have on students' perception and activity. For example, if the teacher in the language arts condition had suggested that the students would benefit from evaluating their stories based on science criteria as well as language arts criteria, would we have seen the same differences across groups? However, how then do we create invitations for students to draw upon other disciplinary frames (such as the arts) or understandings that they bring with them from their home or other out-of-school activities? Addressing these questions will be particularly valuable as we aim to support teachers in continuing to encourage cross-disciplinary/cross-context activity in a productive and robust manner.

Finally, these results have very clear implications for how we think about assessment and evaluation of student learning in elementary classrooms. Had we used these critique sessions as opportunities for formative or summative assessment of students' science learning, the students in the language arts condition might have been found lacking whereas the students in the science condition would have shown clear evidence of learning gains. While we assume that teachers and researchers would not intentionally put students in such an odd position as evaluating their science learning in language arts contexts, it may be that these conditions are unknowingly created for students. After all, if simply beginning a session by suggesting that the group is focused on science began our framing, it may be possible to inadvertently accomplish the same thing. Furthermore, we assume that such inadvertent framing is even more likely for those students who are less familiar with the “school game”, and whom are already at a disadvantage when being evaluated based on knowledge that presumes an awareness of how school works.

Conclusion

There is ample evidence that the context of learning matters. The present work extends this into a deeper consideration of how disciplinary framing acts as a context and transforms students’ perceptions of their learning environment with minimal effort. Simply calling an activity science or language arts can lead students who are engaging in an identical task such as critiquing a book about bees to treat it as quite different, focusing on an entirely different set of disciplinarily-appropriate criteria for their work. This is particularly striking given that it took place in a first and second-grade classroom, where students have spent very little time learning about the disciplinary frames that are so present in school. Given these results, future work can now attend to these simple framing moves to better support the teaching, learning, and assessment of disciplinary content.

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Footnotes

[1] While Witte and Haas were referring to Activity Theory in particular, we see their concern as being relevant to the broader collection of sociocultural theories of learning.

[2] Student ID numbers were generated for this manuscript in order of appearance and do not reflect the students' classroom IDs nor their research subject IDs.

Tables

Table 1

Mean number of written critique elements coded as Language Arts

		Pre		Post	
Condition	N	M % (count)	SD	M % (count)	SD
Language Arts	18	21.89% (3.83)	16.82%	47.98% (6.06)	23.45%
Science	19	9.49% (1.83)	8.76%	17.09% (2.72)	14.66%

Table 2

Mean number of written critique elements coded as Science

		Pre		Post	
Condition	N	M % (count)	SD	M % (count)	SD
Language Arts	18	9.41% (1.05)	10.55%	8.08% (0.79)	10.08%
Science	19	23.79% (3.05)	18.75%	57.36% (6.11)	19.81%

Table 3

Between conditions comparison of students verbal references

	Condition	N	% talk LA	$\chi2$	% talk Science	$\chi2$	% talk non-specialized	$\chi2$
Pre	Language Arts	122	19%		11%		25%	
	Science	102	23%	0.465	32%	16.03**	12%	5.99*
Post	Language Arts	99	22%		9%		11%	
	Science	51	18%	0.43	51%	33.02**	6%	1.09

* significant at $p < .05$
** significant at $p < .01$

Figures

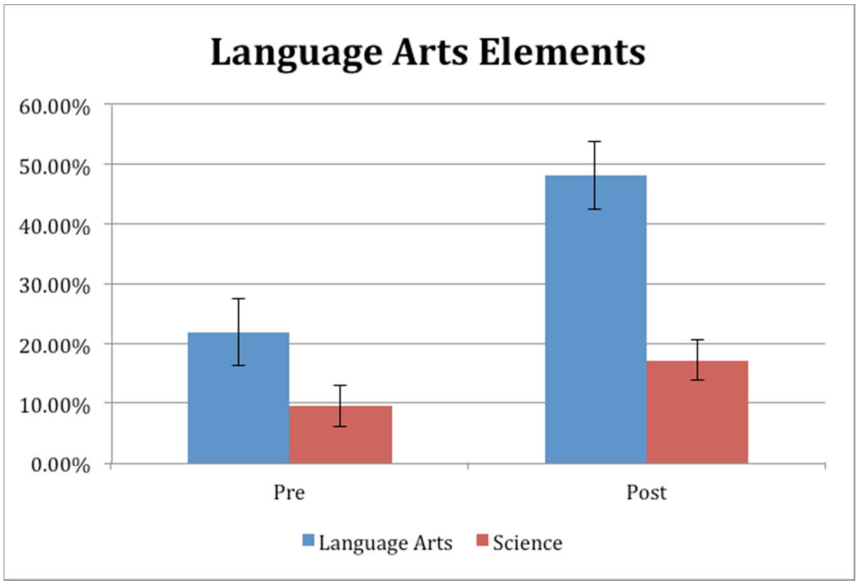

Figure 1. Percentage of written representational critique elements coded as Language arts.

Remaining percentage refers to items coded as non-specialized or other.

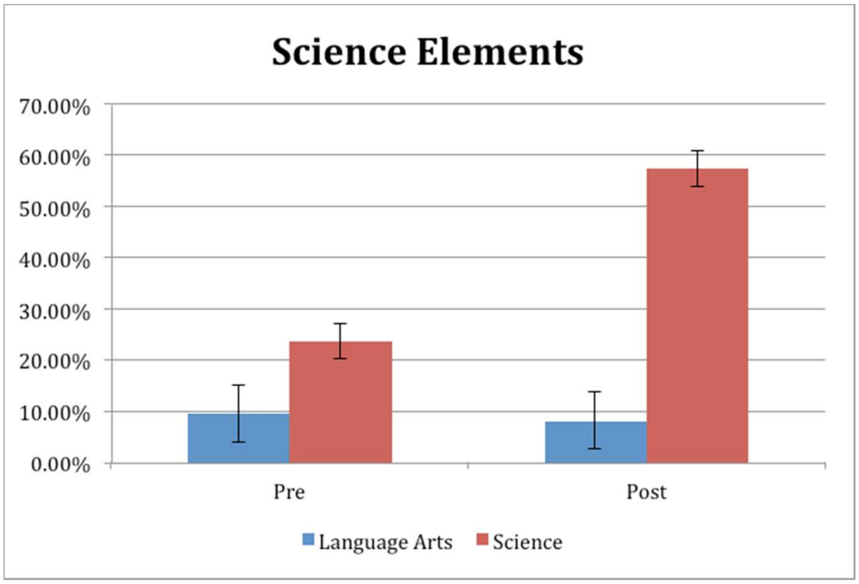

Figure 2. Percentage of written representational critique elements coded as Science. Remaining percentage refers to items coded as non-specialized or other.

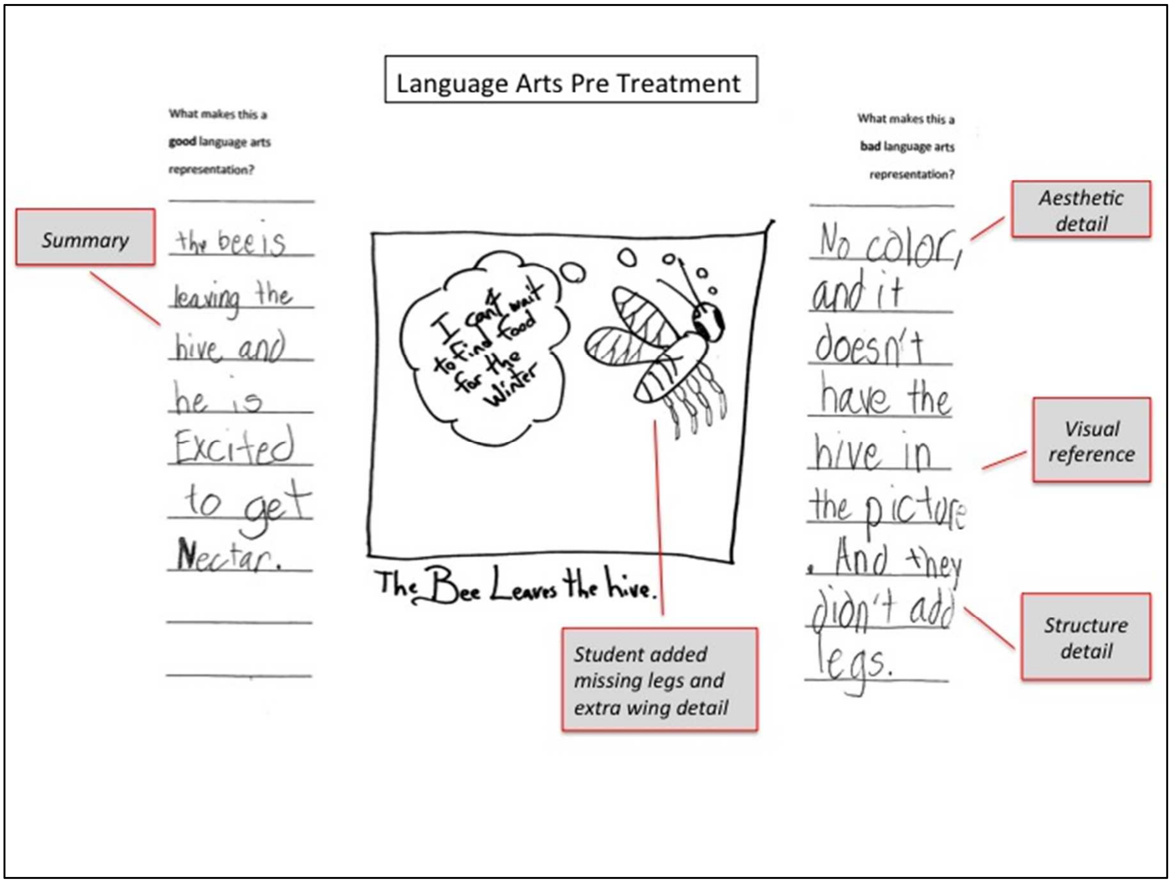

Figure 3. Sample language arts pre-intervention critique from Student 1

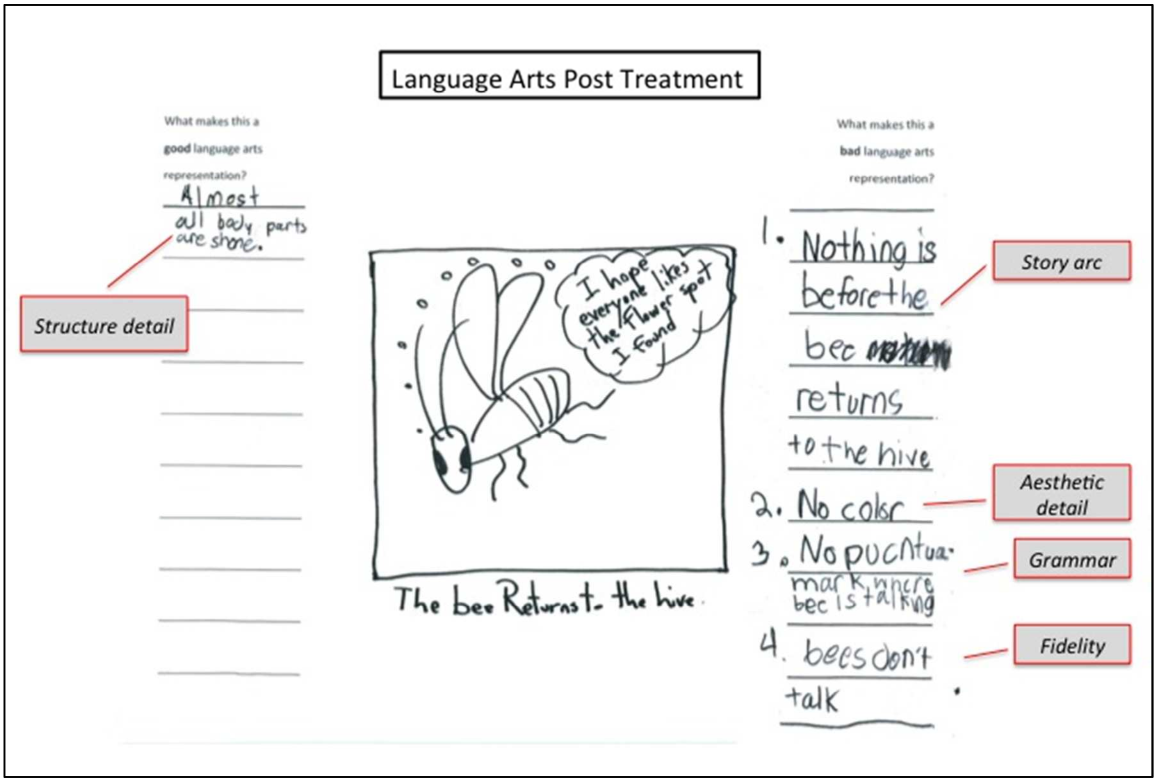

Figure 4. Sample language arts post-intervention critique from Student 1

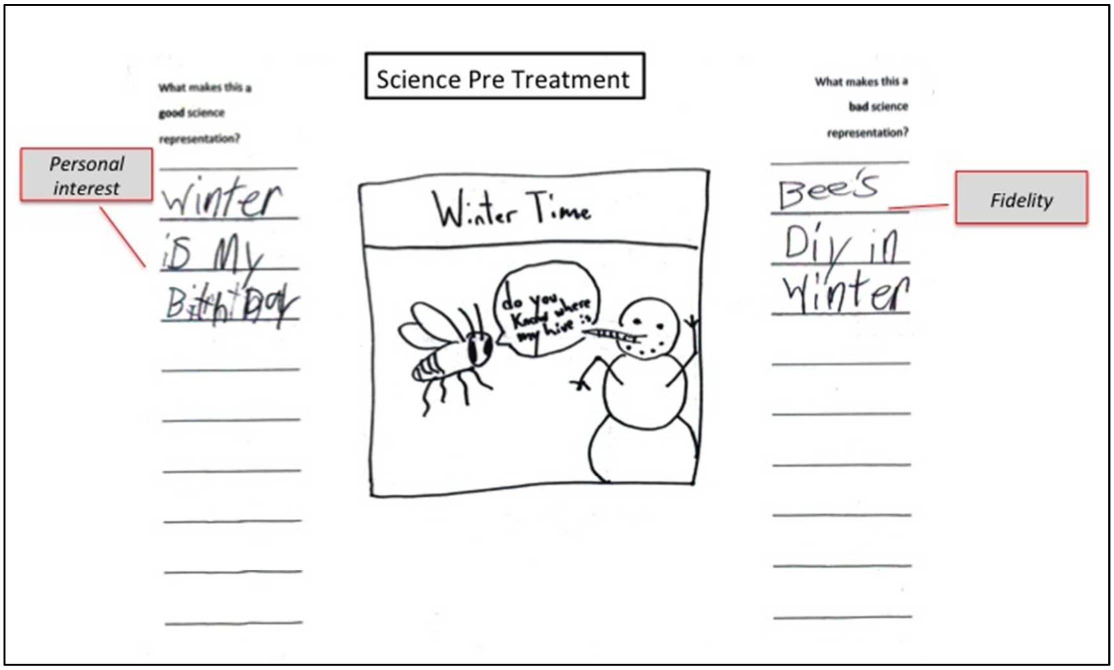

Figure 5.

Figure 5. Sample science pre-intervention critique for Student 2

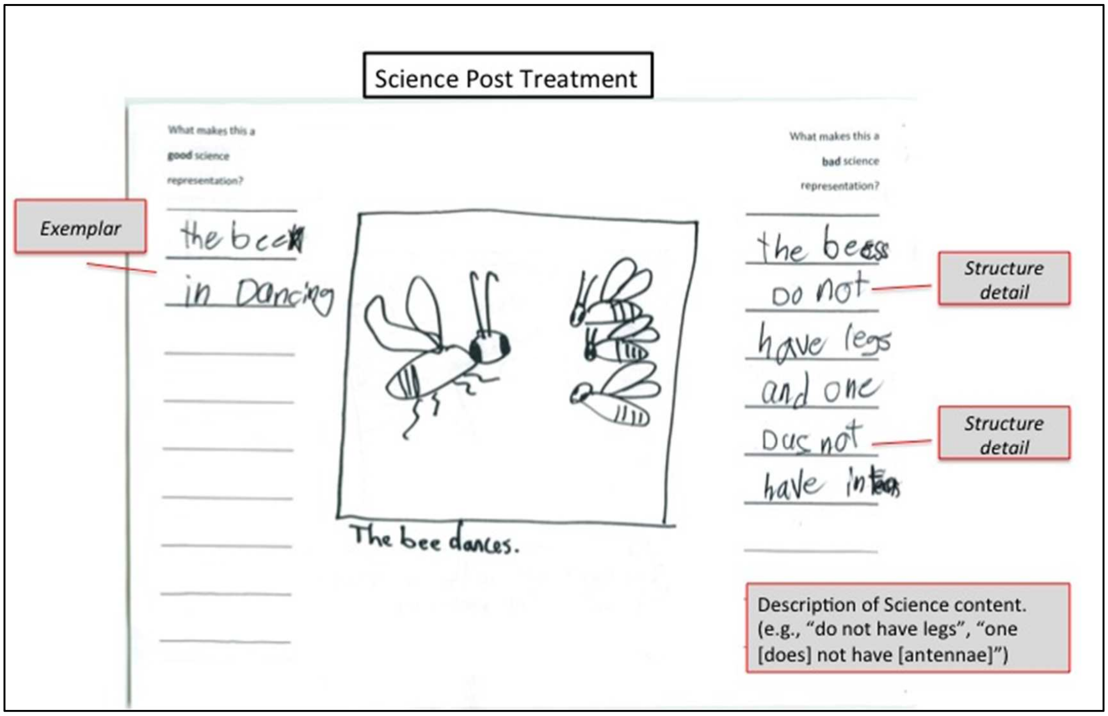

Figure 6. Sample science post-intervention critique from Student 2