Fostering Scientific Argumentation by Creating a Need for Students to Attend to Each Other's Claims and Evidence

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Abstract: Scientific argumentation can provide students and teachers with opportunities to use evidence to make sense of the phenomena being studied and to engage in central practices of the scientific community. We posit that fostering the practice of argumentation requires transforming classroom interactions in order to create a need for students to attend to each other's claims and evidence. This paper examines the enactment of a 7th grade ecology unit created to generate this need and support these discussions. Our analyses of the student discussions show students moving beyond typical classroom interactions in order to understand the ways in which their claims differ and to evaluate one another's claims, in light of the evidence. Thus, we conclude that this approach of creating a need and supporting students as they attend to and critically evaluate one another's claims and evidence appears to be a promising strategy for fostering scientific argumentation.

In the last two decades, two related themes of science education reform have emerged. First, reforms call for conceptual understanding and sense making about mechanisms to be cast as the goals for science learning (e.g. Linn, Songer, & Eylon, 1996). Second, engaging in the practices of scientists, developing an understanding of the beliefs and values necessary for scientific inquiry, is thought to be core to science learning (e.g. Duschl, 2000; NRC, 1996). Scientific argumentation can help students and teachers achieve both of these far-reaching goals. First, framing the task as presenting and defending understandings focuses students on critically using evidence to make sense of the specific phenomena being studied (e.g. D. Kuhn, 1993). Second, using available evidence and scientific knowledge to defend and evaluate understandings in discourse is a central practice of the scientific community (e.g. Driver, Newton, & Osborne, 2000; Duschl, 2000).

Both of these aspects of argumentation – the sense making and discourse – create challenges for students. First, students tend to be inconsistent in whether they carefully distinguish their claims or theories from the evidence that supports them. For example, they are likely to ignore or re-interpret anomalous data in order to defend an erroneous knowledge claim (e.g. D. Kuhn, 1989). Kuhn argues that these findings suggest that learners have difficulty distinguishing and coordinating theories and evidence and that this weakness affects students' ability to engage in argumentative discourse, in which they must evaluate the fit between the claims and evidence. Hogan and Maglienti (2001) suggest that these findings reveal another difficulty facing students; students may not see the distinction between evidence and theories as useful or necessary for their task. That is, everyday arguments may rely equally on coherence or plausibility and evidence, and thus do not depend as centrally on this distinction. Using this interpretation, one design challenge to fostering student participation in scientific argumentation is helping students to *value* evidence in sense making and evaluation.

Second, traditional classroom activities often inhibit the social discourse of critically attending to, defending and evaluating understandings. For example, the common classroom interaction in which the teacher asks a question, a student answers and the teacher responds to the answer given (Mehan, 1979) largely prevents students from engaging in student-to-student discussion (Lemke, 1990). Moreover, this interaction style neither enables nor necessitates that students build upon one another's contributions. Thus, in typical classroom interactions, students have little need to understand the substance of one another's ideas, nor consider whether they understand and agree with them (Lemke, 1990). Motivating and enabling students to connect their own understandings to those of their peers is a second challenge to fostering argumentation.

The solution to these challenges lies in their combination; creating activities that motivate students to attend to one another's ideas can provide a context in which the fit between claims and evidence is a meaningful and important evaluative criterion (e.g. Driver et al., 2000; Duschl, 2000; Hogan & Maglienti, 2001). Fostering these interactions requires classroom activities that necessitate and value the students' contributions and supports that emphasize the alignment between claims and evidence (e.g. Hatano & Inagaki, 1991; Herrenkohl & Guerra, 1998;

Hogan & Corey, 2001; Osborne, Erduran, & Simon, 2004). To explore this approach, we designed classroom activities and supports that motivate students to use evidence in order to convince one another that their claims accurately explain the phenomenon under study. This approach is designed to provide students with the opportunity, motivation and tools to meaningfully attend to and critically evaluate one another's ideas and evidence. In this paper, we examine an enactment of these activities, examining this connection: if we are able to motivate students to attend to one another's ideas, will the fit between claims and evidence become a meaningful criterion?

Design Strategies

To examine the potential connection between students substantively attending to one another's ideas and evaluating claims with evidence, we engaged in a design study. We worked with a 7th grade teacher to redesign an existing 7th grade ecosystems unit (Bruozas et al., 2004). The original version of this eight-week unit was designed to support students as they constructed "evidence-based scientific explanations." These explanations were typically one paragraph long and contained a claim that is supported with evidence and scientific principles. While the existing design supported students in applying ecosystems concepts to understanding interesting phenomena, students had no authentic reason to listen to each other or engage with one another's ideas. Thus, our redesign focused on creating activities that motivated students to substantively attend to one another's ideas, through scientific argumentation.

To do this, we extended the existing task of "explaining" by creating a need for students to attend to and critically evaluate one another's explanations and supportive evidence. In addition, we worked with our cooperating teacher to develop scaffolds that helped students develop criteria for defending and critically evaluating one another's explanations. These supports focused students on one another's evidence. For example, the class developed a list of characteristics that good evidence must have, and a list of possible questions one might ask when evaluating explanations (Kenyon, L. Kuhn & Reiser, 2006). We designed two kinds of activities that placed students in positions which required them to critically attend to the claims and evidence of their peers:

1. Argument Jigsaw: Pairs of students construct an explanation. Two pairs then combine, compare explanations and converge on a single explanation. The goal of this activity is for students with disparate ideas to agree upon a single solution, thereby *creating a need* for students to consider each explanation while determining how they fit together and use the available evidence to choose between them.
2. Whole Class Debate: The groups of four present their final explanations. During the presentations, other students are made responsible for asking the groups questions about their explanations and evidence. These questions reflected the students' criteria for evaluating evidence and explanations. By placing students in the role of questioner we are *creating a need* for the students to attend to one another's presentations.

These two activities work together in that the second, the Whole Class Debate, provides a forum for the product of the first, the Argument Jigsaw. Thus, during the Argument Jigsaw students are aware that the product of their work will be presented to and questioned by their classmates. In this way, the Whole Class Debate is designed to *create a need* for the product of the Argument Jigsaw. Over the course of this 8-week unit the students had three opportunities to engage in these argumentative activities.

Method

The cooperating teacher enacted this unit in three classes, in a large Midwestern city. We observed and videotaped the enactment in one of the classes. This class contained fifteen students, eleven girls and four boys, from diverse backgrounds. We met with the cooperating teacher weekly to evaluate and revise the lessons, in response to the students' and teacher's needs. While observing, the researchers would occasionally work with the students, asking leading questions and facilitating discussions. This study focuses on the videotapes, but the data corpus is augmented with pre and post interviews and the students' written work.

In consultation with the teacher, we selected two "focus" groups to follow throughout the enactment. Both groups consist of two student pairs that converged during the Argument Jigsaw activities. Group 1 consisted of two girls, Janelle and Jalen, and two boys, Peter and Toby. Group 2 consisted of four girls: Keisha, Lanelle, Sarah and Vanessa. Examining the written work and the videos of the presentations reveals that our focus groups' answers

were of similar caliber as those of the rest of their class. Further, the teacher reports having students similar to those in these groups, in each of her three classes.

Analysis

In this study, we designed activities to foster student participation in scientific argumentation. Our design is predicated on the idea that typical school practices do not create a need for students to engage with one another's ideas and that if we were able to foster substantive interactions, the students would use evidence to evaluate one another's claims. This study examines this connection by examining two questions: 1) whether students attend to one another's ideas during the enactment and 2) whether the students use evidence to evaluate one another's claims. To address these questions, we focus on two aspects of critically attending to claims and evidence: 1) comparing claims 2) aligning claims with evidence.

Our analysis for this paper focuses on the third and final explanation that students construct, defend and critically evaluate, in the unit. In this explanation, the students solve a mystery about why most of the finches died on a Galapagos Island in 1977, and why some did not. Solving this mystery entails a two-week investigation of a computer database (Reiser et al., 2001) in which students gather evidence to answer three questions: 1) What environmental change affected the finches' survival? 2) What trait affected the finches' ability to survive the environmental change? and 3) How did that trait affect the finches ability to survive?. Halfway through the project, pairs of students engaged in an Argument Jigsaw, forming groups of four and working to converge on a single answer, identify remaining problems and complete their research. At the conclusion of this process, the class participated in a Whole Class Debate in which they evaluated and questioned one another's solutions.

Comparing Claims

A key aspect of our design approach for fostering argumentation was to motivate students to substantively attend to one another's ideas, building on them and identifying where the claims differ and agree. Unsurprisingly, actively comparing one's own claims to some one else's is one of the challenges facing students (Hogan & Corey, 2001; Sandoval, 2003). In this study, evidence of this challenge emerges during step one of the Argument Jigsaw, in which student pairs exchange work with their counterparts, and evaluate one another's explanations. The worksheets supporting this evaluation ask students to score their counterparts' evidence and claims. In both of our focus groups, students perform this evaluation quickly without discussing the scores within or across pairs. Thus, the explicit task of evaluating the other pair's explanation did not seem to engage students in a substantive comparison or evaluation.

In contrast, as the goal of the task changes from explicit evaluation to agreeing upon a group product, the students in both groups move beyond this cursory evaluation and discuss their explanations in more detail. For example, in Group 1, Toby performs a perfunctory evaluation of Janelle and Jalen's written work. Shortly after receiving this evaluation, Janelle verbally restates her claim and evidence identifying the trait that allowed some finches to survive and explaining why that trait mattered. Throughout her explanation, Toby responds affirmatively saying things like: "yea, that is what we got" (05.26.05 tape #1, 00:33:43). These positive statements suggest that Toby is comparing Janelle and Jalen's work to his own; in this case he determines that they agree. Later in this exchange, Janelle recognizes that the pairs differ on the environmental change they claim to have affected the finches' survival, saying: "What I notice is that your claim and our claim is opposite…" (05.26.05, tape #1, 00:40:25). This begins a lengthy discussion (described in the following section) in which the pairs compare the two claims and their various supports for them. Thus, in Group 1, the students move beyond the cursory evaluation of one another's claims and evidence to engage with one another's ideas by considering the relationship between them; these students are substantively engaging with one another's ideas.

In Group 2, the pairs also compare their solutions to the Finch mystery. Vanessa and Sarah report that the finches' predator, the owls, increased causing the finches to die. They found that finches with longer wings survived and concluded that the increased wingspan helped the birds escape the owls. Lanelle and Keisha found that the changes in weather caused the birds' food to decrease, causing the finches to starve. This pair also reports that the birds with a larger wingspan survived better, concluding that the wing length allowed birds to fly further to find food. In this discussion, the pairs do not explicitly state their points of agreement and disagreement. However, their work to converge on a single solution (discussed in the following section), offers evidence that these students implicitly compared their solutions and identified their points of disagreement.

Thus, the students in both focus groups engage with one another's ideas, substantively comparing them in order to determine how they fit together. In past enactments of this unit, we have seen students evaluate one another's explanations without identifying their points of disagreement. However, in these interactions the students go beyond a cursory evaluation and develop an understanding of each other's ideas. Although this type of interaction is scarce in typical classrooms, it appeared to emerge naturally out of the students' discussions in which they needed to combine their explanations in order to determine whether and how they differed. We hypothesize that the students' engagement emerged out of this activity because the students' goal was to combine disparate answers to construct a single explanation; the students needed to determine where they agreed and disagreed in order to accomplish this goal.

Evaluating Claims with Evidence

In this unit, we motivate students to evaluate the alignment between the claims and evidence by creating activities that create a need for the students to attend to one another's ideas. In the above analysis we see students substantively attending to one another's ideas by determining the ways in which their ideas are similar and different. Our design rests on the claim that this type of engagement will make the need to evaluate claims with evidence meaningful for the students. Thus, in this analysis we examine whether students use evidence to evaluate one another's claims.

Group 1 chooses between the pairs' competing claims about the environmental change that caused the birds' food, the seeds, to decrease: Toby and Peter claim that it was torrential rains while Janelle and Jalen claim that it was a drought. While working on resolving this difference, Janelle pushes Toby for evidence, saying things such as: "but do you actually have numbers that says the rainfall increased? Because you can't say it increased without numbers" (05.26.05, tape #1, 00:40:25). These prompts indicate Janelle's awareness of the importance of evidence; she is unwilling to accept Toby's account unless he supports it with evidence. In this discussion, Toby and Janelle discuss their differing interpretations of the data. For example, Toby sketches the rainfall graph that he remembers in which the rainfall spiked (indicating torrential rains) while Janelle counters with numbers that demonstrate the rainfall decreasing over the course of three dry seasons (indicating a drought) (05.26.05, tape #1, 00:42:33). Both of these interpretations have merit: Toby is looking at the changes from the dry to wet seasons in which the rainfall increases substantially while Janelle is looking more broadly at the wet and dry season cycles. At the conclusion of the discussion, Toby eventually agrees with Janelle's more accurate interpretation, saying: "Yea, it is possible" (05.26.05, tape #1, 00:42:37). Thus, not only do Toby and Janelle use evidence to evaluate a claim, but Toby changes his own understanding to more accurately align with the available data. Not only are these students actively engaged with one another's ideas, but they are using evidence to evaluate their theories.

While discussing their different claims, Group 2 originally attempts to combine the two explanations. Keisha suggests that they combine the claims causally: "Maybe it is the weather that attracts the owls" (05.26.05, tape #2, 00:02:52). Attempting to combine disparate ideas is a viable solution to resolving a conflict. However, in this case, the combined claim is neither supported by evidence nor well thought out (this exchange takes less than a minute). This solution does not last. Instead, while talking to the second researcher, the students realize that the available evidence disproves Sarah and Vanessa's claim that the owls increased.

After the students acknowledge that there is no evidence to support their claim, Sarah asks: "So what do we do now?" (05.26.05, tape #2, 00:21:53). The researcher encourages the students to look on the computers for evidence that will resolve the debate, but the students don't think they have enough time. Vanessa says: "Can't we just agree on an answer and…I mean we have the numbers but theirs makes more sense because, because we looked at the graph and the owl population didn't actually go up [it decreased]" (05.26.05, tape #2, 00:22:34). In this exchange, Vanessa appears to grapple with the fact that her evidence does not support her claim; it contradicts it. The incongruity between the evidence and claim prompts Vanessa to worry about the criteria for selecting claims: should they select the claim for which the students have not reported any supporting evidence or the claim for which the evidence is contradictory? Through this struggle, Vanessa uses evidence to evaluate the claims; and in the end, Vanessa chooses Janelle and Keisha's unsupported claim over her own. From a practical standpoint, this is a good decision because the students are able to find evidence that supports this claim in future class sessions. Moreover, this decision demonstrates Vanessa conceding the intuitive appeal of her erroneous claim that an increase in predators affected the finch population and, in response to her group members' feedback, accepting that the contradictory evidence disproves it. This decision demonstrates Vanessa using evidence to evaluate a claim.

This discussion is clearly not ideal: the other members in this group only participate minimally and an authority figure (the researcher) encourages their focus on evidence. However, even with these caveats, this conversation reveals a student struggling to choose between competing claims by evaluating the evidence. Thus, the need to agree upon a single claim and the pedagogical supports that focused on evidence seemed to help Vanessa (and to varying degrees, the rest of her group) to evaluate the alignment between their respective claims and evidence.

We also see the students take on the challenge of aligning the evidence and claims during the Whole Class Debate. For example, when Group 2 presents their solution to the Finch mystery, the class discusses whether the group has evidence to support their claims. This begins with Lanelle reading Group 2's answer:

> The environmental change that affected the finches' survival was when the Galapagos Islands had a drought during the years of 76 and 77. The trait that affected the finches' ability to survive the environmental change was the wing length because since the food was drying up, they had to fly farther for food and the finches with longer wings were better at flying farther for food (06.06.05, tape #2, 00:25:33).

While discussing this explanation, many students in the class question whether the group has evidence to support their claim that the birds are flying farther for food. As one student puts it: "How do you know that they were flying to get their food?" (06.06.05, tape #2, 00:29:01). This sparks a discussion, spanning two class periods, in which the class attempts to determine whether the finches fly to find food. Members of Group 2 defend their assertion that the birds fly to find food by presenting database descriptions of the birds "walking" and "wandering" to their food. But, there is no conclusive evidence that the birds *fly* to find food. Throughout this discussion, the class struggles in considering the inconsistency between the claim (birds *fly* to food) and evidence (birds *wander* or *walk* to food). In the end, Group 2 resolves this question by assuming "wandering" means "flying." As they state in their final written solution: "We know that the ground finches' were *flying* farther for food because in the field notes, it said that they were *wandering* around the island searching for food" (emphases added). The group's resolution is a bit unsatisfying; they have interpreted inconclusive evidence in a manner that ignores the ambiguity and supports their claim. However, given their time constraints and the lack of deterministic evidence, it seems understandable.

In each of these examples, the students evaluate explanations by aligning the claims and evidence. During the Argument Jigsaw the evidence led both groups to select the stronger of the two claims. In Group 1, the students determined that a drought caused the birds' food (the plant seeds) to decrease. Likewise, in Group 2, the students figured out that rather than an increase in predators, the finches died because of the weather. Moreover, in the Whole Class Debate, the class realized the available evidence was too vague to conclusively evaluate the claim. Thus, in all three of these examples, we see the students using evidence to evaluate their claims.

Discussion

The activities in our curriculum were designed to foster argumentation by creating a need for students to critically attend to one another's claims and evidence, thereby making the distinction between evidence and claims meaningful and relevant to their interactions. This study was admittedly small and requires additional research with more classes and teachers. However, analysis of this pilot study suggests that this approach of creating a need for the students to substantively attend to one another's claims and evidence seems to be a promising solution to the dual problems of supporting students as they 1) productively attend to one another's ideas and 2) evaluate claims with evidence.

First, the students substantively attend to their ideas as they compare claims, identify the points of disagreement in order to construct a shared response during the Argument Jigsaw. While the first step of the Argument Jigsaw seemed to motivate students to perform cursory evaluations of one another's work, similar to the evaluations one might expect in a typical classroom, the larger goal of convergence seemed to motivate students to move beyond these perfunctory evaluations, in order to identify their points of difference and similarity.

Second, the instructional supports (Kenyon, L. Kuhn & Reiser, 2006) and teachers guide the students to use evidence when evaluating one another's claims. While the students struggle with this emphasis, they appear to use evidence in their final decisions. Moreover the Whole Class Debates provide additional opportunities for students to

evaluate claims with evidence. In the example provided, the class works to interpret vague evidence in order to determine whether that evidence supports the provided explanation.

These conversations are challenging for the students; throughout the discussions, they struggle to articulate and understand the differences in their interpretations of the data and are unsure of the criteria to choose between their claims. Thus, while this pilot study begins to support our conjecture that creating a need for students to evaluate claims with evidence fosters student participation in the practice of scientific argumentation, we need to revise this approach to more explicitly help students develop a language to engage in these discussions.

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