

Make or Break Collaborative Disciplinary Engagement in Science: Managing Conceptual Uncertainty in Group Work

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Abstract

While conceptual uncertainties position students to engage in the disciplinary practices of science in meaningful ways, that engagement is dependent on how students respond to and manage such uncertainties. The current study examines various epistemological, social, and affective dynamics and how they influence the management of conceptual uncertainties in one group of middle school students in a science classroom. Using multimodal discourse analysis, we found that students' persistence in disciplinary engagement is not only dependent on the presence and recognition of conceptual uncertainties but also on how students take up and manage challenges along epistemological, social, and affective dimensions. Our work can inform educators interested in supporting students to navigate the complex and multidimensional dynamics of collaborative sensemaking in service of promoting disciplinary engagement in science.

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Problem

Education reforms emphasize engaging students in authentic practices of science where students are positioned to construct mechanistic explanations of scientific phenomena by navigating ambiguous data, making connections between different concepts, and resolving conflicts through argumentation (NGSS, 2013; NRC, 2012). Collaborative group work in science classrooms provides valuable opportunities for students to share their ideas, wrestle through and negotiate conceptual uncertainties, and deepen each other's understanding of scientific phenomena (Michaels & O'Connors, 2015; Radinsky, 2000, 2008). While conceptual uncertainties may be essential for students' engagement in sensemaking (Chen et al., 2019; Manz, 2015a), how such uncertainties are addressed and negotiated within a group can either sustain or hinder disciplinary engagement (Conlin, 2012; Engle & Conant, 2002; Engle et al., 2014). This study examines the various social, affective, and epistemological dynamics that arise within a group of eighth graders as they work through conceptual tensions during an argumentation activity in a biology classroom. The research question addressed in this study is: *What are the key epistemological, social, and affective dynamics that emerge in a small group as students manage conceptual tensions arising from a science problem with ambiguous data?*

Theoretical Framework

The primary goal of science is to construct evidence-based, mechanistic explanations of natural phenomena (Machamer et al., 2000; Russ et al., 2008). Informed by this goal, current reforms in science education envision classrooms as spaces where students draw on facts and theories, prior knowledge, intuitive ideas, and observations to construct evidence-based, mechanistic explanations of phenomena (Bell & Linn, 2000; Kelly & Green, 1998; Russ et al., 2008). For learners to engage in such disciplinary practices reflective of the goal of science, it is important that they are provided rich science tasks that allow them to wrestle through ideas and debate various lines of reasoning (Manz, 2015b; Sampsom et al., 2011). Research on scientific argumentation highlights the important role conceptual uncertainty plays in creating such opportunities for engagement (Chen et al., 2019; Manz, 2015a). Working through uncertainties is particularly important for collaborative group work where engagement can be viewed as involving cycles of construction, critique, negotiation, and refinement of ambiguous conceptual ideas (Oliviera & Sadler, 2006; Roschelle, 1992). This work involves the pursuit of alignment between multiple conceptual viewpoints in service of developing coherence among different ideas and advancing the collective understanding of the group with respect to the phenomenon under investigation (Sikorski et al., 2009; van de Sande & Greeno, 2012).

Managing conceptual uncertainty involves debating, discussing, and evaluating differing or opposing claims in order to develop a consensus understanding (Radinsky, 2008). However, this process can often lead to conflicts and tensions shaped by how students respond to and navigate the uncertainty. Students might respond with different understandings of the nature of the work (e.g. sensemaking versus doing school work; Jiménez-Aleixandre et al., 2000), and different ideas about the social interactions needed to negotiate divergent ideas (collaborative sensemaking versus deferring epistemic authority to a particular group member), as well as the roles that each are expected to play and the perceived influence that they have in those roles (Engle et al., 2014). In addition, conceptual uncertainty might generate different emotional

responses for students; some might be very curious to “figure things out” while others might be scared or frustrated to engage with the unknown (Jaber, 2014).

Management of conceptual uncertainty, therefore, may be shaped by how students navigate the various epistemological, social, and affective dynamics that may arise, dynamics that have the potential to either foster or destabilize student engagement (Ha & Kim, 2020; Radoff, 2017; Shim & Kim, 2018). For example, Engle and colleagues (2014) show how the social positioning of one student led to the favoring of a weakly supported scientific argument over a stronger one, limiting the group’s disciplinary engagement and their conceptual understanding. Building on this line of research, we argue that it is important to examine the various social, affective, and epistemological dynamics that emerge within students’ negotiation of conceptual uncertainty and how such dynamics may be channeled in ways that support collaborative disciplinary engagement. In this study, we empirically examine a group of middle school students engaged in a science task to understand the key epistemological, social, and affective dynamics that emerged as they negotiated conceptual uncertainties.

Design

This study is part of a larger professional development project geared towards supporting teachers to foster student sensemaking about science through talk. The lesson, *Mechanisms of Evolution in Venezuelan Guppies* (Sampson & Schleigh, 2013), occurred in an eighth grade biology honors class across two days and positioned students to explore an existing data set and develop evidence-based claims from those data in response to the guiding question: *What causes color variations in Venezuelan Guppies?* The data set was ambiguous in nature--there were multiple variables with marked variation in the data for each. The concepts targeted included natural selection, sexual selection, and the interplay between these mechanisms and how they shape population traits over time and space. Students spent much of their time working in small groups to develop their argument and create a poster to share with their peers.

In this current study, we examined a case of one small group consisting of four students--Desmond (Caucasian boy), Marshal (Asian boy), Sandi (Caucasian girl) and Jessie (African-American girl). This diverse group of students engaged in a sustained discussion that lasted about 50 minutes spanning the two days of the lesson. Data drawn upon included video and audio recordings of students’ discussions along with classroom artifacts. Drawing on tools from video analysis (Derry et al., 2010), multimodal and behavioral interaction analysis (Jordan & Henderson, 1995; Stivers & Sidnell, 2005), and discourse analysis (Gee, 2004), we analyzed the data to (1) identify moments of conceptual uncertainties and (2) examine the epistemological, social, and affective dynamics experienced by the group members during those moments.

Findings and Analysis

During the initial discussion on the first day of the two-day lesson, we observed students grappling with multiple conceptual ideas in response to the guiding question. Brief moments of conceptual uncertainty were often resolved when the students presented additional evidence or a revision of an explanation. However, as the episode progressed, two contrasting lines of ideas started to emerge--*Number of Predators* and *Turbidity*-- as the main factors affecting the coloration of the guppies, resulting in a major conceptual tension among the group members. This conceptual tension persisted for the majority of the episode and was shaped by, as well as led to, a variety of epistemological, social, and affective dynamics within the group.

The conceptual tension was first made public by Sandi who explicitly oriented her peers to the two lines of reasoning around turbidity and predator as a point of conflict in the group: *"I (Sandi) think that the coloration is affected by the turbidity because drab colors would blend more in with more drab water. And bright colors would pop more in less drab waters. But, that's one aspect of it but you guys also argued that it has something to do with the predator population. So, we need to know why the predators are going down to make evidence and reasoning. Cause if we just make that claim, we need to back it up. So. And there could be more than one reason why the predator population is going down, but we should at least try to highlight one.....So why? What changes..what changes from (pool) one to two?"*

Day 1- Wrestling through the Conceptual Tension: After identifying this conceptual tension, students worked to resolve it by presenting and conjecturing multiple forms of evidence and reasoning. Two possible explanations were being considered to explain the decrease in the number of predators including the pool location (*"Location and predators have like- as that goes up (pool location goes above the waterfall), that goes down (number of predators decrease)"*) as well as the behavior (hunting and movement between pools) of the predators (*"The rivulus fish is the only fish that....even travelled to (pool) number three."*).

Desmond was in strong support of the number of predators as the main factor affecting coloration of the guppies (*"Yeah the brighter ones wouldn't be able to mate because they would get eaten by the predatory fish so then they wouldn't pass that on"*). Sandi on the other hand strongly supported turbidity as the main factor (*"But, that would be true for all of the guppies. Why..Why is there such a big, larger trend here? It's because of turbidity, right?"*). Both of them were trying to explain their point of view to each other using multiple evidence and explanations. The discussion between Sandi and Desmond was causing confusion for the other members of the group. Earlier Jessie had questioned the claim about the predators (*"Maybe predation has nothing to do with it because we're not finding anything that says it has anything to do with it"*). Later, she started questioning whether turbidity even had an effect anymore (*"I don't even think it's turbidity anymore."*). The conceptual tensions appeared to have a profound effect on Jessie as she decided to take some time and think about it outside the class (*"Mr. Jerry, can I take a picture of this? Of the table thing. So I can make up my mind before tomorrow"*).

Examining how the group managed these divergent lines of reasoning made visible the multidimensional nature of their negotiation and allowed us to see how various epistemological, and affective dynamics shaped the group's engagement in Day 1, especially around the end of class where students felt the pressure to reach some kind of consensus. The persisting conceptual uncertainties as well as the time constraint triggered some epistemological tensions in the group: While students were grappling to identify the evidence to support the two claims, Marshal was more focused on finalizing a claim to put on the group's poster. Worrying about time running out, Marshal urged the group to select one of the two claims to put on the poster explaining that they could discuss additional evidence in support of the other claim during the presentation. (*"We can like..I mean like..Maybe like, when you're explaining it when we do the presentations, you can mention it but I don't think we have enough..like theres..There's so much more evidence we need if we want to. So just toss that off"*).

As the group continued to debate the two lines of reasoning and in light of the time pressure, affective tensions started to build up. Jessie for example was frustrated that the group had not finalized a claim complaining about the ways in which the group interactions were

unfolding (*"This is stressful. We didn't even get a claim. Why would he put us together? We all argue too much"*). Sandi also exclaimed in frustration: *"Wow. I hate fish because of this"*.

Day 2- Picking up where they left off: The conceptual tensions that were unresolved at the end of the first day continued into the second day of the lesson: The students were still torn between the claims of turbidity and predators as the factors affecting the coloration of guppies. Unlike the previous day, the students were more aware of the time crunch--they had about 20 minutes to finish the poster that they had not even started to make. While Sandi and Desmond who refused to relent from their respective conceptual stances continued to engage in active scientific argumentation, Marshal's insistent press to finish the poster (*"Just pick... a claim where we can have enough evidence to support it and then just go with it because we have 20 minutes."*) led the group to simply select the claim of turbidity. However, once again, the unresolved tension surfaced various epistemological, social, and affective dynamics within the group

We noticed the epistemological tug of war between Sandi and Marshal. Marshal was advocating for "getting a claim down" on the poster (*"We just need something down. So how about we get a claim down and you can change it on your own"*) while Sandi continued to press the group to figure out the reasoning behind how predators are affecting the coloration (*"Oh my god! We're trying to say why it does it"*). Along with her desire to make sense of the phenomenon, Sandi also wanted to have a unanimous decision about the claim that the group will select. She worried about Desmond feeling left behind or ignored, a worry that made her uncomfortable; she kept insisting in various ways to include everybody's points (*"I don't even think he's wrong, but I don't think it's the main thing affecting it"*).

These various dynamics surfaced intense emotions from certain group members. Desmond, for instance, became frustrated that others did not understand his explanation (*"I haven't even- I haven't said population ONCE"*). His bowed head with his eyes avoiding contact with other members of the group indicated his frustration that the discussion had gone on long enough without the group coming to an agreement. Marshal was also frustrated, but he used laughter to lighten the tensions palpable in the group. Sandi on the other hand continued to be vexed about not being able to figure out the phenomenon (*"we have to figure out a claim"*).

Day 2- Tensions re-ignited: In response to Marshal's press to finalize the poster, the group had—though half-heartedly—almost finalized their claim when Jessie showed a little hesitation with her acceptance of the turbidity claim (*"I don't... mm"*). Since she was in the position of the scribe, her hesitation had a profound effect on the group. Sandi asked: *"Do you not agree with that now?"*. While Jessie made explicit her hesitation by not writing the claim, she was also torn: she wanted to get a clearer understanding of the phenomenon while at the same time she was aware of the need to finish the poster on time. When she made a bid to revisit the argument by asking Sandi to prove why turbidity was the factor affecting the coloration of guppies, Marshal interrupted her saying that there was no time and they needed to go with a claim. Jessie gives in.

This last bid by Jessie to express her hesitation about the claim reignited the conceptual tension and resulted in heightened affect among the group. There were rich affective displays at this point and frustration was running high. We see Sandi with her hand on her head eventually burying her face in her arms; Jessie with her hand on her cheek while writing the poster with the other hand; Marshal was looking with a frustrated look at Jessie and Sandi; and Desmond was standing and fidgeting with his hands while watching Jessie write on the poster. At one point Desmond raises his hand and exclaimed: *"I HAVEN'T said population"* while Sandi noted: *"I*

HATE this.” Jessie at one point stopped writing and started swinging her hands on the side and she commented: “*We all have different opinions. Why would he put us together? Oh my gosh.*”

Summary: Our analysis revealed that the initial disciplinary engagement was triggered and by the conceptual uncertainty introduced by the ambiguous data set. However, over time, epistemological, social, and affective dynamics played an important role in the manner in which students responded to and managed the conceptual uncertainties. Some students were persistent in their quest to understand the scientific phenomenon (Sandi), while others prioritized making the poster leading to their superficial conceptual engagement (Marshal). We also saw students buckling under the mounting epistemological (Jessie) and affective tensions (Desmond), finding it hard to manage the conceptual uncertainties. These data suggest that persistence of students in disciplinary engagement is dependent not only on the presence and acknowledgment of conceptual uncertainties but also, and perhaps more importantly, on how they take up and manage challenges along the epistemological, social, and affective dimensions. The data also hint at the idea of a threshold of tensions. Some conceptual tensions are an essential aspect of disciplinary engagement, but when those tensions are extended for too long, or are accompanied by tensions along the other dimensions, they may eventually lead to disengagement. Scientists’ threshold for such tensions is high, as they have learned to wrestle with ideas and have come to enjoy such wrestling as part of their scientific pursuits (Jaber & Hammer, 2016). Examining how students manage these tensions can give us insights into supporting students in developing such a tolerance that can sustain their disciplinary engagement.

Contributions to Teaching & Learning of Science

Research on scientific argumentation views the process as a collaboration in which students negotiate and clarify their conceptual uncertainties (Asterhan & Schwarz, 2009; Chen, 2020). However, this process can be challenging and tensions may emerge. In the current study, we presented an analysis of the management of conceptual uncertainty by a group of eighth grade students engaged in a science activity and how this management was influenced by myriad emerging epistemological, social, and affective dynamics. Our analysis suggests that although conceptual uncertainties act as a driver for refinement of student understanding, this alone is not sufficient to drive the overall disciplinary engagement in science. Indeed, students need to also navigate the epistemological, social and affective parameters that emerge in the process.

Impact and Interest to NARST Membership

Given the vision of science education presented in current reforms (NGSS, 2013), the field is in need of descriptions of how students engage in collaborative disciplinary engagement to understand what this work requires of them. In this research, we present a case study of collaborative disciplinary engagement and highlight the kinds of conceptual, epistemological, social, and affective tensions that students grapple with during an argumentation session. Understanding the nature of the myriad tensions experienced by students is an initial step toward designing supports to enhance collaborative disciplinary engagement. Our work will be of importance to NARST members interested in supporting students to navigate the complex and multidimensional dynamics of collaborative sensemaking in service of promoting disciplinary engagement in science.

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