“I wanted to break the pencil”: The Teacher’s Role in Reframing Moments of Epistemic Vexation

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Abstract

Science Education has transitioned to science proficiency-- students are to gain the ability to engage in sense making about the natural world (National Research Council [NRC, 2012])--learning to “figure things out” (Passmore, 2014). One emerging area of focus is the emotional work students participate in during science sense making. There is growing recognition that these emotions are not just unnecessary by-products of scientific work, but rather they are part-and-parcel of doing science, as these emotions are part of what “instigates and stabilizes disciplinary engagement” in scientific pursuits (Jaber & Hammer, 2016b, p. 189). The research question that guided this study is: What is the teacher's role in reframing moments of epistemic vexation, so students experience productive meta-affect in the science classroom? After reviewing video footage and student and teacher interviews, three themes emerged: (1) Without reframing from the teacher during moments of epistemic vexation, students disengage from sense-making, (2) Productive meta-affect is more likely to occur when students understand why the teacher allows for failure to connect ideas or understand scientific concepts, and (3) When the teacher does not reframe moments of epistemic vexation, students build solidarity and reach out to each other for emotional support in developing productive meta-affect.

Subject & Problem

Science Education has transitioned from a portrait of science learning as one driven by the recognition of “facts" to that of science proficiency--in which students are to gain the ability to engage in sense-making about the natural world (National Research Council [NRC, 2012])--learning to “figure things out” (Passmore, 2014). To allow for the development of this proficiency, it has been argued that students should engage with science in ways that, to some degree, mirror the work of scientists (Davidson et al., 2020). By engaging in the practices of science in concert with using the ideas and concepts to construct explanations about the natural world, in short--engaging in the doing of science--students are thought to gain epistemological insights about the discipline (Duschl, 2008; Engle & Conant, 2002; Ford, 2008; Hodson, 2014). The emphasis on more authentically engaging in the discipline of science asks students to share, discuss, and refine thinking about scientific phenomena in a classroom community (Bamberger & Davis, 2013; Berland & Reiser, 2009; Manz & Suarez, 2018; McNeill et al., 2006).

Many aspects of this disciplinary engagement have been widely studied and continue to be a focus of ongoing investigation. For instance, examining how students come to know and use the discursive practices of constructing explanations from evidence and evaluating claims through argumentation has been a particularly rich arena (Ford, 2008; Ryu & Sandoval, 2012; Walker et al., 2014; Zembal-Saul et al., 2013). One emerging area of focus is that of the emotional work involved in science sense-making. Davidson and colleagues (2020) argue that epistemic affect--learning how to *feel* as scientists do when engaged in their work-- should be recognized as a central component of meaningful disciplinary engagement in science (Arango-Muñoz, 2014; Jaber & Hammer, 2016a, 2016b). Epistemic affect includes “the emotional responses, feelings, and dispositions that emerge as one participates in the construction of knowledge through figuring things out about the natural world” (Davidson et al., 2020, p. 1008). There is a growing recognition that these emotions are not just unnecessary by-products of scientific work, but rather they are part-and-parcel of doing science, as these emotions are part of what “instigates and stabilizes disciplinary engagement” in scientific pursuits (Jaber & Hammer, 2016b, p. 189). From this position, epistemic affect is recognized as an essential aspect of scientific research and thus needs to be considered as students are learning to engage in science practices (Davidson et al., 2000; Jaber & Hammer, 2016a).

A number of studies have described the affective dimension of students’ disciplinary engagement. The elementary students that Engle and Conant (2002) studied were recognized as being passionately engaged in their debate around the categorization of orcas. This notion of passion is found elsewhere as well. Manz (2012) describes “explosions" when students are engaged in generative sense-making, Berland and Hammer (2012) describe deep levels of “passion” as students are engaged in argumentation, and Zion et al. (2004) describe how this passion and excitement is important in carrying students through “changes and intellectual crossroads" (p. 749). Much of the extant research focuses on the role of emotions in propelling or enhancing disciplinary engagement. However, it must be recognized that negatively balanced emotions such as vexation, confusion, anger can also hinder or halt that engagement (Davidson et al., 2021). Encounters with uncertainty inherent in science can be uncomfortable, invoking emotions such as anxiety, frustration, vexation, and fear (Anderson et al., 2019). However, in the right circumstances, emotions around uncertainty shift from a negative valence toward more positive emotions, such as excitement or curiosity which can act as motivators to persevere in light of uncertainty (Anderson et al., 2019; Davidson et al., 2021). Jaber et al. (2019) describe how "having the space to share and interact with each other's affective expressions" can allow students to keep students engaged in their sense-making work. Thus, teachers' efforts to keep students engaged involves recognizing their confusion and vexation while helping students associate these feelings with excitement, which is necessary if students are to persist in the face of uncertainties (Davidson et al., 2021; Manz, 2015, Manz & Suarez, 2018).

We have argued elsewhere that if educators are to support students' disciplinary engagement, teachers should learn to "listen and validate students' feelings and emotions and to help students come to see that uncertainty is a normal and natural part of disciplinary engagement in science" (Davidson et al., 2021, p. 7). Jaber (2021) describes that teachers need to be ready to attune themselves to "students' intellectual and emotional experiences in moments of sense-making to gain perspective on their own ways of thinking and feeling, a perspective that enables teachers to be more attentive and responsive to students' contributions in their instruction." (p.7).

Research Question

While this is an emerging area of inquiry, much work remains in terms of understanding how teachers can support their students as they learn to manage the emotions inherent in disciplinary engagement. Toward those ends, this work provides a description of a teachers' efforts in supporting his students in navigating these emotions. The question at the center of this research is: What is the teacher's role in reframing moments of epistemic vexation, so students experience productive meta-affect in the science classroom?

Design & Procedure

Methodology

A qualitative approach was used by analyzing interviews given by the participants. Thematic coding was employed by the research team to better understand the relationship between the role of the teacher in moments with of student epistemic vexation and productive meta-affect for students. A team of two researchers coded the interview transcripts. After reviewing their coding, the researchers were able to align their usage of thematic codes.

Context & Participants

Data for this study comes from a larger four-year professional development project focused on supporting teachers in their work to foster student sense-making through productive science talk. Specifically, we selected the first year of this project and the experiences of one high school science teacher and his students to focus on. Danny, our focal teacher, is a white-male chemistry teacher who was followed through four lessons that he designed to focus on aspects of student sense-making through talk. In addition, we focused on a racially diverse group of female students (Candice, Emily, Hannah, and Rose) who shared their rich experiences around the lessons Danny taught, and their feelings around specific moments that occurred in the classroom.

Data Collection & Analysis

Data sources for this study include classroom video recordings, teacher interviews, and student interviews. Analysis for this study was done using a constructivist grounded theory approach (Charmaz, 2017), where patterns were identified in both Danny and his students' perceptions of his teaching. The first author adapted the coding scheme from Radoff et al. (2019) to identify common themes in the student interviews. These interviews were split into two parts, the first part focusing on recall of the four lessons and student feelings during and throughout the lessons, while the second part focused on whole group discussions that occurred in the class and how specific researcher-selected clips made them feel. The second author drew out common trends in Danny's four post lesson interviews and two end of year interviews to identify how he frames student emotions when teaching. The post lesson interviews asked questions about the implementation of the individual lessons, and the end of year interviews summarized experiences across the entire year. Authors then met to discuss the alignment of what students and Danny were saying in these interviews compared to what was seen in the classroom videos.

Findings & Analysis

In order to better understand the themes developed, a vignette and the themes that emerged from our analysis of this vignette are presented below. This moment was one of two video excerpts shown during student interviews at the end of the school year. This moment from Danny's AP chemistry class happened during a discussion after an investigation. Students were asked to develop a claim for the guiding question: How are the different wavelengths of light seen in the flame tests related to the electronic structure of their atoms? Students conducted the investigation the prior class period and explained their thoughts to respond to the guiding question in a whole group discussion. In this whole group discussion, Carol, an eleventh grader, raised her hand:

Danny [2:36]: You have a question, Carol? What's your idea?
Carol: Barium was the weird green one.
Danny: Ok
Carol: Which…would have made it be the one…that took the most…err, with the highest energy. Because it's green.
Danny: You want to elaborate on that more? Why was green the one with the highest energy?
Carol: Because red's the lowest…and…color spectrum.
Danny: So what's the relationship that we're seeing between those colors and the energy?
Carol: Umm…ok, let me say wha-
Danny: Ok let's finish and then we'll get to that
Carol: It's probably going to be a bit of a circle but it's ok. Umm…so…it's green.
[Class laughs. Carol flushes red]
Carol: Umm… it's outer level is… It's the 6s group.
Danny: Ok
Carol: It's a pretty high energy level.
Danny: Ok
Carol: So, it takes more energy for the… umm… and it has a full outer dude, I think. I don't know.
Danny [3:59]: So what do you mean by outer dude?
Carol: Valence ring… I think. I don't… I really don't know.
Danny: Ok
Carol: I know what I am trying to say, I just can't say it.
Danny: Ok, does someone else know what she's trying to say? Maybe can kind of clarify for us what she is trying to say?
[Carol puts her head in her hands]

Theme 1: Without reframing from the teacher during moments of epistemic vexation, students disengage from sense-making.

In the vignette above, Danny has multiple opportunities to reframe the moment for Carol. Instead, he says, "Ok," six times. While he gives Carol space to work through her thinking, he did not ask her probing questions that prompted her to work through the academic vocabulary block she experienced. The vocabulary Carol struggles with was taught in a previous chemistry course. Danny expressed in an interview his lack of patience for students who struggle to recall information he believes they should already know.

"Instead of it being like, a building kind of thing, you [student] really should know this if you graduated from middle school to high school. And I'll talk to them in that kind of way as they're walking through it…. for them it feels like I'm just being mean to them." -Danny

This unmet expectation may be why Danny does not reframe the moment for Carol. Regardless, at the end of the interaction, Carol is seen putting her head down in her hands in frustration. She does not engage in the conversation again. Other students noticed this and Danny's responses during their interaction. In her interview, Rose spoke about this vignette.

"I remember like this discussion being like particularly painful… [Carol] especially would start saying things and then just shut down and like no one understood was going on and Danny would just like keep like asking her like trying to get out of her and she would just not say anything… but like he was just like, hammering [Carol] and it was just like to a point where it's like this isn't productive anymore."

Theme 2: Productive meta-affect is more likely to occur when students understand why the teacher allows for failure to connect ideas or understand scientific concepts.

Danny prioritizes giving his students experiences where they have the responsibility to make decisions, which may lead to emotions similar to those of scientists. In the previous class, Danny had students design their own procedure and work on sense-making in small groups to further their understanding. This was not an uncommon experience in Danny's classroom. Students understood why Danny would give them these experiences for their own sense-making.

"It definitely felt more like we were the scientists, not the students, I guess let's put it that way. It felt like we were, we were scientists and not like we were making a discovery, although it was already proven, but like, still felt a lot more interesting." -Candice

"And I feel like that's also related to the labs, with the labs, you had to choose your own adventure with it. So like, it's very independent learning I guess. Like it's more so he wants you to think about it first and then he'll like guide you from there." -Hannah

However, when students did not understand why Danny would not answer their questions or give them closure on concepts, they experienced frustration to a level of unproductivity.

"You would ask him like, well why does this happen? You'll be like, I don't know, figure it out and you're like, I need help. I am 16 years old. Okay. I am not a chemist. I don't know. Please help. Um, but that one was [Chemical Equilibrium Investigation] just frustrating cause I never got closure on anything...With this one [Chemical Equilibrium Investigation], we weren't getting it so he was frustrated with us and we were mad at him and it was just a really toxic environment because everyone was mad at everyone." - Candice

In the vignette above, Carol exhibits physical signs of frustration by putting her hands in her hands and flushing red. Based on observations of the class recording, her participation in the rest of the lesson is limited.

Theme 3: When the teacher does not reframe moments of epistemic vexation, students build solidarity and reach out to each other for emotional support in developing productive meta-affect.

A common topic in student and Danny's interviews is Danny's response when students ask questions.

“So, usually I always focus on the "why". My kids will tell you that "Why?" is my favorite question. And if they can't answer that, I'm not gonna let them not, so I'll just keep pressing them until eventually they tell me what they know.” -Danny
“Even whenever he's teaching, if someone has a question, he asks them like, okay, well how do you think this will happen?” -Hannah
“He would never give us a direct answer and even when I had like come to him and ask him a specific question, he would make me work myself to the answer.” -Emily

In the vignette above, Danny asks Carol, “Why was green the one with the highest energy?” This turn of questioning began to lead Carol away from the idea she was initially trying to express. The epistemic vexation Carol exhibits is observed by others in the classroom and provides a common experience which later helped build solidarity amongst students. Hannah speaks about this in her interview.
“During that lesson, I didn't feel as bad cause I think I felt like, okay, like majority of the class isn't getting it either. So it's not just me.”

This solidarity helped students be more empathetic with each other’s sense-making which in turn led them to emotionally supporting each other when they experienced feelings of frustration or confusion.

Students expressed their gratitude for their peers throughout the interviews.
“But I always had partners so we could talk about it together. So it wasn't just me like figuring out the answers.” -Emily
“Yeah, well I think it's like the whole class having that discussion, it just makes it a lot easier because it's not just you and even if it was just you and your group, you know sometimes you and your group really might not know the answer. Some when it is the whole class. At least one person's bound to get it right or like at least one person at least somewhat understands and can help explain it.” -Hannah

Danny revealed in his end-of-year interview he purposely moves on to the next stage in the lesson as a strategy to encourage student sense-making.
“As they're going through it to make sense of it. There's always people that are like, "Okay, what's going on?... then they go through what they're doing and the other people who were actually listening are like "So here's why that works this way and if you change this, this thing is going to change as a result" and then they're like "Oh okay, that makes sense. This is what I wrote down anyway, so."

While student support and solidarity can build a sense of community, it is not enough. As seen in the vignette above, a lack of reframing from the teacher when a student experiences epistemic vexation can have a lasting impact.
“Yeah, I think like, I don't know, I don’t know like [Carol] especially like towards the end of the year, like stopped talking as much as she used to. I don't know why that was. And so like it didn't happen as much.” -Rose

Contributions & General Interest

Although the three themes that have been found thus far are preliminary, the ongoing study should provide further understanding to the impact of reframing moments of epistemic vexation, the roles teachers play in epistemic vexation, and how teachers learn to reframe these moments. As the study progresses, other themes may arise that may infer how science teachers can support their students so they experience productive meta-affect.

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References

Anderson, E., Carleton, N., Diefenbach, M., & Han, P. (2019). The relationship between uncertainty and affect. *Frontiers in Psychology, 10*: 2504.

Arango, S. (2014). The nature of epistemic feelings. *Philosophical Psychology, 27(2),* 1-19.

Bamberger, Y. &. Davis, E. (2013). Middle-school science students' scientific modelling performances across content areas and within a learning progression. *International Journal of Science Education, 35*(2,) 213-238, DOI: 10.1080/09500693.2011.624133

Berland, L., & Reiser, B. (2009). Making sense of argumentation and explanation. *Science Education, 93(1),* 26-55.

Charmaz, K. (2017). The power of constructivist grounded theory of critical inquiry. *Qualitative Inquiry,* 23(1), 34-45.

Davidson, S. G., Jaber, L. Z., & Southerland, S. A. (2020). Emotions in the doing of science: Exploring epistemic affect in elementary teachers' science research experiences. *Science Education*, *104*(6), 1008-1040.
Davidson, S., Jaber, L., & Southerland, S.A. (2021, June). *Encountering uncertainty and learning to "try and try and try": The development of teachers' perseverance within science*. Paper presented at the annual meeting of the International Society of the Learning Sciences, virtual conference.

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education, 32*(1), 268-291.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, 20(4), 399-483.

Ford, M. (2008). Disciplinary authority and accountability in scientific practice and learning. *Science Education*, 92(3), 404-423.

Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education*, 36(15), 2534-2553.

Jaber, L. (2021). "He got a glimpse of the joys of understanding": The role of epistemic empathy in teacher learning. *Journal of the Learning Sciences.* https://doi.org/10.1080/10508406.2021.1936534

Jaber, L. Z., & Hammer, D. (2016a). Engaging in science: a feeling for the discipline. *Journal of the Learning Sciences, 25*(2), 156-202.

Jaber, L. Z., & Hammer, D. (2016b). Learning to feel like a scientist. *Science Education, 100*(2) 189-220.

Jaber, L. Z., Hufnagel, E., & Radoff, J. (2019). “This is really frying my brain!”: How affect supports inquiry in an online learning environment. *Journal of Research in Science Education*. https://doi.org/10.1007/s11165-019-09884-y

Manz, R. (2014). Understanding the codevelopment of modeling practice and ecological knowledge. *Science Education, 96*(6), 1071-1105.

Manz, E. (2015). Resistance and the development of scientific practice: designing the mangle into science instruction. *Cognition and Instruction, 33(*2), 89–124.

Manz, E. & Suarez, E. (2018). Supporting teachers to negotiate uncertainty for science, students, and teaching. *Science Education, 102*(4), 771-795.

McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences, 15*(2), 153–191. https://doi.org/10.1207/s15327809jls1502_

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

Next Generation Science Standards (NGSS). Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: Achieve Inc.

Passmore, C. (2014, November 10). Implementing the Next Generation Science Standards: How your class is framed is as important as what you do [web log post]. Retrieved from http://nstacommunities.org/blog/2014/11/10/implementing-the-next-generation-science-standards-how-your-classroom-is-framed-is-as-important-as-what-you-do-in-it/

Radoff, J., Jaber, L., Hammer, D. (2019). “It’s scary but it’s also exciting”: Evidence of meta-affective learning in science. *Cognition and Instruction, 37*(1), 73-92. doi: 10.1080/07370008.2018.1539737

Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education,* 96(3), 488-526.

Walker, J. P., Sampson, V., & Zimmerman, C. O. (2011). Argument-driven inquiry: an introduction to a new instructional model for use in undergraduate chemistry labs. *Journal of Chemical Education, 88*(8), 1048-1056. https://doi.org/10.1021/ed100622h

Zembal-Saul, C., McNeill, K., & Hershberger, K. (2013). *What’s your evidence? Engaging K-5 students in constructing explanations in science.* Pearson Education.

Zion, M., Slezak, M., Shapira, D., Link, E., Bashan, N., Brumer, M., ... & Valanides, N. (2004). Dynamic, open inquiry in biology learning. *Science Education*, *88*(5), 728-753.

Appendix A: NSTA Proposal Information

1. Planning for Perseverance: How to Support your Students in Overcoming the "Shut-Down" Moment
2. Workshop
3. 60 minutes
4. Middle & High School
5. Claudia Hagan (chagan1@student.gsu.edu; Georgia State University), Victor Kásper (vk10c@my.fsu.edu; Florida State University), Sierra L. Morandi (sm16k@my.fsu.edu; Florida State University), Sherry A. Southerland (ssoutherland@fsu.edu; Florida State University).
6. This session will provide strategies for teachers to help their students learn to embrace uncomfortable feelings as part of the scientific experience.
7. It's common knowledge that students can shut down or disengage when a concept or activity is overwhelming. With science education focusing on students "figuring out" how the world works, students encounter emotions associated with sense-making such as anxiety, frustration, and confusion. However, in the right circumstances, emotions around uncertainty shift from negative feelings toward more positive emotions, such as excitement or curiosity which can act as motivators to persevere. In order for students to not shut down, they need space to share and build solidarity with their peers while sense-making. The purpose of this session is to provide strategies for teachers to help their students learn to embrace uncomfortable feelings as part of the scientific experience. Participants will have the opportunity to role-play scenarios, develop strategies for their own classroom, and share their own expertise in this area of classroom facilitation. At the end of the session, teachers should have several quick and effective interventions to help their students persevere when doing science