Building Trust: Supporting Vulnerability for Doing Science in School

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Abstract. Science education's emphasis on supporting students' participation in science knowledge-building practices, often through talk and collaboration, have become increasingly important goals for learning. But this emphasis creates both social and epistemic risks for students: the process of building knowledge requires continually identifying and wrestling with uncertainty, and building knowledge collectively requires making that uncertainty public. In this study, I investigate how a classroom community shifted to become a place where students regularly participated in risky science knowledge-building. I theorize that this shift occurred through a process of *trust-building*, and utilize this case to further elucidate the phenomenon of trust-building in the context of science learning.

Rationale

This paper explores the interpersonal dimensions involved in doing science in school. Talk and collaboration have become increasingly emphasized goals for learning (Colley & Windschitl, 2016; Kelly, 2007). These goals are particularly pronounced in science, especially given current reforms in the US (National Research Council [NRC], 2012; NGSS Lead States, 2013) and the magnitude of the pedagogical shifts from "teaching science as usual" that these reforms require (Bybee, 2014).

Typically literature on interpersonal dynamics in disciplinary contexts has taken a knowledge-oriented stance: we need to understand how to support interactions so that these interpersonal dynamics enable science learning (e.g., Chin, 2006). On the other hand, literature on supporting interactional goals such as collaboration as learning goals in and of themselves tends to be content-agnostic in the sense that these skills support learning in any arena (e.g., Rummel & Spada, 2005).

In contrast to both of these perspectives, I argue here that the interpersonal and epistemological dimensions of doing science should be treated as *mutually constituted* learning goals. In other words, figuring out how to engage with each other in collaborative work is central to the epistemological work of doing science; and, simultaneously, the rigorous doing of science is a context for developing ethical interpersonal relationships.

To make this argument, I draw on literature from science studies and organizational psychology, as well as philosophical critiques of science and of education, to show how doing science in school is socially and epistemologically risky for students. In light of these risks, I argue that a critical component of teaching science is building trust within the classroom community. Using a paradigmatic case approach, I examine how one teacher effectively built trust between students while simultaneously supporting them in developing sophisticated epistemologies for building science knowledge.

Theoretical perspectives and framework

This work is situated within the context for K-12 science education in the United States in which a key goal undergirding current reforms emphasizes students' participation in science practices as a means of making progress in building core disciplinary ideas (NGSS Lead States, 2013; NRC, 2012). Importantly, students' participation in practices is not intended to have them carry out rote skills or procedures, but instead asks them to leverage practices such as scientific modeling and argumentation as goal-directed strategies for building knowledge (Berland et al., 2016; Ford, 2015).

Learning to participate in science practices as goal-directed strategies requires sustained, extended engagement in those knowledge-building practices. Students are not doing one-and-done science labs; instead, they conduct extended explorations of phenomena that leverage multiple data sources to help make sense of those phenomena (Windschitl, Thompson, & Braaten, 2008). A particular challenge for sustained engagement in knowledge-building practices is that is requires engaging with and interrogating *uncertainty* (Kirch, 2010; Watkins, et al., 2018). In other words, students do not have a full explanation for a phenomenon for a long time. They might figure some things out today, and a little bit more tomorrow, but it might take weeks or months before they produce a satisfying explanation.

This need for engaging with sustained uncertainty has been present but often implicit in the science education literature. It has often been framed as a need to problematize content such that taken-for-granted ideas or assumptions are called into question in light of pushback from new evidence (e.g., Kapur & Bielaczyc, 2012; Reiser, 2004). These questions then drive participation in meaningful, emergent forms of disciplinary knowledge building (Engle & Conant, 2002; Manz, 2015). If we consider these design principles from a student perspective, the extended experience of uncertainty becomes more apparent: pursuing science knowledge-building goals requires identifying areas of confusion or doubt, and then making decisions about how to manage, interrogate, and re-evaluate the ideas that have been called into question. In other words, doing science well means being explicit about what you do *not* know, and then doing careful work to fill in those gaps.

This framing implies a different definition of success than what is often seen in schools: success requires *not-knowing*, and should be measured by how you are making progress around those areas of not-knowing. And to be sure, there is explicit recognition with the science education literature that meaningfully participating in science practices is a departure from school-as-usual (Berland et al., 2016; Jiménez-Aleixandre, Rodríguez, & Duschl, 2000). However, distinctly missing from the majority of this work (c.f. Watkins et al., 2018) is the acknowledgement that uncertainty is actually a *risky* epistemic stance for students because it asks them to go against what has been culturally constructed as being "successful" in science and in schooling. In typical schooling, displaying uncertainty is itself a risk. There are historical epistemic and power imbalances in traditional classrooms in which the teacher is the one with epistemic authority (i.e., "knows things") and students start out knowing "nothing." Traditional learning follow a "banking pedagogy" philosophy (Freire, 1970/2018) in which students are expected to collect or "bank" the knowledge that the teacher provides for them. Therefore, the measure of success is demonstrating that you have "banked" the appropriate knowledge. Uncertainty, by this model, is the precise definition of failure.

Additionally, common cultural constructions of what it means to do science make uncertainty risky. Specifically, the values of individualism, competition, and abstracted intellectualism have historically characterized professional science (Harding, 1986; Longino, 1987). Though recent accounts of science emphasize the value of uncertainty in science practice (e.g., Watkins et al., 2018), these historical values of professional science make their way into classrooms and shape what it means to be a "good science student." In combination with the culture of traditional school described above, the construction of a "good science student" is often one who shows "muscular intellect" (Archer, et al., 2017) and who finishes work quickly and accurately without many questions (Carlone, Haun-Frank, & Webb, 2011). In sum, asking students to take on the epistemic stance of uncertainty is asking them to take on what likely feels to students a stance of failure.

To be certain, these risks are not distributed equally; different students will experience these risks differently, and to varying extents, based on their own demographics and histories. Much further work will be needed to piece apart these complex intersections of individual identity and experiences of risk. In addition, I recognize that there is much ambitious academic and practical work aiming to shift the cultures of schooling and/or of science. In this paper, I focus on how teachers might shift specific classroom microcultures such that success is redefined and there are different norms around being uncertain such that the risk of doing so becomes worthwhile for students.

The role of trust in shifting classroom microcultures

Work in both math and science education has focused on how to design for and dynamically develop supportive classroom cultures for rich disciplinary activity. These designs include specific norms around disciplinary accountability (e.g., Engle & Conant, 2002), discourse goals and sentence starters for guiding interaction (e.g., Michaels & O'Connor, 2015). Similarly, mathematics education researchers have identified general social norms that sustain classroom microcultures that promote mathematical practices such as explanation, justification, and argumentation as well as particular sociomathematical norms, or the aspects of mathematics discussions that were specific to mathematical activity (e.g., Yackel & Cobb, 1996). In addition, research on small group collaboration has highlighted the importance of *psychological safety* in supporting effective teams (e.g., Miyake & Kirschner, 2014). This work points out that disciplinary knowledge is insufficient for productive collective knowledge-building. Thus, across multiple bodies of research, there is understanding that how students interact with each other and with ideas matters for the kind of disciplinary work that they do.

To more carefully interrogate how productive norms for interpersonal interaction develop, I draw on psychological and philosophical definitions of *trust*. Psychologically, trust is a "psychological state of being" that allows one to be vulnerable with another (Mayer, Davis, and Schoorman, 1995/2006). Philosophically, trust is embedded in relationship, and takes the form "X trusts Y to do Z" (e.g., Jones, 2012). That is, because X trusts Y to do Z, X is then able to act in particular ways. In other words, trust is a social mechanism that allows for the development of relationship between X and Y by reducing social uncertainty and transforming it into risk (Luhmann, 1979/2018). Trust develops by being built up and shaped by a history of interactions over time (Kramer, 2006). Operationally, this suggests that in order to identify trust, we must identify *changes in interactional patterns over time*, especially in situations where interacting in particular ways requires vulnerability. Given the literature summarized above, expressing uncertainty, asking questions, and publicly sharing tentative ideas are actions that likely require demonstrating some degree of vulnerability on students' part.

I conjecture here that trust-building processes can support the development of a classroom microculture that supports a version of science learning that pushes back on the traditional definitions of success embodied by science and schooling. In particular, I examine how trust-building might support values emphasized by feminist critiques of science and of schooling: doing science with intellectual vulnerability through collaboration that demonstrates caring for one another's growth, broadly invites people to the table, and invites joint exploration (Krist & Suárez, 2018; Noddings, 1988). Notably, these values describe how science is done *in terms of the nature of the relationships it creates*. Noddings describes this alternative as a *fidelity to persons*: the commitment of one person to the growth and well-being another, grounded in a caring relationship. This orientation guides interaction and joint work. Thus, teachers' pedagogical decisions and strategies should support their students in developing as persons who care and are cared for by each other. While not explicit in her writing, Noddings' focus on caring can also be extended to student-to-student interactions: when students are epistemic agents, they are responsible for shaping and supporting each other's learning.

In addition, I conjecture that trust-building is both a micro-interactional and a longitudinal process. It is micro-interactional in that it is within the dynamics of moment-to-moment talk and interaction that various forms of interaction are affirmed or rejected. And it is longitudinal in that, over time, the affirmed patterns of interaction become stabilized and social uncertainty around them is reduced. As such, I posit that methodologically, we need to "see" trust development by characterizing both micro-moments of interaction and at how those moments thematically recur and are shaped over time.

Methodological approach: Paradigmatic case study

I used a paradigmatic case approach in order to explore the process of building trust to support increasing social and epistemic vulnerability in science classrooms. I selected this case to elucidate and elaborate on key elements of the phenomenon (Pavlich, 2010). I then took an informed grounded theory approach to analysis (Thornberg, 2012) and aimed to identify theoretical replication within the phenomenon (Yin, 2009; i.e., multiple instances and dimensions of trust-building). Specifically, my analytic process involved looking for moments of vulnerability and then carefully characterizing how the teacher and students responded to that vulnerability.

Case context

The focal video set for this analysis comes out of a larger corpus of video data collected as part of my dissertation work that examined students' epistemological development over three years (Krist, 2016). This video set consists of recordings from one school, "Mountain View," a K-8 school located in a working- to middle-class suburb of a large Midwestern city. This school has a strong commitment to engaging students in scientific practices consistently across the three years of students' middle school science courses (6th-8th grade), supported by their use of the IQWST curriculum (Krajcik, Reiser, Sutherland, & Fortus, 2012). The three science teachers at Mountain View had been involved in developing and pilot-testing the IQWST materials, and had been using some version of them for the past ten years at the time of data collection.

Demographically, Mountain View is mixed. The K-8 students enrolled in 2014-2015 were 52% White; 31% Asian/Mid-Eastern; 12% Hispanic; 4% multiracial; and 2% African-American. 18% were designated English language learners and 18% received free or reduced-priced lunches. Forty-six languages other than English were spoken at home, with Spanish and Urdu being the most common. The class period analyzed in this study generally reflected the demographics of the school as a whole.

The focal case for this study comes from video collected in one of Mr. M's 8th grade class periods over the course of one 5-month unit (Sept 30, 2014 - Jan 21, 2015). This class period was selected because there was a lack of both participation in science knowledge-building practices and demonstration of care for each other and ideas at the beginning of the unit, but both of these features were characteristic of the class by the end of the observed unit (Krist, 2016; Krist & Novak, 2016). In addition, Mr. M was intentionally working to rebuild a "productive classroom culture" during this unit. Therefore, I use this set of videos as a case of a classroom in which trust developed in order to examine *how* it developed over time.

During this time period, Mr. M enacted an 8th grade Earth Science unit organized around the driving question, "How is the Earth changing?" Students worked to build a model of plate tectonics in order to explain various geologic features on Earth. The lessons that were selected for observation and video recording were ones in which students were doing some synthesis work in order to construct the core models for the unit. These lessons included Lesson 1 (5 days of instruction), Lesson 5 (4 days of instruction), and Lesson 10 (6 days of instruction).

Analysis

I took an informed grounded theory approach that involved iteratively viewing and re-viewing video, combined with an assemblage of techniques drawn from other analytic approaches. These techniques included content-logging (Jordan & Henderson, 1995) and both analytic and reflective memoing (Thornberg, 2012) in order to progressively refine hypotheses through my iterative viewing.

Guided by Strauss & Corbin's (1998) advice to "stay grounded" yet also maintain "theoretical playfulness" (Thornberg, 2012) during constant comparison, I treated theoretical indicators of vulnerability and risk derived from the literature reviewed above as "sensitizing indicators" (Blumer, 1954). When watching the video, I identified moments of potential vulnerability and characterized how the teacher and students responded to those moments. I also noted how the teacher framed the activity within which a particular moment occurred. Then, I searched for earlier moments when either (a) the students demonstrated a distinct *lack* of that same type of vulnerability, or (b) the teacher response to or framing of an otherwise unremarkable interaction paralleled a later, significant framing. I then re-watched these moments in sequence, noting parallels and shifts. In this way, I characterized the trust-building processes by tracing thematic links in framing and action over time (Figure 1).

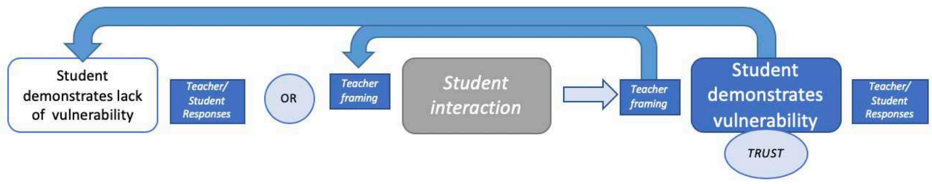

Figure 1. Analytic framework for examining how trust was built over time.

Findings

I have identified multiple types of vulnerability that the teacher explicitly re-framed as not only acceptable but desirable for their learning, and that students later demonstrated, suggesting that trust had been developed around that area of vulnerability (Table 1). In this paper, I present an example illustrating how trust developed around the first type of vulnerability, "Going public with ideas." This example both demonstrates the utility of the analytic method for examining trust development as a progressive interactional process and highlights how this process embodies a critical approach to science and schooling: that doing science *means* caring for one another's growth and engaging in joint exploration in ways that welcome broadly both people and ideas.

Table 1: Types of vulnerabilities observed and their shifts over time

Type of Vulnerability	Initial enactment	Later enactment(s)
Going public with ideas	Going public is uncomfortable	Ideas made public will be taken seriously (even if they seem silly)
Displaying intellectual uncertainty	Uncertainty is embarrassing	Uncertainty helps push learning forward
Making a bid to revise an idea, rendering it tentative	Your own initial ideas are tentative and you can make bids to revise them	Textbook ideas and community consensus ideas are tentative and you can make bids to revise them

Initial enactment: Going public as uncomfortable

On the first day of a new Earth Sciences unit, Mr. M had students record some of their initial ideas about where volcanoes and earthquakes are typically found, including drawing a model if it helped. He then had gone around and asked three students to draw their models on the board and was having each student describe their model. Two other students independently asked to draw their models on the board as well. After each student described their thinking, Mr. M would say, "Cool," and move on to the next person. The third student he asked to share was Christine. When Mr. M called on her, she said that her friend Lisa was going to share (a surprise to Lisa!). Mr. M said that it was fine to skip it and not talk about it. In response, Nora encouraged Christine to share. Nora laughed, saying "I don't want to!" Mr. M then asked if he could "talk about it for a minute?" and Christine agreed. Mr. M then described what he thought he saw in Christine's model—that volcanoes tended to be near water, and that a volcano "Goes up then comes down [in elevation]?" She affirmed this interpretation.

What we see in this moment is that Christine knew that she was *supposed* to talk about whatever she had drawn on the board, but talking about her model in front of the class was uncomfortable for her (though it is also worth noting that Christine was comfortable enough to resist at least a portion of the teacher's expectation for her to share her model publicly, and she did not get "in trouble" for doing so). The teacher's response to her discomfort—asking if he could describe some of what he saw in her model—reflects a careful balancing of priorities. Christine likely was not uncomfortable about her *idea*, as she volunteered Lisa to describe it for her. She just did not want to do the public talking about it. Christine was also not a particularly shy person; she regularly contributed to discussions in other ways. Mr. M's solution, to describe what he thought he saw and to check in with her about it, was a compromise: it still allowed her *idea* to be made public, but it didn't require *her* to take the risk of saying something that others might not understand or disagree with.

Mid-way enactment: Jokingly presenting your ideas as public

Five school days later, Mr. M's value for taking ideas seriously showed up in how the he framed their activity. The class was sharing the questions they had generated about volcanoes and earthquakes over the past five days and building the driving question board, a public display of their questions that would be used to drive the remainder of the unit. As each student shared their question, they tacked them on a world map bulletin board either in a geographic location that made sense or near other related questions. In introducing how they would share their questions with each other, Mr. M said:

> And this morning my class had a lot of fun presenting, but I wasn't convinced honestly that like everyone was tracking, so I started asking like, hey, can you restate that? And uh, I don't know. So you should be able to restate like what that question was. That's evidence that you're listening, right? And uh, and that you really value the person. Otherwise if they're up here, and they say something that you don't look like you're paying attention, then they're like, well, I guess you don't care. We wanna let them know you care. […] Let's try to build as rich a set of connections as we can.

We see here how he was making explicit a lot of what was implicit about his response to Christine: he cared about both her and her idea, and wanted her idea made public so that people could make connections to it.

About halfway through the activity, Zach said he had two questions to share. He presented his first question and put it on the board. He was about to sit back down when Mr. M asked him about his second question:

Mr. M:	Okay, what's your second one?
Zach:	My second one is, is [inaudible; *((crosstalk))*] Is there such thing as an earth-cano? *((Zach smiles; laughing and clapping from students))*
Mr. M:	What's that? What's an earth-cano? *((crosstalk; more laughing and clapping))* Shh.
Zach:	Where an earthquake is happening, and then it starts [inaudible]
Mr. M:	Oh, so you're wondering if an earthquake is the cause of the volcano.
Zach:	No, if it could happen. *((crosstalk))*
Mr. M:	I don't understand. Somebody restate Zach's idea. I don't think I get it. *((Several students raise their hands))*. Zach, call on someone else.

Zach called on Carmen, who addressed Mr. M:

Carmen:	Ok. So, he was saying that maybe if like, in an area that a volcano could be happening, and an earthquake at the same time, creating an earth-cano.
Mr. M:	[to Zach] Is that what you mean?
Zach:	No. *((laughter; several students raise their hands; Zach gestures to Gideon))*
Gideon:	I think Zach means like, where a earthquake's inside of a volcano. *((laughing))*
Mr. M:	You gotta, Zach, maybe you gotta give it another shot. *((laughter))* Shh.
Zach:	I mean like, if an earthquake happens, and then it just starts a volcano because of all the like, the shaking. *((crosstalk))*
Mr. M:	Maybe, just so we know we get Zach's idea. Zach, somebody has to restate it because it's clear that I didn't understand it. *((Zach gestures to Bel))*
Bel:	Is it like, an earthquake causes an eruption?
Zach:	Yes.
Mr. M:	Ok, got it.

In this moment, Zach asked what was clearly a silly question about an "earth-cano" (note that this was during the height of popularity of the "shark-nado" memes). Based on his classmates' laughter and applause, it seemed they all knew that this was not an entirely acceptable kind of question. Mr. M could have easily responded to Zach by saying that his question was not appropriate, or otherwise reject Zach's idea of an earth-cano as irrelevant and disruptive. Instead, Mr. M took seriously the *need to understand what Zach was asking*: Mr. M encouraged Zach to keep having students restate his idea until he was satisfied with their version.

What became clear through these restatements was that although Zach presented what was on the surface a silly idea, he had some serious thinking behind it. It is possible that Zach presented this serious thinking with a humorous cover in order to make himself less vulnerable: if his classmates ended up rejecting his idea, it would be ok, because it had just been a joke anyway. But in taking Zach's idea seriously, Mr. M demonstrated—and also required three others to demonstrate—that they cared about Zach, and that he had an idea worth understanding.

Later enactment: Students taking seriously (silly) ideas made public

Much later, during the sixth day of Lesson 10, another student, Mark, presents a similarly "silly" idea that made no logical sense on the surface. Students had been presenting their candidate explanations for what was causing their observed patterns of earthquakes and volcanoes at the Horn of Africa. After a particularly generative 20-minute discussion, the groups of students who had initially presented competing explanations had coalesced around a fairly complex "two slowly moving hotspots" model. After reaching this agreement, Mark (who was not in either group) proposed a new idea: that "wind or air" was making the African plate move. Mr. M was skeptical and almost dismissed the idea, but "threw it out to the rest of the class" to get their reactions to it. One student, Nora, responded to Mark in a way that paralleled Mr. M's response to Zach's idea almost three months earlier:

Nora: Well this is what you [Mark] said, when you said air. Do you mean like the air that we're breathing right now?

Mark: No.

Nora: So what do you mean?

Mark: Air from the ocean.

Nora: From the ocean would be water.

Mark: I know, but like the wind.

Nora: Like the air above the ocean?

Mark: The wind pushes the water and that makes the air.

Nora: From the plates under there?

Paccia: The plate is under the ocean from the layers of sand.

Nora: [to Mark] Do you think the plate has air?

Paccia: No, I think he thinks that the water is pushing the plates. But the plate is underneath the water.

After several more minutes of (equally difficult to follow) conversation, Nora and Paccia realized that Mark was confusing the "bubbles" of magma in their volcano model for air bubbles. In essence, he was saying that all the "bubbles" of magma were moving, kind of like wind, to "blow" the African plate around. Once this confusion was cleared up, Mark aligned his idea with the class' "giant slow-moving hotspot" model.

Nora and Paccia took up Mr. M's disposition towards Zach's idea, demonstrating both the importance for them of understanding Mark's thinking, but also the importance that he came to consensus with the rest of the class in his own understanding. This episode also illustrates how the definition of "success" in science had become about interrogating uncertain claims. This was the *end* of the unit—surely students should be certain about a lot of science by this point! Instead, they sustained a 20+ minute conversation attempting to build an explanation that was tentative but fit their models and evidence.

Significance and implications

The moments presented here demonstrate how the act of going public with an idea was initially risky and uncomfortable for (at least some) students; but that, over time, it developed into an area of vulnerability that students trusted would be met with seriousness and care. They illustrate how displays of vulnerability occurred at the intersection of disciplinary and social demands and, as such, the interpersonal and epistemological dimensions were mutually constituted. Specifically in these examples, Mr. M asked students to take social risks because they were necessary for their science knowledge-building work; and when students "went public" with tentative or silly-sounding ideas, they were met with responses that demonstrated simultaneous care for the person and for fully understanding the idea. In this way, *the rigorous doing of science became a context for developing ethical interpersonal relationships.*

This work contributes to conversations about what productive norms are from both disciplinary-centered (e.g., sociomathematical norms [Yackel & Cobb, 1996]) and disciplinary-agnostic (e.g., norms for psychological safety in collaboration [Miyake & Kirschner, 2014]) bodies of literature by beginning to elucidate how they come to be. In addition, it builds on both of these literatures by articulating how the two work together. Coupling them together allows for important questions around the ethics of teaching and learning to be re-visited. In this paper, have primarily emphasized the question, "What kind of (science) people are we wanting to develop?" But we might also re-visit what kind of science (or mathematics, or social science) we want students to do while simultaneously considering how those goals are linked (or not) to the kind of people we want to develop.

There is also much room for further research both within this case and extending beyond it. Within this dataset, I hope to next examine ways in which trust did *not* develop, and for whom. Extending beyond these data, the constructs of social uncertainty, risk, and vulnerability need to be further elaborated to take into account the variations in how students experience school and science based on factors such as their ages (e.g., what counts as a risk likely varies between middle school and high school), demographics (e.g., Black and Latinx students in the US have historically been systematically excluded from schooling and are currently more likely to be counseled towards "non-academic" tracks, and this likely impacts what counts as a risk), and academic histories (e.g., being uncertain may actually be more risky for high-achieving students).

Finally, future research might explore how teacher preparation and professional development programs could take up trust-building as a central part of content-area teaching rather than relegating it to generic areas of instruction such as classroom management or socio-emotional learning. Depending on the students in the classroom, teachers may need to more specifically or explicitly acknowledge the particular ways—both interpersonally and scientifically—they are asking students to be vulnerable. Examining how we support teachers to grow in supporting these complex classroom dynamics is a key focus for future work.

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