What Epistemological Resources Affect Chemistry Teachers' Sense of "What Works" When Implementing Transformed Curricular Materials?

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Abstract:

Teachers' sense of "what is taking place with respect to knowledge" drives their perspective on "what works" and "what is likely to work" in their classroom context. Scholarship by Hammer, Russ and many others indicates that this "sense" is very often context-sensitive and may be productively modeled as a local coalescence of small-grained epistemological resources. Presented here is an investigation of the epistemological resources contributing to high school chemistry teachers' framing of "what works" in their learning environment. Teacher reflections are unpacked and characterized for classroom information noticed and responded to when considering "what worked" during the 2019-2020 school year. Preliminary findings suggest epistemological resources guiding "what worked" often align with a view of knowledge as *propagated stuff*. Thus, implying that teachers' reasoning about "what works" is guided by how well knowledge is transferred to students. Also present was evidence that epistemological resources aligned to views of knowledge as *fabricated stuff* were activated. The perspective that knowledge is inferred or developed from other knowledge, rather than passed from an authority figure, aligns well with reform efforts that emphasize student sensemaking. This study is part of a larger program in which a teacher-researcher collaborative adapts and refines evidence-based curricular materials for an undergraduate chemistry course for use in high school. These materials are structured around scaffolded progressions of big ideas (e.g., energy, electrostatic and bonding interactions) that build in complexity as students make sense of increasingly complex phenomena. Ongoing improvement of transformed materials is dependent upon the ability to initiate and stabilize a sense of "what works" consistent with sensemaking aims.

Subject

Students in high school chemistry classrooms are expected to develop knowledge and practices that allow them to make sense of chemical phenomena in terms of atomic- and molecular-level behavior (NGSS Lead States, 2013). Sensemaking is a complex process in which students must build and refine explanations to resolve gaps or inconsistencies in their knowledge (Odden and Russ, 2019). Recently, a suite of learning materials was adapted from the evidence-based undergraduate curriculum Chemistry, Life, the Universe, and Everything (CLUE; Cooper and Klymkowsky, 2013) with the central goal of supporting high school chemistry students in making sense of chemical phenomena. This suite of learning materials supports students in making purposeful and explicit connections between the behavior of particles on the atomic scale and perplexing macroscopic events. As these learning materials serve high school teachers and learners, they are creatively named high school-CLUE (HS-CLUE; Stowe *et al.*, 2019).

The HS-CLUE materials support students in sensemaking by focusing instruction on scaffolded, interconnected sequences of core ideas that build in complexity as students make sense of increasingly complex chemical phenomena (Stowe *et al.*, 2019). Several high school chemistry teachers work with our research team to develop and refine the elements that make up HS-CLUE. Alterations to existing materials are guided by teachers' dynamic perceptions of "what worked" in their local context as well as assessment data. As the ultimate aim of our program is to produce a curricular activity system that can be used and productively adapted by teachers outside our co-developer team, figuring out how to initiate and stabilize a sense of "what works" that is consistent with sensemaking aims is extremely important.

Teachers' perceptions of "what worked" in the classroom is driven, in part, by their sense of "what is taking place with respect to knowledge" – that is, their epistemological frame (or e-frame)(Scherr and Hammer, 2009). The e-frame a teacher adopts can shift moment-to-moment and guides how they act and even think in a situation. For example, a study by Russ and Luna (2013) illustrated two frames exhibited by a biology teacher, one during group discussions and another during laboratory activities. During discussion, the teacher engaged in practices that encouraged students to grapple with concepts by asking and answering questions. By contrast, the teacher enacted practices during lab that emphasized task management, encouraging students to complete activities using procedural knowledge. The distinct features of these two frames (one on concept development and another on completing procedural tasks) echo findings from other investigations that what a teacher attends to and reasons about during class are context-dependent (e.g., Talanquer *et al.*, 2015). One might think of a "frame" as a local coalescence of epistemological resources (Hammer *et al.*, 2004), that is small-grained, reusable knowledge elements about the nature and appropriate use of knowledge (Hammer and Elby, 2002). Epistemological resources can describe an individual's view of the sources of knowledge (such as *knowledge as propagated stuff* or *knowledge as fabricated stuff*) or epistemological activities in which knowledge is used (such as *accumulation, formation,* or *guessing*). How teachers activate and connect epistemological resources in the moment will guide how they interact with their environment, such as the kinds of information they attend to and how that information is used (Hammer and Elby, 2002).

The processes of attending to and reasoning about information in a learning environment (*e.g.*, student responses to assessment items, student-to-student interactions, and teacher-student

discourse) is described as teacher noticing. van Es and Sherin (2002) define teacher noticing as involving distinct processes of (1) identifying important classroom events, (2) connecting what is identified to broader aspects of teaching and learning, and (3) using knowledge of the context to interpret what was identified. Many studies have characterized what and how teachers notice (Russ and Luna, 2013; Luna, 2018; Russ, 2018; Haverly *et al.*, 2020). Meanwhile, other investigations have sought to characterize the relationship between student understanding and teacher noticing (Talanquer *et al.*, 2013, 2015; Barth-Cohen *et al.*, 2018), or even characterize teachers' noticed about their own classroom practices (Benedict-Chambers and Aram, 2017). While math education researchers, including van Es and Sherin, have targeted research on characterizing teacher noticing, work in science education typically investigates teacher attention as part of other teaching and learning phenomena (Roth *et al.*, 2011; Windschitl *et al.*, 2011; Russ and Luna, 2013). Our work is consistent with that of scholars in science education in that our focal phenomena is teacher perspectives on "what worked" rather than "what was noticed".

In their 2013 study, Russ and Luna (2013) demonstrated that patterns of noticing are useful to infer how teachers frame a learning environment in the moment. Here, we aim to use coarse-grained accounts of teacher noticing to investigate teacher perceptions of "what worked" when implementing or modifying HS-CLUE materials in their classroom. What a teacher notices and responds to in the learning environment can be leveraged to infer characteristics of frames that are stable over time. In particular, we are interested in the epistemological resources that teachers commonly activate when enacting and modifying transformed chemistry materials. Understanding patterns of resource activation can inform the development of HS-CLUE materials that better support teachers in initiating and sustaining sensemaking-focused frames in the classroom. The research questions guiding this investigation are:

RQ 1) What do high school chemistry teachers notice and respond to about the learning environment when reflecting on their implementation of HS-CLUE materials?

RQ 2) How does high school chemistry teachers' reasoning when implementing or modifying HS-CLUE materials reveal the epistemological resources informing "what worked?" across classroom contexts?

Design

Sample and Setting. Inherent in teacher noticing investigations is a prompt or brief activity (*e.g.*, watching a recoded class segment) that situates the teacher within the learning environment. Asking a chemistry teacher what they noticed *during* class time would likely disrupt the flow of class and affect the teachers' typical mental processes. Thus, the prompt serves to remind the teacher what occurred in class *after* class is over, initiating an opportunity to reflect on what they noticed and how (or whether) they responded to what was noticed. While other studies have used video recordings and student artifacts to prompt teacher reflections, the investigation described here employed reflective logs submitted by high school chemistry teachers on a weekly basis. This investigation characterizes the use of classroom materials (which could span several days) as opposed to features of classroom discourse (which could span seconds to minutes). Considering reflective logs are a common tool used to characterize implementation of learning materials (Ball, 1999; Rowan and Correnti, 2009; Harris *et al.*, 2015), we feel they appropriately elicit evidence of epistemological resources teachers tended to activate over extended periods of HS-CLUE implementation. Teachers received a survey each

week to structure their reflections. The surveys included prompts to encourage reflection about learning materials they implemented that week, salient information from the learning environment, and reasoning for why materials were implemented or modified. A total of nine high school chemistry teachers participated in this study, implementing HS-CLUE materials in their classrooms and submitting weekly reflective logs about the use and modification of any materials used. Teachers submitted the reflective logs during the fall and spring semesters of the 2019-2020 school year, resulting in roughly 15-17 weeks of reflections per teacher per semester.

Data Collection and Analysis. The fall 2019 reflections were separated from the spring 2020 reflections, essentially splitting the data in half. The fall 2019 reflective statements were first broadly categorized by what the teacher noticed about the learning environment, separating the data into statements about the students, HS-CLUE materials, and themselves (i.e. the chemistry teacher). As the ultimate goal of this program is to understand how the HS-CLUE curricular activity system can be leveraged to support sensemaking frames, we investigated each category for evidence of how teachers viewed the nature and appropriate use of knowledge in their classroom. Teacher statements included how their knowledge, affective stance, and pedagogical practices contributed to or were affected by implementing or modifying HS-CLUE instructional materials in the learning environment. For example, teachers may modify materials so that students "know X thing" (e.g., gas laws, nomenclature), supporting the inference that "knowing stuff" was the aim. This example indicates activation of the resource *knowledge as propagated stuff* (Hammer and Elby, 2002). To establish trustworthiness of code application, two raters separately coded about 15% of the Fall 2019 teacher statements for the nature and appropriate use of knowledge, An interrater analysis of code applications from each rater resulted in a Cohen's kappa of 77.55, indicating a substantial agreement (Cohen, 1960). Minor modifications to code descriptions were made and this process was repeated until complete agreement was reached. Once the codebook was established, the coding scheme was applied to the Spring 2020 data. Again, two raters separately coded roughly 15% of the data, resulting in a Cohen's kappa of 94.12, indicating strong agreement (Cohen, 1960). From these codes, we were able to infer epistemological resources (e.g. Hammer and Elby, 2002) enacted by the teachers to inform "what worked" in their local context.

Findings

Since the reflective logs were completed on a weekly basis, we did not expect fine-grained recollections of classroom occurrences. This investigation can viewed as a macroanalysis, illuminating what was noticed and responded to on a day-to-day timescale, as opposed to the minute-to-minute timescale common with other teacher noticing studies (*e.g.*, Talanquer *et al.*, 2013, 2015; Barth-Cohen *et al.*, 2018). Aligning with the main goal of this investigation, the weekly reflections allowed for a characterization of "what worked" over the course of an entire school year implementing (or modifying) HS-CLUE materials. Although our findings do not capture the dynamic, moment-to-moment fluctuations in teacher frames *during* class, the schoolyear-long patterns in teacher noticing illuminate perspectives on "what was going on" that were stably adopted over extended time scales. The remaining paragraphs include teacher reflective statements as italicized and in brackets [*As shown here*].

Results aligned to RQ1 indicate that teachers noticed and responded to features of the learning environment that affected or were affected by the students, HS-CLUE materials, and the

chemistry teacher. For example, teachers enacted materials to situate scientific practices within the learning environment [*I like to use Chemmatters articles… as opportunities for students to practice reading comprehension skills and creating claims, evidence, and justification to respond to prompts*]. Here the teacher's pedagogical practices emphasized student engagement with scientific practices but makes no mention of the teacher's epistemological goals for providing students with these opportunities. There is no guarantee that engaging students in activities that bear the structural hallmarks of scientific practices (e.g., claims, evidence and reasoning) will be undertaken with knowledge construction goals consistent with sensemaking (Berland *et al.*, 2016, 2020). For the activity mentioned previously to engage students in argumentation rather than pseudo argumentation, students need to recognize the benefit in being able to craft an evidence-based argument for the purpose of convincing others, *not* because the teacher said to (Berland and Hammer, 2012). As such, we are more interested in the teachers' epistemological resources informing their sense of "what worked," since we hope to develop HS-CLUE materials that afford students with opportunities to have productive epistemic agency (Miller *et al.*, 2018).

RQ2 seeks to address the epistemological resources shaping teachers' reasoning about "what worked" when implementing and modifying HS-CLUE materials. Examining categories that detail noticed pedagogical practices and changes to materials reveals that teachers implement or change HS-CLUE materials for reasons associated with chemistry "stuff to know," science and engineering practices, and experiencing a phenomenon. Additionally, teachers would cite local limitations, such as preparing for the ACT or aligning instruction with other teachers in their professional community, as reasons materials were or were not enacted or changed.

Chemistry "stuff to know" was the most prevalent reason for implementing or modifying HS-CLUE materials. Statements using this reasoning indicated teachers value students knowing chemistry content. For example, teachers may only address certain chemistry content in a lesson [*I only selected material that directly related to Lewis structures and VSEPR.*] or modify lessons to better emphasize certain topics [*I had to add time to teach students how to name ionic and covalent compounds*]. Teachers may even re-order a unit to retain emphasis on certain chemistry concepts [*I ended Unit 2 with so much focus on the electrons and their movement, it felt so much more natural to continue to focus on the electron*]. The emphasis on "stuff to know" aligns with epistemological resources such as *accumulation* which position knowledge as something to be received by the student (Hammer and Elby, 2002). In this way, teachers may view knowledge as *propagated stuff,* meaning they might frame "what works" in the learning environment in terms of how well they can "transfer" knowledge to the student. "Stuff to know" represents the status quo in chemistry classrooms and is likely reinforced by external pressures, such as anticipation of what colleges and standardized assessments are "looking for."

Alternatively, providing students with opportunities to engage in scientific practices and with chemical phenomena were also present in teachers' reasoning for implementing and modifying HS-CLUE materials. Teacher reflections such as [*I started with asking students about scientific questions and really diving into what it means to gather scientific data and develop scientific explanations to support claims*] illustrate how teachers would implement or modify materials to engage students with scientific practices. Teachers also recognized that ongoing development of HS-CLUE materials should focus on developing opportunities to engage

students with scientific practices [*I think we need to continue to tweak materials to provide students with as many opportunities to struggle with designing their own experiments, analyzing their own data, and making claims from their own analysis of authentic data*]. Additionally, teachers would attempt to engage students with phenomena by adding videos [*Students initially watched a video about the double slit experiment. We discussed the phenomena of constructive and destructive interference and how interference supports the claim that light is a wave.]* and by implementing certain labs [*We transitioned into the CLUE sequence by having students experience the phenomenon of 50mL water + 50mL ethanol does NOT equal 100mL]*. These reflections align with epistemological resources such as *application, checking,* and *formation.* Resources in this vein posit learning activities as opportunities for students to grapple with complex situations so they can construct their own knowledge from personal experiences. Thus, the resources informing "what works" are more closely aligned to views of knowledge as *fabricated stuff* (i.e. constructed by the individual from other sources) (Hammer and Elby, 2002).

Contribution to teaching and learning of science

The epistemological resources informing a teacher's sense of "what works" often aligned to views of knowledge as *propagated stuff.* Thus, teachers likely reasoned about "what worked" in terms of how knowledge could be transferred to the student. Reflective statements also indicated activation of epistemological resources aligned to viewing knowledge as *fabricated stuff* by engaging students with scientific practices in the context of chemical phenomena. The design of future HS-CLUE materials needs to better support teachers developing a sense of "what worked" that is consistent with sensemaking aims. This will undoubtedly involve stably activating and connecting epistemological resources that align with authentic scientific practice (e.g., *knowledge as fabricated stuff*). There is significant scholarship attesting to the notion that foregrounding "making sense of phenomena" will help teachers create a much more authentic and meaningful learning science learning environments (Windschitl *et al.*, 2012; Brown, 2014).

Contributions to interests of NARST members

Presented here is an investigation into what teachers notice, including how they reason, when implementing and modifying learning materials in their classroom. Teacher noticing was applied as a framework to guide the interpretation and analysis of weekly reflective logs submitted by high school chemistry teachers. Traditionally, teacher noticing has been employed to characterize events *during* instruction (Chan *et al.*, 2020)*;* however, we have expanded this framework to broader aspects of teachers' attention to and reasoning about classroom events. As Kam Ho Chan and others noted in their 2020 review of teacher noticing, the applicability of teacher noticing has expanded from *during* class attention and reasoning to broader aspects of learning and the learning environment. As such, the research community may benefit from explorative studies (*e.g.* the study presented herein) to define the applicability of this framework that involves teachers' attention to and reasoning about learning and the learning environment.

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