Axes of Support: Explicit to Implicit and Practical to Epistemic

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Abstract: Drawing from analyses of teaching and learning, we posit a theoretical framework of axes, practical to epistemic and explicit to implicit, which frame four quadrants of support needed to know how and why to use the crosscutting concepts in sensemaking. This work has implications for the design of learning environments that use the crosscutting concepts in scientific sensemaking.

The major issue addressed

One aspect of scientific sensemaking is the use of analytical lenses, crosscutting concepts (CCCs), to provide varied perspectives on the big ideas of the science disciplines and help scientists engage with disciplinary practices. CCCs, such as *systems and system models* and *patterns*, have "explanatory value throughout much of science and engineering" and "help provide students an organizational framework for connecting knowledge" (National Research Council (NRC), 2012, p. 83). Generally an implicit part of science teaching at all levels, studies emphasize the need to explicitly support students' use of the CCCs to make sense of phenomena (e.g., Hmelo et al., 2000), however, further clarity is needed around what it means to explicitly support student learning of and for use of the CCCs (Fulmer et al., 2018). Here, we examine the types of support students require in order to understand and use the CCCs for scientific sensemaking.

Potential significance of the work

This work provides called for descriptions (Fulmer et al., 2018) of the kinds of support students need to use the CCCs to make sense of phenomena and engage with disciplinary practices. With disciplinary practices, Berland et al. (2016) argued supporting students' meaningful use of disciplinary practices to understand how and why what they are doing will help them achieve their scientific goals. In this paper, we apply this argument to the use of the CCCs. We propose that there is practical and epistemic knowledge involved in using the CCCs.

Axes of support for the CCCs

We present a theoretical framework for examining existing supports, articulating how we are and are not supporting students to develop practical and epistemic knowledge about the CCCs. We envision this framework as a set of axes of support that students need to develop knowledge of how and why to use the CCCs in the future (Figure 1). The two axes include (1) an implicit to explicit continuum and (2) a practical to epistemic continuum.

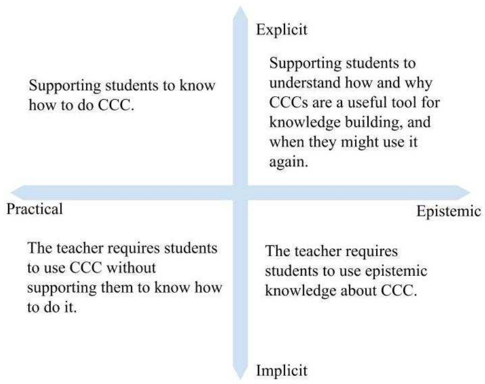

Figure 1. Quadrants of support based on the practical-epistemic and implicit-explicit axis.

First, the *Framework,* as well as researchers studying learning of CCCs, argue for the need for explicit instruction (Hmelo et al., 2000). Here we see *implicit* use as students using the CCCs, without support to know that they are doing so. We see *explicit* use of the CCCs as including support for students to know how and why to use the CCC for sensemaking. Second, we hypothesize that students need both practical and epistemic knowledge to use the CCCs in sensemaking of phenomena (cf. Berland, et al., 2016). The *practical* knowledge is the information that students need in order to be able to use the CCC for their current sensemaking process. The *epistemic* knowledge is what students need to know in order to be aware of how and why they are using the CCC and this CCC in particular to support their sensemaking. To articulate how different supports might fit within the implicit-explicit and practical-epistemic continuum, we identified and analyzed examples from lesson plans and instructional dialogue of inservice and preservice elementary teachers. Because each of these studies focused on use of the CCCs in elementary settings, researchers co-developed a coding scheme for identifying instances of CCC use within the lessons or discussions based on *Framework* descriptions of the CCCs (NRC, 2012). We present two examples here.

One example comes from a lesson plan that preservice teachers (PSTs) developed for a third grade classroom where students use data to explain how changes in the environment can cause changes in the external traits of a peppered moth population. A PST-created handout includes ***explicit*** and ***practical*** support, in the form of a graphic organizer, to call students' attention to the CCC of cause and effect and to support its use. PSTs planned to support their students' eventual use of the CCC on the handout in several ways throughout the lesson, such as through the use of teacher questions, "What was the cause and effect relationship?" In a second example, an elementary PST's lesson plan focused on investigating the structure and function of stems. After the investigation, the teacher intended to say:

> Scientists collect observations from each other and put them all together so they can notice patterns. ...Patterns in science are when we see something a lot in our observations. As we share and put the observations on the chart, I want you to think about patterns that you notice.

In this example, the teacher plans to be ***explicit*** in naming that the students are looking for patterns. The use of the CCCs would be ***practical*** in that the teacher expected students to use the CCCs to engage sensemaking around a phenomenon, yet how to look for patterns to make sense of phenomena remains implicit. The teacher would provide support for ***epistemic*** knowledge by briefly describing how scientists use patterns in knowledge development.

Discussion: Defining the continuum

Drawing from the examples we analyzed as well as the literature, we hypothesize the most implicit-side of the continuum as being when the CCC is used for sensemaking but neither the student nor the teacher are aware of CCC use. On the other hand, the most explicit side of the continuum would support understanding of what the CCC is, facilitate knowledge development of how and why to use the CCC and how this relates to scientific practices and disciplinary core ideas, and provide support for using the CCC. Most of our examples fell on the practical side of the practical-epistemic continuum since these support students to use the CCCs in sensemaking of science ideas and engaging in science practice. Explicit reference to how scientists use the CCCs could support students to know how and why to approach using them in the future, epistemic knowledge around this CCC. We suggest that a diverse set of scaffolding is needed to support students in building knowledge about how and why to use the CCCs to make sense of science phenomena, extending research on the CCC (Fulmer, et al, 2019). Although many areas of Figure 2 were not represented by examples, we hypothesize that support for CCCs from each quadrant would play a role at different points in students' learning. This suggests avenues for future research examining the support needed for students' development of practical and epistemic knowledge about and for use of the CCCs in both implicit and explicit ways. The implicit-explicit and practical-epistemic knowledge continuums have implications for the development of CCC scaffolds in learning environments.

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