International Conference NEW PERSPECTIVES in SCIENCE EDUCATION

Utilizing the Cross Cutting Concepts to Design Effective Science Sensemaking Experiences and Scaffolding Scientific Knowledge

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Abstract

The Next Generation Science Standards (NGSS) are becoming more widely adopted across the United States. Even many states whose standards aren't directly based on the NGSS have had their standards influenced by NGSS. NGSS is based on the idea of three-dimensional learning: Disciplinary Core Ideas (DCIs), Science & Engineering Practices (SEPs), and the Crosscutting Concepts (CCCs). The CCCs are generally given the least attention by teachers, even though they are a tool that can help teachers build curricula around storylines and a theme, and enhance students' scientific and critical thinking. We view the CCCs as a vital resource for teachers – both pre- and in-service – and students, because they support sensemaking of phenomenon, help link concepts together, and connect scientific and non-scientific disciplines. When teachers and pre-service teachers frame lessons with the CCCs, this can facilitate and improve lesson design, and enhance student engagement with scientific practices (SEPs) and concepts (DCIs). We share suggestions and resources for making the CCCs an integral part of science teachers' planning and implementation of curricula, as well as examples of lessons developed by pre-service teachers that make CCCs visible and explicit, thus supporting phenomenon-based and three-dimensional teaching and learning. Such lessons allow students to notice and wonder about the bigger picture, and how to facilitate this approach has utility to both practitioners and researchers.

Keywords: *Cross Cutting Concepts, Curriculum, Instruction, Lesson Design, Sensemaking*

The central pedagogical principle on which the Next Generation Science Standards (NGSS) are built is that of *three-dimensional learning*. This principle puts forward that through meaningful integration of the disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs) that students will attain an understanding of both the knowledge and processes of science. Regarding that third dimension of cross cutting concepts, it is noted in *A Framework for K-12 Science Education* (2012) [1] that: "… crosscutting concepts have value because they provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas" (p. 218). However, the authors' experience in working with hundreds of pre- and in-service teachers over the years is that teachers lack the familiarity or confidence to support their students in using the CCCs as intellectual tools in this way. It would be easy for the CCCs to become the forgotten thread in the tapestry of 3 dimensional teaching and learning because the DCIs are connected to content that science teachers know and the SEPs are related to the process and inquiry skills with which science teachers are familiar. However, we make the case for giving the CCCs the full and explicit attention they deserve as a way to support students in using them as intellectual tools for sensemaking of phenomena.

In an integrated instructional model, teachers and students use crosscutting concepts to link and apply content knowledge between disciplines to make sense of phenomena. Students at all levels may have varying prior experience with thinking about or applying crosscutting concepts to their science content. An individual science lesson, or series of lessons as part of a unit, can incorporate a crosscutting concept. The idea of crosscutting concepts have been present as instructional guides for some time, as the precursor to the NGSS, the National Science Education Standards (NSES), referred to Unifying Concepts as did the College Board (CB), while the concurrent American Association for the Advancement of Science (AAAS) referred to Common Themes. NGSS identified seven CCCs: Pattens, Cause and Effect, Scale, Proportion, and Quantity, Systems and System Models, Structure and Function, Energy and Matter, and Stability and Change. Many states that formally adopted the NGSS as their own state science standards, or adapted them slightly to fit into a state's existing standards structure, also embraced and adopted the seven CCCs for teachers to integrate into their instruction.

Scientists routinely ask questions, perform investigations in which they make observations and collect, analyze, interpret, and critique data and debate and evaluate evidence, hypotheses, and theories. These ongoing process is a practice that science teachers can incorporate into their pedagogy and curriculum and provide opportunities for students to develop critiquing skills and the ability to use evidence from various data sources and engage in true scientific inquiry and sensemaking about various phenomena [2]. When students have these experiences, true learning is more likely to occur, and students will have a more secure understanding of a scientific concept [3]. By simulating the practice of real scientists, students may develop a richer, deeper understanding of scientific practices and develop critical and analytical thinking and reasoning skills along the way.

The CCCs are the tool for teachers to develop themes around their lessons and offer a storyline to reach the intended learning outcomes. They are the conceptual framework for students to organize their thinking and develop deeper, richer, even novel ways of making sense of phenomena. Practicing teachers and pre-service teachers may see the CCCs as being outside of the content and adding an additional layer of instruction on an already filled science curriculum. However, the use of a single chosen CCC can offer focus to the type of questions teachers can generate about a given phenomenon (i.e What pattern exists between the lava composition of a volcano and the volcano's location?), or a lens to view the data collected during an investigation. Encouraging students to respond to questions using the actual CCC terms (either verbally or written) allows for reasoning while maintaining the intended theme of the lesson.

Modeling of this practice with pre-service teachers in undergraduate and graduate level teaching methods courses and professional development workshops with practicing teachers is critical. We model lessons using a variety of phenomena so that pre-service and practicing teachers can have that lived experience of a CCC-themed and embedded lesson, and then deconstructing the lesson experience to examine all the ways the CCC was manifested throughout the lesson. We also require students to read an article in a science teacher practitioner journal to ensure they can identify and explain the use of the CCC in that described activity and how it may benefit student learning. Students apply their understanding of the CCCs as they develop a science lesson, write a lesson plan, and ultimately teach the lesson in class. Informal student response via class journals and lesson design reflections indicate that our pre-service teachers find them to be a useful tool to aid in developing lessons to be more interactive, engaging, and focused with the overarching goal in mind, and more creative ways to practice scientific process skills.

There are several analogies in how to view the CCCs: the highway that takes us to our destination, the frame of a picture, or the frosting on a cake as it spreads across and through the cake (the science content), or a thread or chain link that holds things together. We see them as essential tools for science teachers to enhance and enrich students' learning and sensemaking of phenomena across science discipline and across grade levels, including and especially introductory level science courses that serve as general education requirements for universities. The CCCs are the lenses that can provide greater and deeper insight into natural phenomena. Over time, and with consistent use and application, students will perform investigations and approach solving problems and scenarios as scientists do - with increased sophistication, flexibility, and ability to see the bigger or long-range picture. We anticipate future research with pre-service teachers in a National Science Foundation-supported Master's residency program and monitoring and assessin their understanding and use of CCCs in lesson, and the impact on their student learning outcome, in hopes students will be able to connect novel phenomena and show deeper and complex relationships across the different scientific disciplines. We see the CCCs as supporting the learning goals for all of science, and for improved scientific literacy.

References

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