STEMTLnet
August 2021 Theme of the Month
Rebooting the Science Classroom: Sensemaking and Phenomena-driven Instruction
Synthesis

This month's Theme explores what we have learned about effective science teaching from the past year and a half of COVID shut-downs. Many teachers are heading back to the physical classroom this Fall with some lessons learned after a tumultuous year as a result of the pandemic. Our interactive webinar will focus on pedagogy that is centered on student sense-making in phenomena-driven instruction. Our moderator was Jason Crean, and he was joined by an expert panel comprising Gretchen Brinza, Michael Fumagalli (who contributed the month's blog), Kristin Rademaker, and Janelle Scharon. The panel posted several links to sources for curriculum materials that can support the phenomena-centered, sense-making approach they discussed during the webinar.

An old challenge takes on a new form during COVID. It has long been a truism of science education that there is traditionally too much focus on learning "concepts," that is, terminology and jargon, There are studies that have found that high school science texts require students to learn more new vocabulary than a foreign language course typically does (see here for a recent paper on this issue, and here for a classic study). As our panelists noted this hedge of words is discouraging for many learners who might otherwise be engaged by the subject matter, and it is part of why it's been difficult to broaden participation in the sciences, as students from under-served populations are put at a disadvantage. Kristin Rademacher said:

> ...look at the work that's been done by Okhee Lee and her colleagues and the report that's from National Academy Press about how we have to stop using vocabulary as a precursor to learning, it's really powerful in thinking about how we really need to let our students, no matter what age they are, experience those science concepts themselves and use their own language wherever they are in their language development, to explain what they're seeing and to ask questions around what they're seeing and not really focused so much on do they use the words the right way.

Moreover, it's entirely possible for students to acquire vocabulary, have some facility with science ideas at a conceptual level, and yet not realize that they don't really understand the science at all, when it comes to using it to explain or investigate phenomena. Jason Crean speaks of "the illustion of explanatory depth" (a phrase originating in Keil's study of folk science, for example here) as a way to characterize the contrast between actual, usable understanding of science, and the acquisition of science language.

As our panelists noted, the challenge of student engagement with science as traditionally taught was even more severe when the COVID pandemic forced schools to go on-line. In addition to the static instruction that teacher-centered, word-focused science tends to foster, the teachers noted the loss of another factor that had helped some of their students stay attentive in science class — the personal relationship of trust and respect between the students and the teacher as well as the mutual support that the students offered each other when physically present in the classroom. As Michael Fumagalli said,

> I leaned on my relationship with students to engage them. In other words, I had a really harmonious classroom, right? Students were excited about coming to class. I think they enjoyed having me as their teacher. I enjoyed having them in class. We had wonderful community, but what I was leaning on was the relational component and the relational temperature of the classroom in order to engage them in science instruction. So, really what they were doing was they were engaging in what I was asking them to because they wanted to make me proud, not because they were really invested in figuring out the answers to their questions.

When COVID disrupted classroom routines and conventions, what took their place?

Focusing on phenomena: sense-making, story-lines, and coherence. Our panelists have found that a phenomena-based approach, in which student thinking and sense-making drive the questions, the learning and teaching that happens, was the best foundation for successful science learning over the past year. Their experimentation during the crisis brought home to them the wisdom — and the feasibility — of the three-dimensional science learning advocated by the Next Generation Science Standards. Jason Crean said:

> sensemaking has really become a focus in the three-dimensional classroom and we have a definition here. Sensemaking is the idea that students make sense of the world around them by observing phenomena, asking questions and investigating the answers to those questions through the use of science and engineering practices.

An approach to curriculum called "story-lining" (see the Resources) invites student investigation of a phenomenon, and then unfolds as student questions are generated and possible strategies for answer-seeking — and explanation-building — unfold. The students follow the questions that have meaning for them — that help them build understanding, and also have importance to them. Thus, both interest and identity are engaged and motivate the work. As Dewey wrote, such a growthful, social, learning experience

> involves seriousness, absorption, definiteness of purpose ; it results in formation of steadiness and persistent habit in the service of worthy ends. But this effort never degenerates into drudgery, or mere strain of dead lift, because interest abides — the self is concerned throughout. (Dewey 1913, pg. 15)

The teacher's art in supporting and guiding this kind of science learning is in large measure based on an attention to the *coherence* of the developing investigation. Coherence is a word with many meanings in education, but in this case, things in a phenomenon-based, sense-making process are coherent when each piece "fits" the current need of the students, as their explanatory understanding develops and new questions arise. Gretchen Brenza described it in her practice this way:

> I think of coherence from a student perspective, like a puzzle, right? That there are pieces that obviously go together. And if we go from piece to piece and try to stick in a piece that's not from the kid's perspective, that's really the piece that needs to go there, the puzzle is not going to work. And so we need to acknowledge that what we think the pieces are, are not really the pieces, right? That they're really something else from the kid's perspective. And that when the kid builds those ideas over time, it's meaningful to him or her, them.

Mike Fumagalli elaborated from his own experience over the past year and a half:

> they are genuinely invested in it because it is reliant upon what they have figured out previously, right? And so we often talk about how students are motivating the next step in the process as students are motivating the next lesson in the sequence, in the storyline, because they're genuinely invested in it. They care, and they have to answer these questions that they have about the world around them. So, that's the best way that I can capture it, but also speak from my personal experience of how my thinking shifted when I really started to leverage coherence in a powerful way.

This coherent, student-driven sense-making about phenomena of interest — whose interest increases as the investigation proceeds — can involve students of all backgrounds and "achievement" in science to that point. The questions are central, and science practices work alongside conceptual/theoretical understanding to push and test understandings — starting from the phenomena, and going back to the phenomena to verify or challenge the developing explanations. Janelle Scharon made the link to equity:

> the investment in the questions from students also built relevance and not just in the science, but also the connection you feel in your identity with the science like, "Oh, this is my connection." And I think that's where a lot of the equity piece and the cultural frames of references, like what students learned before they came in or what they're learning concurrently, because they are learning all the time, really builds out on this coherence piece.

> And I think the piece that I've learned so much about this work as well is just that when you focus in addition to relationships on this, I think that you become a better listener because with science, we often cut off the answer, right? We're like, "Done, moving on, let's keep going." And that's not this process. This process is about being able to listen and to make sense and make room and space for students to figure it out as they're going.

Finally, the students' investment of their interest and their imagination in the work of following their questions about real-world phenomena, means that bridges can be built naturally to the world beyond the school walls. During COVID school shut-downs, "school" entered millions of homes in unprecedented ways. Students' sense-making journeys invited their families to overhear, to ask, to connect in ways that were authentic both to the school learning, and to the students' "real lives." Kristin Rademaker reflected on a new kind of circulation between home and school:

> how are we connecting with kids beyond of the traditional walls of our classroom and how are we taking that and even broadening that scope to their home life? When the pandemic hit, we really had to rethink about what science looked like for students....when we've been doing all of this rich sensemaking in science learning around real phenomena and engaging kids in a way that they had never been engaged before...Why can't we build the things for kids to be able to do with their families, with their brothers and sisters around these big science ideas?
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> ... And Mike was really instrumental in this work too in that he had this idea about having dinner table discussion daily dues, which really invited parents or other adults in the home or guardians to really interact with students around things that happened in the kitchen when they were preparing food. So, how does our soap work, and why does popcorn pop, and what happens to marshmallow when you put it in the microwave? And all those fun things that involve a lot of rich engaging science that we never ever thought to bring to the classroom before.

As Dewey wrote (pg. 15), "*interest means a unified activity*."

Conclusion

Our Theme, and the expert panel's discussion, build in intriguing ways on very deep precedents. Johann Pestalozzi (1746–1827), blending prior educators' ideas with his own deep appreciation of children's development, advocated a phenomenon-based approach that built from natural curiosity to guide children's learning. John Dewey incorporated these insights, along with the results of new psychological research, into his broader theories about human inquiry and education. Modern reformers, including the great NSF-funded curriculum projects of the post-Sputnik era, brought this vision to classroom materials and teacher education. The importance of "asking questions of Nature and making sense of her answers" (as Feynmann said) was central to this enduring and ambitious vision (Hawkins 2002).

Yet the generations of standards and guidelines, and frameworks have only slowly made inroads into the resistant "grammar of schooling" (Tyack and Cuban 1997). Our expert panelists have told us how the disruptions of the pandemic made all these insights about student interest, investment, ownership, and sense-making indispensable in helping their students make science learning their own business. Perhaps, as Mike Fumagalli wrote in this month's blog, we have willy-nilly stumbled into a time of transformation.

Recommendations for teacher leaders

In this transition back to in-person learning (or hybrid classrooms), it is important for teacher leaders to engage with their colleagues in reflection and analysis of the sort exemplified in the Expert Panel discussion this month.

It may be that the phenomenon-driven sense-making approach is particular to science or STEM learning — or perhaps it is more broadly valuable across the curriculum. As seen in other Theme discussions, interdisciplinary collaborations have been important in many schools' response to COVID. Teacher-leaders across the curriculum can encourage their schools to explore pedagogical cross-fertilization.

New pedagogical approaches require teacher learning and the reconstruction of practice; this was hinted at by our expert panel though there was not time to follow up on the question. Teacher leaders may be in a good position to identify learning challenges emerging for their colleagues from the innovations being shaped and tried in this dynamic COVID era.

Recommendations for researchers

Teachers, policy-makers, and teacher leaders are saying that education is experiencing important changes triggered or entailed by the disruptions of COVID and its aftermath. For example, Mike Fumagalli's blog suggested, "we are in the middle of the largest educational experiment that has happened in human history and we have a ***responsibility*** to figure out how we move forward."

Researchers can support and advance the field of learning and teaching by examining some of the shifts that have taken place. How different are curriculum, pedagogy, and assessment in science classrooms now? What changes in school culture have come about to enable or respond to changes in science education? What new links to the community and home have developed, what benefits and challenges have they brought, and how durable or persistent are the changes in a year, two years, or five.

Recommendations for administrators and policy-makers

Teachers, students, and families have been put under tremendous pressure to cope with the public health crisis that is not yet "over." No doubt administrators also have been pressed hard. Leaders need to be intentional about making space to examine and evaluate the changes that have come about, often improvisationally. What innovations can or should continue, what should not? What are the key criteria for helping make such judgments, and what data will support your decision-making? What new consultative (or conversational) processes are needed to help your system (school, district, community) adjust and carry its mission forward? What research could be done, perhaps in research-practice partnerships, that would help you in your work?

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Written by:
Brian Drayton,
Co-Director for the Center for School Reform at TERC.

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