

## Promoting shifts in teachers' understanding and use of phenomena in instruction and assessment

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**Abstract:** This paper examines an online professional learning intervention to develop teachers' pedagogical design capacity to develop five-dimensional (5D) learning and assessment opportunities, which involve integrated use of science and engineering practices, disciplinary core ideas, and crosscutting concepts in science to make sense of phenomena and problems that are interesting to students and support students as knowers, doers, and users of science. We present findings from our design study, which suggest both the promise of such an approach and some of the challenges and tensions experienced by teachers as they chose and used phenomena to support 5D learning opportunities for students.

### Introduction

An important focus of professional learning is to support teachers' development of pedagogical design capacity (PDC), that is, their capacity to create and adapt materials that can deepen their practice and improve student learning (Brown, 2002). Supporting this development is an intensive, iterative process that requires preparing teachers to choose, adapt, and create materials to align with instructional goals (Brown, 2009). This approach to professional learning acknowledges that teachers are in fact *designers* of learning opportunities for students, not just implementers of others' designs (DeBarger et al., 2013).

The purpose of this design study was to develop and test an online professional learning intervention for teachers to support them in designing and using assessments that are aligned to the vision of science teaching and learning articulated in *A Framework for K-12 Science Education* (National Research Council, 2012). Assessments that align with this vision are quite different from those typically used in science classrooms: they demand tasks that are compelling to students and require them to use science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) in science to make sense of phenomena and problems (NASEM, 2019; National Research Council, 2014). Bell et al. (2016) argued that the *Framework* presents a five-dimensional (5D) vision of instruction and assessment that not only includes a three-dimensional (3D) vision of science, involving the integration of DCIs, SEPs, and CCCs, but also two additional dimensions: engaging student interest and supporting students' identity development as knowers, doers, and users of science.

A particularly vexing challenge for science curriculum and assessment designers and teachers alike is choosing phenomena for instruction and assessment. Phenomena are observable events that students can explain using science knowledge and practices and are key to realizing the vision of the *Framework*, because they provide contexts for students to use the dimensions together to engage in science (NASEM, 2019). It is challenging to choose phenomena for instruction and assessment, because it is possible to choose phenomena that are interesting to students but that do not provide opportunities for students to develop and demonstrate understanding of 3D standards. Similarly, it may be possible to choose phenomena whose explanations address 3D standards, but do not connect with students' interests, experiences, and identities. What designers in any role need is a type of "design know-how" (van den Akker, 1999) for choosing and using phenomena that support students' 3D understanding, while also accounting for their interests and identity development. This paper explores how we supported the development of this "design know-how" or PDC with rural teachers in the context of an online professional learning intervention.

### Description of our intervention

Our intervention is an online adaptation of a two-day, face-to-face workshop series to help teachers design assessment tasks aligned with the NRC (2012) *Framework*. Penuel et al. (2019) found that teachers who participated in these workshops improved the quality of their designed tasks. Building on this work, we identified five PDC areas that teachers need to develop 5D instruction and assessments, namely their capacity to 1) "unpack"

the targeted 3D understandings found in the standards, 2) learn about their students' interests and prior experiences with science, 3) understand what phenomena are and how they can be used to frame instruction and assessment, 4) choose phenomenon contexts that are engaging and productive for students to develop and demonstrate targeted understandings, and 5) develop assessments that prompt students' integrated use of the 3Ds to explain phenomena. These areas are interconnected, as teachers' unpacking of standards and understanding of their students' interests influence how they choose phenomena and design prompts that support student sensemaking and identity development. In this paper, we explore how our intervention supported teachers in understanding the purpose and value of using phenomena and the challenges involved when choosing appropriate phenomena to frame instruction and assessment opportunities.

We used a storyline approach (Reiser et al., 2021) to design three sets of lessons and tools to support the development of teachers' PDC. Teachers engaged in 25 hours of synchronous, online learning over nine afterschool sessions during Fall 2021, with additional asynchronous work and opportunities for feedback between sessions. In Lesson Set 1, we co-developed with teachers a 5D, *Framework*-aligned vision of instruction and assessment. We introduced teachers to tools designed to help them elicit information about their students' interests and science-linked identities and unpack the targeted 3D understandings from the standards. In Lesson Set 2, we co-developed with teachers characteristics of phenomena that would help students achieve the targeted 3D learning goals, engage student interest, and support students' science identity development. Using these characteristics and tools, teachers identified and evaluated candidate phenomena and developed assessment scenarios that included data to present these phenomena to students. In Lesson Set 3, teachers collaboratively analyzed examples of phenomenon-driven assessments from different grade bands and content areas and developed and administered their assessments to their students. Using evidence from student work and surveys, teachers developed rubrics to make claims about students' 3D understanding and provide feedback.

## Methods

This design study involved three middle and eight high school science teachers from two rural districts and two facilitators. All teachers were beginning to implement their state's 3D standards. To analyze how our intervention supported teachers in understanding, choosing, and using phenomena, we analyzed data sources from the second lesson set (Sessions 4-6, 7.5 hours), when teachers began integrating the PDC areas named above: (1) field notes, which synthesized detailed descriptions of the facilitation and teachers' engagement with the ideas and tools, (2) virtual artifacts that documented shared thinking, and (3) exit tickets, where teachers shared how each activity met the session's learning goals. Analysis of data sources involved identifying each instance where teachers discussed or wrote about phenomena. In the context of the intervention's designed learning trajectory, we characterized teachers' ideas about phenomena and the "rules of thumb" they developed for choosing phenomena. Since teachers were new to 5D instruction and assessment design, we identified challenges that teachers named or encountered when designing with phenomena. We created and discussed analytic memos and identified themes about how teachers understood and began to use phenomena and the 5Ds in design.

## Findings

Our paper focuses on the shifts and tensions observed in teachers' considerations when choosing phenomena.

### Teachers deepened their understanding of the role of phenomena

The intervention's planned trajectory was designed to deepen teachers' understanding of the considerations that they needed to think about when choosing and using phenomena. Teachers posted their initial definitions and characteristics of phenomena on a digital interactive whiteboard (i.e., Jamboard). Teachers focused initially on two aspects of phenomena: (1) they should be "observable" and involve "real world" situations and (2) they should be "engaging" and prompt students to wonder or ask questions. These aspects of phenomena aligned with two dimensions: engaging student interest and creating authentic situations that could support the development of practice-linked identities. However, only two of the initial 29 characteristics connected the use of phenomena to the development of scientific understanding. Leveraging these initial ideas, facilitators engaged teachers in an activity to use these characteristics to evaluate candidate examples of phenomena. These examples varied in intentional ways to allow teachers to distinguish between phenomena, which foregrounded observations for student sensemaking, from non-examples, which included concepts or "big ideas" (e.g., evolution) or components of an explanation that could be used to explain a phenomenon. Through this activity, teachers clarified and iterated upon their ideas to develop "rules of thumb" for identifying phenomena and lenses for making examples more "phenomenon-like". For example, teachers clarified that phenomena were not "scientific facts" for explaining a phenomenon. One teacher shared that a card that read, "Chlorophyll causes plants to appear green" was a "scientific fact" that could be used as part of "a good explanation of a phenomenon," but was not a phenomenon.

(Session 4 Field Notes, 9/21/21). Upon reflection, a teacher shared why it made sense for phenomena to focus on what was observable rather than components of an explanation, “when you explain it in detail, it’s just spitting out facts - not leaving space for the students themselves to question and figure it out. It needs to not be fact, but something that leaves room for learning” (Session 4 Field Notes, 9/21/21). Thus, this teacher connected her understanding of what phenomena are to the role that phenomena play in inviting students to wonder and support student sensemaking in service of the desired learning goals.

Although teachers could articulate what phenomena were *not*, teachers continued to encounter challenges with describing phenomena as observations to be explained. After discussing our rules of thumb for identifying phenomena, one teacher desired to apply what they had learned to describe what the phenomenon was from that session, where teachers watched a time-lapse video showing a badger decomposing on the side of the road. When describing what the phenomenon was in the video, the teacher described the explanatory processes involved (“the multiple stages of decomposition the badger include”), while another focused on the medium used to present the phenomenon (“the time lapse video of a dead badger”) (Jamboard, 9/21/21). In response, the facilitator pressed teachers to think about what the students observed, which helped teachers to describe the phenomenon as the disappearance of the dead badger over three days. Thus, deliberating on our description of the phenomenon helped teachers refine their rules of thumb for describing phenomena, which was an important stepping-stone for designing 5D learning opportunities for students to make sense of phenomena.

## Teachers experienced design tensions when choosing phenomena

The intervention used three key tools to support teachers in developing 5D, phenomenon-driven learning opportunities for students: 1) the *Student and Community Interest Inventory* to elicit understanding of students’ interests and science-linked identities, 2) the *Unpacking Tool* to analyze the targeted 3D understandings at grade band, and 3) the *Choosing Candidate Phenomena Tool*, which used findings from the first two tools to evaluate the appropriateness of phenomena and choose data sources that invited student sensemaking using the targeted 3Ds. While teachers made progress with considering how phenomena could frame 5D learning opportunities, teacher required additional support, even with the support of tools, when developing their own assessments. We describe some of these challenges and tensions below.

### Weighing student interest with 3Ds when choosing phenomena

In the course, teachers considered how students’ explanations of phenomena could support students in developing and demonstrating an understanding of the target DCIs. At the same time, teachers were expected to consider student interest and identity as well. Several teachers came to appreciate the design challenge of designing for all 5Ds and not just the 3Ds foregrounded in standards documents. For instance, one teacher wrote, “It is actually harder than it seems to come up with compelling phenomena that can be used to both grab students’ attention and get at a deeper understanding!” (Session 6 Exit Ticket, 10/5/21). Facilitating conversations around these tensions helped to develop teachers’ lenses for evaluating and enhancing phenomena. In one task, teachers chose between two phenomena to help students demonstrate a high school chemistry standard (HS-PS3-4), “Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system”. One teacher in a small group discussion argued for using hot springs as the phenomenon, since she felt it was *better aligned with the target DCIs*. In contrast, another teacher argued for melting polar ice caps, because she thought it would be *more compelling and relevant to students*. She contended, “That’s going to get the interest of the kids! [...] If my aunt is affected because she lives in Key West, they’re going to say, ‘The scientists need to monitor it!’” (Session 5 Fieldnotes, 9/28/21). In response, the first teacher offered ideas for enhancing the DCI alignment of the melting polar ice phenomenon by foregrounding the contact between warmer ocean water and the polar ice to show how “the transfer of thermal energy when two components of different temperature are combined” (HS-PS3-4) could explain the phenomenon (Session 5 Fieldnotes, 9/28/21). In this small group discussion, we observed tensions when considering a phenomenon’s 3D alignment and its interest to students. However, the group found a way to consider both lenses to enhance the 5D-alignment of phenomena and the importance of content expertise when choosing and enhancing phenomena.

### Weighing authenticity of data sources for assessment scenarios with 3D learning goals

Facilitators intended to focus on the use of scientific data as one of several ways to present a phenomenon to students when designing assessment scenarios. Some teachers became overwhelmed by the search for data. For example, one teacher shared, “I had to stop halfway through and do some deep breathing, because it overwhelms me. Do you know how long I spent searching for data, local data - searching, searching, searching for an entire day. It’s just a lot of time” (Session 6 Fieldnotes, 10/5/21). Teachers analyzed an example assessment that used

modified scientific journal data to support student sensemaking, which may have contributed to feelings that the inclusion of scientific data was essential to scenario development. In conversations with teachers, facilitators recognized that some teachers lost sight of the purpose for using the data, which was to present the observations or information needed to support student sensemaking of the phenomenon. To alleviate this tension, facilitators attempted to broaden teachers' vision for the type of data that would be needed to meet their targeted 3D goals and pointed them to resources for finding data or phenomena that could be adapted.

## Conclusion

Phenomena are key to realizing the vision of the *Framework*; but, choosing phenomena that align with targeted 3D learning goals, engage student interest, and support students as knowers, doers, and users of science is an ambitious and complex design task. The lack of examples of high quality, phenomenon-driven assessments highlights the need for interventions to develop teachers' capacity to design 5D assessments. Our intervention has designed tools to help mediate this work, and our initial findings suggest that teachers improved in key PDC areas that can support them as designers and adaptors of existing materials. Although our research surfaced challenges and tensions that teachers face when engaging in this work, our intervention created time and space for teachers to process and apply what they learned with support. All instructional and assessment examples used in the intervention came from freely available materials, so that teachers could have a model from which to base their designs and consider ways to implement what they have learned in instruction. To summarize, our initial findings suggest that when used in a collaborative context, the intervention tools can foster the development of teachers' capacities to act as designers of 5D learning opportunities for students.

## References

- Bell, P., Stromholt, S., Penuel, W. R., & Van Horne, K. (2016, March 31). *How to Make Science Instruction Compelling to Students: Designing Formative Assessments to Build on Learners' Interests AND Knowledge* Workshop presented at Nashville National Conference, National Science Teacher's Association (NSTA) Annual Meeting, Nashville, TN.
- Brown, M. W. (2002). *Teaching by design: Understanding the intersection between teacher practice and the design of curricular innovations* [Doctoral Dissertation, Northwestern University]. Evanston, IL.
- Brown, M. W. (2009). Toward a theory of curriculum design and use: Understanding the teacher-tool relationship. In J. T. Remillard, B. A. Herbel-Eisenmann, & G. M. Lloyd (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17-36). Routledge.
- DeBarger, A. H., Choppin, J., Beauvineau, Y., & Moorthy, S. (2013). Designing for Productive Adaptations of Curriculum Interventions. *Teachers College Record: The Voice of Scholarship in Education*, 115, 298 - 319.
- NASEM. (2019). *Science and Engineering for Grades 6-12: Investigation and Design at the Center*. The National Academies Press. <https://doi.org/doi:10.17226/25216>
- National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. The National Academies Press. <https://doi.org/10.17226/13165>
- National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards*. The National Academies Press. <https://doi.org/doi:10.17226/18409>
- Penuel, W. R., Lo, A. S., Jacobs, J., Gardner, A., Stuhlsatz, M. A. M., & Wilson, C. D. (2019, April 3). *Tools for Supporting Teachers to Build Quality 3D Assessment Tasks* NARST 2019 Annual International Conference, Baltimore, MD. <http://learn4bir.org/resources/tools-for-supporting-teachers-to-build-quality-3d-assessment-tasks>
- Reiser, B. J., Novak, M., McGill, T. A. W., & Penuel, W. R. (2021). Storyline Units: An Instructional Model to Support Coherence from the Students' Perspective. *Journal of Science Teacher Education*, 32(7), 805-829. <https://doi.org/10.1080/1046560X.2021.1884784>
- van den Akker, J. (1999). Principles and Methods of Development Research. In J. van den Akker, R. M. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds.), *Design Approaches and Tools in Education and Training* (pp. 1-14). Springer Netherlands. [https://doi.org/10.1007/978-94-011-4255-7\\_1](https://doi.org/10.1007/978-94-011-4255-7_1)

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