Science Learning Progressions

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Guided by the 2011 U.S. National Research Council framework for science education (1), the most recent draft of the Next Generation Science Standards (NGSS) is briefly open for public comment (2). Key goals of this effort (3) include (i) reducing coverage to a select set of “big ideas” (e.g., atomic molecular theory, biodiversity, energy); (ii) providing a progression to facilitate coherence in learning of these ideas over the course of schooling; and (iii) promoting a practice-oriented approach to inquiry-based science learning.

This reform of standards is meant not merely to update content, but to shift the way U.S. kindergarten through high school (K–12) science education is conceptualized and implemented. The NGSS reflect an evolved vision of inquiry-based learning, emphasizing science as a knowledge-building endeavor. An improvement over prior science education standards (4), the NGSS are embedded in learning progressions (LPs)—research-based cognitive models of how learning of scientific concepts and practices unfolds over time. This stresses coherence in the conceptual growth of scientific reasoning across grades.

We discuss the theory and implications of the LP approach underlying the NGSS. We highlight key features of LPs and examine some challenges that accompany development and validation of these constructs.

Reframing the Science Content

Embodying a developmental approach to learning, LPs describe paths by which students might develop more sophisticated ways of reasoning over extended periods of time (5–7). LPs begin with consideration of learners’ prior knowledge and build toward targeted learning goals through carefully designed instruction. These progressions define intermediate levels in students’ understanding, derived, where possible, from research on student learning.

A feature of LPs, reflected in the NGSS’s guiding framework (1), is that core disciplin-}

ary concepts are built and refined through engagement with the practices of scientific inquiry. The framework views scientific inquiry as a theory-building enterprise that uses systematic and evidence-based approaches to create models that explain the world around us (8). Scientists develop these models within a community with socially constructed and continually negotiated epistemological norms regarding what is knowable, how best to come to know it, and what understandings and developing increased complexity, applicability, and epistemological rigor with each learning opportunity.

Stepping-stone understandings on the LP path toward targeted knowledge in a domain can be substantially different from accepted scientific concepts. For example, at the middle school–level, students should understand genetic information as specifying the structure (and consequently, the function) of proteins (10). Such a conception, while grossly incomplete, is a highly productive intermediary that allows students to explain how genes bring about their observable effects. Similarly, establishing weight as a property of matter is important in early grades, necessary to understanding that even invisible things (e.g., gases and atoms) have weight (11). This targeted understanding conflates weight with a more scientific notion of mass, but serves as a productive step toward developing a full understanding of the particulate nature of matter in later grades. The term “mass” is meaningless to young learners and using it does not help them understand this concept.

Although inaccurate understandings can be conceptually productive stepping stones, the extent to which these should be reflected in standards and curricula is controversial. Developers are reluctant to present wrong ideas in standards, and teachers are concerned about teaching them (12). It is important to differentiate between scientifically inaccurate ideas that are conceptually unproductive and inaccurate, yet productive, understandings that can foster learning of more sophisticated understandings.

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cally perform poorly across items (8). Such assessments can detect the range of students’ abilities or levels of sophistication, as well as the appropriateness of particular assessment items for evaluating different student groups (13, 14).

However, the process of developing assessment measures to diagnose levels of student reasoning on a LP presents challenges. Students at the high end of a LP tend to demonstrate reasoning that is robust and nuanced ways, as opposed to simply whether or not they “got it.” Likewise, assessments play a critical role in informing the development, validation, and use of individual LPs. Such assessments can detect the range of students’ abilities, or levels of sophistication, as well as the appropriateness of particular assessment items for evaluating different student groups (13, 14).

Challenges to Assessment

When compared with traditional content-centered scope and sequence, LPs present advantages and challenges to the development and use of science assessments at both local and national scales. LPs can inform the design of assessments that capture the nature of students’ developing understandings in nuanced ways, as opposed to simply whether or not they “got it.” Likewise, assessments play a critical role in informing the development, validation, and use of individual LPs. Such assessments can detect the range of students’ abilities, or levels of sophistication, as well as the appropriateness of particular assessment items for evaluating different student groups (13, 14).

Engaging the Scientific Community

Given the time-consuming and resource-intensive nature of LP research, only a limited array of fully developed exemplar LPs exists to inform conversations about educational policy, curriculum, and assessment. Little is known about how existing LPs interact within and across disciplines. For example, there are several LPs that together describe development of the big idea of atomic-molecular theory across segments of the kindergarten through college continuum. Yet, stitching these discrete progressions into a coherent trajectory that spans schooling is not trivial. The field has yet to examine how cross-cutting big ideas, such as energy, develop concurrently within progressions across the biological, physical, and earth sciences. That being said, efforts around LPs build on available research in cognition and learning (23) and can help us make informed conjectures regarding the most productive directions for science standards, curriculum, and assessment.

As the NGSS come into play (with targeted completion in 2013), it is important for the scientific community to be partners in the dialogue, even as we are mindful of the promises and pitfalls of LPs and their translation into standards. Scientists need to be aware of the long view taken by this approach and the conceptual role of simplified stepping-stone ideas in the learning process.

References and Notes


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