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An argument for formative assessment with science learning progressions

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ABSTRACT

Learning progressions—particularly as defined and operationalized in science education—have significant potential to inform teachers' formative assessment practices. In this overview article, I lay out an argument for this potential, starting from definitions for "formative assessment practices" and "learning progressions" (both in science education and more subject-general literature). By aligning the challenges that teachers face in enacting formative assessment practices with the affordances of learning progressions, I explain how learning progressions may support these practices. Finally, I preview how the articles in the special issue address this hypothesis.

The articles in this special issue address the hypothesis that learning progressions can serve as tools to guide science teachers' formative assessment practices. In this overview article, I lay out an argument for why there is reason to believe that learning progressions, particularly those in science, might serve this purpose. I start by articulating what we mean by "formative assessment practices" and then describe some of the challenges that teachers face in implementing these practices. Next, I introduce the construct of learning progressions as discussed both in the science education literature and in more subject-general literature. I align affordances of learning progressions with the challenges that teachers face in implementing formative assessment practices to explain how learning progressions, particularly those in science, might support these practices. Finally, I preview how the articles in the special issue attempt to address the hypothesis that follows from this argument.

Formative assessment

According to the Chief Council of State School Officers (CCSSO), formative assessment is a process "used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes" (McManus, 2008, p. 3). The process involves both students and teachers in making these adjustments. Thus, students have an important role to play in formative assessment—not only in making adjustments in response to feedback provided by a teacher (e.g., Heritage, 2008), but also as active participants in self- and peer-assessment (e.g., Brookhart, 2001; Linquanti, 2014; McManus, 2008). While acknowledging students' role in formative assessment, this special issue focuses on teachers and the ways that learning progressions might serve as tools to inform their formative assessment practices.[1]

For teachers, the process of formative assessment comprises practices through which they elicit and interpret evidence of students' learning needs in order to respond with appropriate instructional supports. While requiring effective tools and strategies for eliciting student understandings,

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[1]Although most efforts to use learning progressions to inform formative assessment have focused on teachers, future research might explore how learning progressions could inform students' formative assessment practices.

"formative assessment" is not a type of assessment instrument; rather, it refers to the use of assessment tools and strategies within a larger set of practices (Bennett, 2011; Linquanti, 2014; McManus, 2008; Nichols, Meyers, & Burling, 2009). These practices can take place formally (e.g., using evidence collected through assessment instruments) or informally (e.g., in the midst of a classroom discussion). In either case, formative assessment requires clear articulation of learning goals (e.g., Linquanti, 2014; McManus, 2008) and an orientation toward understanding, rather than solely evaluating, students' ideas (e.g., Coffey, Hammer, Levin, & Grant, 2011; Minstrell, Anderson, & Li, 2011). Although researchers have defined teachers' formative assessment practices in slightly different ways, one common formulation is: eliciting, interpreting, and responding to evidence of student thinking (e.g., Ruiz-Primo & Furtak, 2007). Eliciting entails collecting information about student thinking with tasks and/or questions. Interpretation involves making sense of student ideas and understanding what may cause a student to think in a particular way. Responding can be in the form of feedback to students and/or instructional adjustments to be made by the teacher (e.g., Andersson & Palm, 2017).

Despite recent critiques about the nature of empirical evidence for the effectiveness of formative assessment (Bennett, 2011; Kingston & Nash, 2011), this process is widely considered crucial to effective instruction (e.g., Linquanti, 2014) and, thus, to student learning (e.g., Shepard, 2009). However, although there has been sustained interest in formative assessment for almost two decades (i.e., since Black and Wiliam's 1998 research synthesis), widespread implementation of high quality formative assessment practices remains elusive (e.g., Gotwals, Philhower, Cisterna, & Bennett, 2015). Significant expertise is required to implement formative assessment practices effectively (Bennett, 2011) and, as outlined in the following section, teachers face a number of challenges in doing so.

Challenges teachers face in implementing formative assessment practices

All aspects of the formative assessment process may pose challenges to teachers. Most fundamentally, teachers' framing of and attention to students' ideas may not support high quality formative assessment practices. Researchers have identified a dichotomous ("gets it"/"doesn't get it"; Otero, 2006) view of student understanding as both common in teachers' interpretation of students' ideas and problematic for formative assessment purposes (e.g., Minstrell et al., 2011), as this interpretive stance does not focus on uncovering students' specific learning resources and learning needs. As discussed below, a right-wrong view of student understanding negatively affects all three practices comprising the formative assessment process.

First, a "gets it"/"doesn't get it" framing may lead teachers to focus their elicitation of students' ideas on information needed to make this evaluative judgment. Teachers may focus on vocabulary (Otero, 2006) or facts, often implicitly asking "'can you guess what I (the teacher) am thinking' questions" (Gotwals & Birmingham, 2016, p. 373) that can be easily interpreted as right or wrong. In contrast, "questions that [allow] a range of responses and [that are] at a higher cognitive demand level" are required to elicit students' reasoning (Gotwals & Birmingham, 2016, p. 381) and, thus, the information required to support further learning.

Second, once student ideas have been elicited (either collected using a formal assessment instrument or noticed in more informal ways), interpreting those ideas may be challenging (e.g., Stahnke, Schueler, & Roesken-Winter, 2016). Consistent with a dichotomous framing of student understanding, teachers often revert to holistic judgments about students' ideas as either "right" or "wrong"—even when they have succeeded in eliciting more nuanced information about their students' reasoning (e.g., Gotwals & Birmingham, 2016).

Finally, there is evidence that responding to students' ideas—whether planning instruction on the basis of assessment information (Heritage, Kim, Vendlinski, & Herman, 2009) or providing feedback to advance student understanding (Schneider & Gowan, 2013)—may be the most difficult step in the formative assessment process. Teachers' feedback tends not to be of a form that will advance students' learning (Kluger & DeNisi, 1996). As Shepard (2009) points out, "formative information is of little use if teachers don't know what to do when students are unable to grasp an important concept" (p. 37). Without a deeper understanding of students' ideas beyond the evaluation of right/wrong, it is difficult to know what to do other than provide the correct answer (e.g., Stahnke et al., 2016).

Learning progressions as support for teachers' formative assessment practices

Learning progressions have been recommended as one means of supporting teachers' formative assessment practices. Black and Wiliam's (1998) suggestion of "a sound model of students' progression in the learning of the subject matter, so that the criteria that guide the formative strategy can be matched to students' trajectories in learning" (p. 37) has been echoed more recently in consideration of "learning progressions" (e.g., Alonzo, 2011; Bennett, 2011; Black, Wilson, & Yao, 2011; Corcoran, Mosher, & Rogat, 2009; Furtak, 2012; Heritage, 2008; Shepard, 2009). Indeed, the CCSSO (McManus, 2008) has identified "learning progressions" as one of "five attributes" that are "critical features of formative assessment" (p. 4).

In science, learning progressions have been defined as "descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn" (National Research Council [NRC], 2007, p. 219). Although used synonymously, "learning progressions" in more subject-general literature (e.g., Heritage, 2007) have a slightly different meaning. In this literature, the focus is on breaking a larger learning goal into more manageable pieces (e.g., Heritage et al., 2009; McManus, 2008), rather than characterizing the changing nature of students' thinking as their understanding develops. Both conceptualizations articulate "a trajectory of development" (Heritage, 2008, p. 4), with a top level that describes targeted understandings and/or performances and lower levels that characterize increasingly sophisticated ones. As described in the subject-general literature, however, these lower levels contain "correct but incomplete" components (or building blocks) that "add up to achievement of the desired proficiency" (Heritage, 2008, p. 4). By contrast, in a science learning progression, these lower levels "may reflect mistaken or imperfect understandings of the target concepts that have to be revised or abandoned before the student can move on" (Corcoran et al., 2009, p. 18). In other words, while both describe how students may, over time, reach targeted understandings, the general approaches emphasize how components of content accumulate (such that levels differ by the amount of content students have mastered), while progressions in science emphasize how student thinking evolves (such that levels differ qualitatively).[2]

Much of the subject-general literature about learning progressions is also applicable to science learning progressions and vice versa; however, the features that distinguish science learning progressions from learning progressions in general are ones that may be especially important for formative assessment. In particular, I argue that these features may afford more diagnostic potential for science learning progressions, as compared to learning progressions in general. In order to more fully attend to the specific affordances of science learning progression, this special issue focuses only on these learning progressions. Due to the substantial overlap between the two conceptualizations, however, findings and insights have implications beyond science education. At the same time, it may be important to attend to science-specific details (of both the learning progressions and of the results) when attempting to generalize to other subject areas. To aid this consideration, in the discussion below, I have tried to highlight features of science learning progressions (as distinct from features of

[2]The distinction between these two conceptualizations can be seen further in recommendations for the construction of learning progressions. In general approaches, learning progressions are constructed either by content experts, based on their expertise in the domain—in particular, "what constitutes the 'big ideas' of the domain and how they connect together"—or by "curriculum content experts and teachers … based on their experience of teaching children" (Heritage, 2008, p. 12). In contrast, recommendations for science learning progressions state that such learning progressions are "based on research about how students' learning actually progresses—as opposed to selecting sequences of topics and learning experiences based only on logical analysis of current disciplinary knowledge and on personal experiences in teaching" (Corcoran et al., 2009, p. 8) and, thus, explicitly reject the methods used in general approaches to learning progressions.

learning progressions in general) that may be important for the mechanisms linking learning progressions and formative assessment.

To ameliorate the challenges that teachers face in engaging in formative assessment, the field has suggested providing resources for teachers, in the form of: frameworks or models with which to reason about students' ideas (e.g., Bennett, 2011; NRC, 2001; Nichols et al., 2009); high-quality assessment instruments (e.g., DiRanna et al., 2008); and enhanced knowledge, often pedagogical content knowledge (PCK; e.g., Falk, 2011; Heritage, 2007; Heritage et al., 2009). Learning progressions may serve as (or facilitate) all three types of resources recommended. First, they *are* frameworks for reasoning about students' ideas. By laying out the landscape that students traverse in coming to full understanding of a topic, learning progressions both focus attention on specific aspects of students' ideas and provide a structure for interpreting and responding to those ideas.

Second, as a model of student cognition, learning progressions can serve as the "cognition" vertex of the "assessment triangle" (NRC, 2001) and, thus, aid in a high-quality process of developing and interpreting the results of assessment instruments and strategies. Third, particularly in science, where common student learning difficulties are represented, learning progressions contain significant PCK (e.g., Corcoran et al., 2009),[3] which can be thought of as "research-based knowledge to support formative assessment activities" (Alonzo, 2011, p. 125). While the insights that science learning progressions provide about the nature of students' developing ideas may provide more diagnostic potential and, thus, more responsive instructional moves, all learning progressions may suggest ways of identifying appropriate sub-goals and, thus, help in structuring instruction to support student learning. In the sections below, I provide a brief overview of how learning progressions, by serving as resources in these ways, are thought to support teachers' formative assessment work—to frame and then to elicit, interpret, and respond to students' ideas—acknowledging where there is concurrence in the literature and where existing debates are relevant to the learning progression-formative assessment hypothesis.

Support for framing of student thinking

Learning progressions may focus attention on students' ideas and, by providing a nuanced framework for interpreting those ideas, support both formal and informal formative assessment practices. Learning progressions (both in science and in general) portray less sophisticated understandings in terms of progress toward—rather than only as deficient in comparison to—targeted understandings (Alonzo & von Aufschnaiter, in press). However, the treatment of student ideas in science learning progressions (which include attention to students' non-canonical ideas) may have additional affordances for supporting teachers' framing. By including students' ideas that are "wrong" but typical—and possibly even productive and necessary—science learning progressions may focus teachers' attention on all features of students' ideas, and not just whether or not they have met the "correct" criteria contained in a given learning goal (or even the "partially correct" criteria obtained by breaking a learning goal into "building blocks").

While there is evidence that learning progressions may influence teachers' framing (e.g., Furtak, Morrison, & Kroog, 2014), such that, over time, teachers may "move away from talking about student ideas [only as] 'wrong' toward using the language in the learning progression to identify and discuss different student ideas" (Furtak, Thompson, Braaten, & Windschitl, 2012, pp. 425–426), there is competing evidence that teachers with extreme views of student ideas may resist this framing and therefore may not understand learning progressions as intended. For example, Furtak et al. (2014) report on a teacher whose views seemed to suggest a "blank slate" or "empty vessel" view of students' minds. Rather than being influenced by the learning progression, this teacher's interpretations of the learning progression were filtered through this view. Even in less extreme cases, teachers

[3]In contrast, writing in the general literature, Heritage (2007) indicates that only domain knowledge (and not PCK) is required to define a learning progression.

who view students' ideas simply as right or wrong may struggle to "make sense of [a] learning progression relative to" this "dichotomous [view] of student thinking" (Furtak et al., 2014, p. 665).

Eliciting evidence of student thinking

Assessment tasks based on learning progressions may elicit more elaborated, more nuanced, and therefore more interpretable evidence of student thinking (e.g., Alonzo & Steedle, 2009; Briggs, Alonzo, Schwab, & Wilson, 2006) and, thus, may provide more diagnostic information than is available with traditional item formats (e.g., Alonzo, 2012; Corcoran et al., 2009). A number of different item types have been developed in order to assess student ideas relative to learning progressions. For ordered multiple-choice (OMC; Briggs et al., 2006) and multiple true/false (MTF; e.g., Alonzo, Neidorf, & Anderson, 2012) items, particular response patterns (OMC options or patterns of true/false choices) are linked to particular levels of a learning progression. Open-ended items types, including two-tier multiple-choice (e.g., Jin & Anderson, 2012), predict-observe-explain (e.g., Hovardas, 2016; Yin, Tomita, & Shavelson, 2013), and scaffolded (e.g., Gotwals, Songer, & Bullard, 2012) items, can be "scored" using learning progressions. Multiple items (and multiple item types) can be connected through the learning progression, since—unlike "partial credit" or "full credit"—"level X" has the same meaning across items.

While some form of assessment is required to develop and refine a learning progression, there is debate in the field as to whether those assessments are *part of* or *associated with* a learning progression. Some researchers argue that assessments (or assessment items) comprise one of a handful of components that must be present in *all* learning progressions (e.g., Corcoran et al., 2009; Krajcik, 2012). Others take the position that learning progressions should be used to develop learning progression–based products or tools, including assessment items (e.g., Gotwals, 2012). In this view, such tools can be used to provide crucial validity evidence for the learning progression (e.g., Songer, Kelcey, & Gotwals, 2009), but are not, themselves, part of the learning progression.

If assessments are not already part of a given learning progression or if teachers need to create/adapt assessments for use in their own classrooms—whether formal assessment instruments or plans to collect assessment data more informally—learning progressions may provide support for this development process (e.g., Furtak, 2012). By describing a range of ways students may think about the content, learning progressions allow assessment developers to anticipate a range of potential responses. Although a learning progression cannot cover all ideas that students may express, learning progressions are designed to capture common or typical patterns of thinking and, thus, can alert assessment developers to ideas that may be particularly important to attend to. Science learning progressions, in particular, alert assessment developers to common student ideas that may be important to uncover. Learning progressions may also provide indicators of key patterns of thinking (e.g., Alonzo, 2011). In these ways, learning progressions may support the elicitation of different levels of student understanding, not merely whether students do or do not "get" the targeted understanding (Alonzo, 2012).

Support for interpreting evidence of student thinking

Classifying a student idea according to a learning progression both places it within a larger continuum of student understanding (Black et al., 2011) and, particularly for science learning progressions, associates it with the qualitative description of student thinking characteristic of that level. As noted by Shepard (2008), "*qualitative* insights about students' understandings and misconceptions" lead more naturally to "coherent, theoretically sound improvements in teaching" (p. 296, Emphasis in original). In classroom discussions, teachers typically must classify student ideas "on-the-fly," with familiarity with the learning progression allowing them to recognize ideas highlighted in the learning progression as potentially important to pursue (e.g., Furtak, 2012). In more formal formative assessment opportunities, aids for interpretation, based on the learning progression framework, are often built into the assessment itself (e.g., scoring schema for OMC and MTF items; rubrics for open-ended items). The ability to diagnose student ideas relative to levels of a learning progression provides more precise and potentially more actionable information than the number of questions answered correctly or a norm-referenced score (comparing students to their peers).

Learning progressions may also support inquiries into students' responses. In particular, further investigation is needed to understand patterns in students' responses to assessment items (e.g., how a particular student responds across a set of items or how a particular class of students responds to a single item and to a set of items; Furtak et al., 2014) and to make sense of responses—and patterns of responses—that do not fit neatly within learning progression assumptions. For example, diagnoses are complicated when a student idea does not fall neatly within learning progression levels and/or students do not respond to all items at the same level (Alonzo & Elby, 2017). Prompted by reference to the learning progression, puzzling about anomalies may yield insights beyond the descriptions of student thinking available through diagnoses of students' learning progression levels. Thus, by focusing attention on relevant features of students' ideas and the typical ways that students' ideas develop over time, learning progressions can help teachers to make sense of students' ideas (e.g., Yin et al., 2013).

Support for responding to evidence of student thinking

There is some debate in the field as to how teachers should be expected to use information about student understanding as part of a learning progression–based formative assessment process, with a continuum of perspectives on this issue. At one extreme, some researchers view the learning progression as a framework for teachers to think about instructional "next steps" (e.g., Alonzo, 2011). At the other extreme, some researchers believe that it is the responsibility of researchers (and others outside of the classroom) to provide appropriate instruction for teachers to implement (either feedback or lessons tailored to the needs of students at a given level). In the latter view, diagnosing a student's learning progression level prescribes what feedback should be provided or which instructional "next step" should be undertaken. A "middle ground," between these two perspectives, views learning progression–based curricular materials, such as "exemplary tasks" and "a repertoire of effective next steps," as providing strong support for teachers' work to elicit and respond to evidence of students' ideas. Rather than being scripted, however, such materials would invariably require further dialogue and local adaptation (L. Shepard, personal communication, October 1, 2017).

Whether teachers or researchers are responsible for identifying productive responses, the learning progression serves as a framework for identifying the gap between students' current understanding and what is targeted and, thus, what could be done to support students in closing that gap. As is explicit in the subject-general literature, learning progressions—by breaking larger instructional goals (i.e., the upper anchor of a learning progression) into smaller pieces (i.e., the lower levels of the learning progression)—identify appropriate sub-goals (e.g., Heritage, 2007, 2008; McManus, 2008). For science learning progressions, as well as learning progressions in general, instruction may be informed more indirectly, as differences between levels X and X + 1 suggest what students need to learn in order to advance to the next level (e.g., Yin et al., 2013) and, thus, "suggest instructional paths forward" (Furtak et al., 2014, p. 642).

Exploring the formative assessment–learning progression hypothesis: Articles in the special issue

Based on the reasoning above, there is a strong basis for thinking that learning progressions may be an effective means of guiding teachers' work to elicit, interpret, and respond to students' ideas. Indeed, the idea of learning progressions has already achieved a great deal of popularity with state departments of education and with commercial entities, sometimes without sufficient awareness of the research and development work required. Thus, this is a particularly important time to examine evidence regarding teachers' use of learning progressions in order to test hypotheses regarding their usefulness to inform formative assessment practices and to explore the conditions under which these tools might be useful. The three empirical articles in this special issue consider how science teachers use learning progressions to support their formative assessment practices. In doing so, the articles draw on a wide range of evidence of these practices: direct evidence of classroom practices (classroom observations, Covitt, Gunckel, Syswerda, & Caplan, this issue; formative assessment tasks, Furtak, Heredia, & Circi, this issue); self-reported classroom practices (as reported in interviews and written assessments, Covitt et al., this issue); and isolation and elicitation of specific practices outside of the classroom context, prompted by video (von Aufschnaiter & Alonzo, this issue) and written scenarios (Covitt et al., this issue).

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