Mobilizing Learning Progressions for Teacher Use: Examining the Utility of Outside Learning Progressions in Task Co-Design

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Abstract: While many learning progressions have been developed in science education, few studies have examined the utility of these progressions as tools for teachers in contexts outside of their original design. This paper is a case study examining how one group of high school biology teachers drew upon two different learning progressions (evolution and carbon cycle) over the course of one academic year as they designed and enacted formative assessment tasks, and then interpreted responses to the tasks. We find that the progressions were taken up differently and may have provided central ideas for the curricular units but primarily acted as tools for facilitators to frame discussion around student ideas. Our findings suggest the progressions appeared not to be ready-to-use tools for teachers in these new contexts.

Introduction

Learning progressions – representations of the sequential development of student ideas and scientific practices within core content domains (Corcoran, Mosher, & Rogat, 2009) – have been the focus of much science education research in recent years (e.g. Duschl, Maeng, & Sezen, 2011). Scores of learning progressions have been developed across multiple disciplinary core ideas and scientific practices in science, and these progressions have been developed and used for a number of different purposes, including curriculum design, assessment development, and modeling of student growth.

Among the lines of research that have developed around learning progressions is a set of studies that have explored, in a qualitative sense, how learning progressions can serve as tools to support teacher design of formative assessments (Briggs & Peck, 2015), their ability to diagnose student thinking (Furtak et al., 2016), and the ways in which they interpret student response data linked to the progressions (Alonzo & Elby, 2014). These results, while encouraging, have each focused on teachers using learning progressions in contexts closer to that in which they were originally designed, either working with similar curriculum materials (e.g. Furtak & Heredia, 2014) or facilitated by designers of the progression (Alonzo & Elby, 2014). As a result, the field has few images from research as to how the multitude of published learning progressions might support teachers outside of the context of the progressions' original design and development. This gap in our collective understanding represents a significant limitation in understanding the scalability of this line of research. This paper presents a case study of a group of high school biology teachers working with two learning progressions to support their engagement in formative assessment task design, enactment, and interpretation.

Background

We frame our research from a situative perspective (Greeno, 2006), taking learning as changes in participation in practice, and teacher and student participation in classroom activity as coordinated by sets of tools and resources that embody particular design principles intended to structure participation in particular ways (Akkerman & Bakker, 2011). In the following sections, we provide relevant background to learning progressions, arguments for using them directly with teachers, and the ways in which learning progressions may support formative assessment task design and enactment.

Learning progressions

Learning progressions are hypotheses about the ways in which student thinking develops over a period of time (NRC, 2007). Several researchers have identified types of learning progressions, including Wilson (2009), Duschl, Maeng and Sezen (2011), and Lehrer and Schauble (2015). The variations in designs range from those with a small (e.g. within one unit) to a large (e.g. across a K-12 span of time) grain size; those that include students' prior experiences and what some might call 'misconceptions' and those that focus on the ways in which students learn *correct* ideas in developmental progression; and those that focus on a single dimension of student understanding versus those that are multidimensional (Catley, Lehrer & Reiser, 2005).

Regardless of the design features of a learning progression, we emphasize that these progressions should not be viewed as developmentally inevitable (Alonzo & Gotwals, 2012), but rather lay out how student thinking and engagement in practice might unfold in the presence of a particular set of learning experiences, such as a curriculum that takes students through particular stages of understanding. From this perspective learning progressions, while likely helpful tools in the development of particular curriculum materials and assessments, likely will not maintain the same meaning when traveling from one locus to another, but will take up different meanings in new contexts (Star, 2010). In fact, teachers might not perceive learning progressions developed outside their local context as useful (Furtak, 2012).

From this framing, a central question about learning progressions as hypotheses about student understanding and engagement in practice is not whether or not learning progressions are 'right' in terms of capturing student learning in all contexts, but the extent to which they serve a particular purpose in a given context of use (Lehrer & Schauble, 2015). In the case of our own research, we ask questions as to whether learning progressions might serve as useful resources for teachers when taken away from the original context of their design. Given the amount of resources dedicated to these progressions and the materials they support, it is important to address the emergent question of whether progressions offer support when used in new settings, and if so, what kind of activity these resources support. We describe one such possible setting - a teacher learning community focused on formative assessment design - in the next section.

Formative assessment design cycle

We have engaged in a series of projects in partnership with teachers, schools, and districts to examine the ways in which communities of teachers draw upon the information included in learning progressions to inform processes of formative assessment task design and enactment. We define formative assessment as the tasks and tools that teachers use to elicit student thinking and organize classroom participation structures around attending and responding to student thinking, as well as the processes in which teachers and students engage to make learning goals explicit, share thinking, and provide feedback to move learners forward (Bennett, 2011).

Our program of research follows assertions made by many in mathematics and science education who argued that learning progressions, while important tools for researchers, might also support teachers' classroom practice. For example, Heritage et al. (2009) suggested that learning progressions might help to concretize the 'next steps' part of formative feedback that can be so elusive to teachers, even once they have diagnosed student thinking. Similarly, Bennett (2011) argued that a learning progression could help teachers distinguish among the ideas students express as they learn. Furtak (2012) suggested learning progressions might serve as frameworks for teachers to design formative assessments help them interpret and respond to student ideas during instruction.

Drawing on these and other studies (e.g. Borko et al., 2008), we developed the Formative Assessment Design Cycle (FADC) as a multi-step process that supports teachers in the development of formative assessment tasks. The cycle begins with facilitators walking teachers through a learning progression to Explore Student Thinking (1), using a learning progression to categorize and interpret student work samples. Next, teachers identify ideas on a learning progression that they would like to assess during their instructional units, and Design Tasks (2) to specifically elicit those ideas, anticipate the ways students might respond to the task, and rehearse the types of feedback they would provide to different types of ideas (Horn, 2010). Learning progressions can provide fundamental support in this step, as they provide a continuum of ideas students may hold as they progress through a sequence of learning. The fourth step has the teachers Enact Tasks (3) in their own classrooms, using a learning progression either implicitly or explicitly to interpret student thinking on-the-fly. Finally, teachers come back together to Reflect (4) on classroom enactment by looking at student work together and using a learning progression to categorize groups of student responses and plan next steps to move students forward on the learning progression. This feedback is discussed in multiple timeframes (Wiliam, 2007), such that teachers identify not only what they will do in the next class session, but also how they will draw upon this information to support students for the rest of the unit, and academic year. At the same time, teachers reflect on the task itself, identifying the extent to which it elicited student ideas on the learning progression, and how it might be improved and revised for the next year.

In this paper, we used previously-developed learning progressions to guide formative assessment task design, enactment, and reflection in the FADC, and collect multiple sources of evidence to respond to the following research question: *How did a biology teacher learning community use two learning progressions during enactment of the formative assessment design cycle? How can learning progressions originally designed for other contexts support teachers in the design and interpretation of classroom assessments?*

Method

This paper draws on data collected as part of a larger study that explores the way that high school science teachers design, enact, and reflect upon formative assessments with the support of multiple learning progressions. We worked with previously-published learning progressions to support teachers' formative assessment design at multiple high schools across content areas. In the present analysis, we focus on the case of one department of biology teachers at Prospect High as they learned about and used two learning progressions as part of their FADC work within the context of their 11th grade biology classes: Matter and Energy Cycling in Socio-Ecological Systems (Mohan et al., 2009), and Natural Selection (Furtak & Heredia, 2014).

Learning progressions

The first learning progression, originally developed as part of the Carbon Time curriculum, traced energy and matter cycling in socio-ecological systems from K-12 and beyond (Figure 1; Mohan et al., 2009). Lower-anchor ideas on the learning progression begin with informal accounts that students often have when they enter school, based upon their observations of plants and animals, decomposition, and flames consuming fuel. Levels of the progression move from more *macroscopic* observations, plant and animal growth, toward a more *microscopic* account of the molecular processes of photosynthesis, respiration, and combustion. Ultimately, at the top level, students are able to examine the ways in which carbon is involved in these processes at the molecular level.

Upper Anchor	**Carbon-transforming process**	Generating organic carbon	Transforming organic carbon			Oxidizing organic carbon		
	Scientific accounts	Photosynthesis	Biosyn-thesis	Diges-tion	Biosyn-thesis	Cellular respiration		Combus-tion
Macroscopic events		Plant growth		Animal growth		Breathing, exercise weight loss	Decay	Burning
Lower anchor: Informal accounts		Natural processes in plants and animals, enabled by food, water, sunlight, air, and/or other things					Natural process in dead things	Flame consuming fuel

Figure 1. Carbon Time learning progression (Mohan et al., 2009, p. 684).

We also worked with the Elevate learning progressions, originally designed for use in high school biology (Furtak & Heredia, 2014). Building Mayr's framework for natural selection (Mayr, 1982), the Elevate progressions integrate ideas from ecology (e.g. biotic potential and population stability), genetics (variation, inheritance), and the consequences of those ideas on differential survival and reproduction of individuals within populations over long periods of time (Figure 2). The vertical levels represent how student thinking can develop over time, from lower-anchor ideas students bring to school toward upper-anchor, scientifically-accepted ideas.

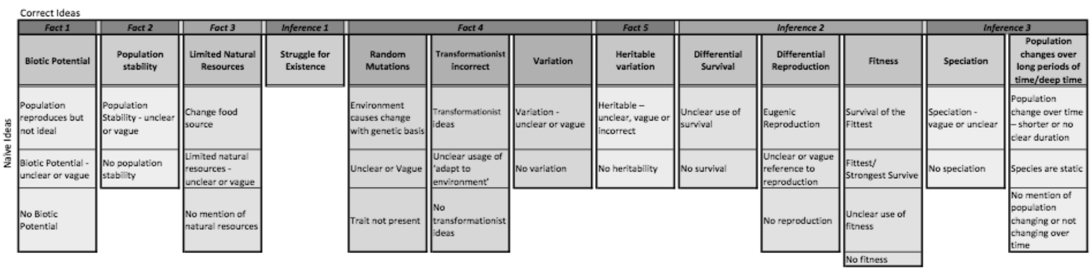

Figure 2. Natural selection learning progression (Furtak et al., 2016, p. 274).

Participants

The five participants in this study were all of the teachers responsible for one or more biology courses at Prospect High in the 2016-2017 academic year. These teachers ranged from 3-19 years of classroom experience, and all had college degrees in biology. We were also participants in the community as facilitators. The first author is a former high school biology teacher who has supported science teachers in formative assessment design and enactment for more than a decade. The second author has a background in K-12 informal science and environmental education and previously worked with teachers on climate change education.

Professional development approach

The authors, either together or separately, met with the biology teachers at their school twice each month during the 2016-2017 academic year to introduce the learning progressions, guide the process of formative assessment task design, and provide structure as teachers categorized student work samples and identified next instructional steps. The meetings were designed to follow the Formative Assessment Design Cycle as described above.

Sources of data

We used multiple sources of data to triangulate our findings for this paper, which reflect our experiences at 11 different on-site meetings at Prospect High school year. Our primary source of data is in-depth fieldnotes created by the two authors at each of these meetings. We also kept copies of teacher learning community meeting agendas, the two learning progressions, copies of teacher-designed formative assessments, and copies of student work. We also took pictures of teacher-created artifacts during on-site meetings. In addition, we conducted interviews with teachers in which we explicitly asked them about their impressions of the learning progressions and how they supported their diagnosis of student thinking.

Analytic approach

Working with fieldnotes and transcribed teacher interviews, the second author developed an initial, open coding approach in which she identified general themes and patterns in the data focused on the ways that teachers used the learning progressions to support their task design. Both authors then met together to discuss these themes and patterns, and then developed a research memo format that would inform the next pass through the data. Both authors then read and analyzed all fieldnotes, creating separate research memos that summarized the ways in which the learning progressions were used in the different phases of the FADC and, as an additional step to search for disconfirming evidence of instances in which the learning progressions could have been used, but were not. These memos were created at a low level of inference and were cross-referenced with the data to create an audit trail. The authors met and discussed the memos in detail, and the second author also pulled teacher responses to interview questions specifically about the learning progressions to discuss and triangulate with the data. During these discussions, the authors recorded all of their adjudicated claims, and kept notes on overarching themes that emerged from the data. We then used these memos to create drafts of our results section, following Erickson's (1986) guidelines for particular description and general commentary.

Results

Teachers' formative assessment task design work spanned 11 meetings across the academic year, with a focus on the matter and energy cycling progression in the fall semester, and the natural selection progressions in the spring. This timing was dictated by teachers' usual progress through the SEPUP curriculum, the adopted curriculum resource at Prospect High. We present our findings according to the teachers' focus on each learning progression individually, and then draw contrasts and comparisons across the progressions.

Matter and energy cycling: The 'Carbon Time' learning progression

The first learning progression we used with the teachers, the Carbon Time progression, was intended to support teachers' formative assessment task design and enactment in their fall ecology unit. This process began in the *Explore student ideas* phase with teachers first developing what we called a 'local scope and sequence', which they created to represent the sequence of concepts and activities they taught with the support of the SEPUP curriculum. Although the university-based facilitators introduced the learning progression to the teachers in an early meeting, the teachers did not use it directly to adapt or revise this scope and sequence document. Mostly, the facilitators used the learning progression to support a discussion of student ideas as a range or spectrum, not just right or wrong answers. At Meeting 2, a facilitator described the learning progression to the group as a way of understanding where students' ideas are and supporting students in developing new ideas. At Meeting 3, a facilitator referred to the Carbon Time learning progression as having significant "upward freedom" for assessment purposes because of the wide range of ideas that the learning progression presents.

As the semester unfolded, the facilitators moved teachers into the *design formative assessment tasks* phase, and teachers created two activities to use in their classrooms, both adaptations from the resources designed as part of the Carbon Time curriculum. Facilitators had reviewed items from the assessment linked to the Carbon Time curriculum prior to the meeting, and selected possible tasks to share with the teachers. One of these tasks consisted of questions about energy and matter in a burning match, and the other included questions about matter and energy cycling in a tree. Despite these materials' link to the learning progression, there was no explicit reference to the progression itself when teachers were adapting the tasks for use in their classrooms in our meetings together. For example, in the iterative design of the Energy and Matter in an Oak Tree formative assessment, teachers discussed the value of having multiple questions that addressed a similar scientific idea so that teachers can better understand what students are thinking. In the final version, shown in Figure 3, students were given several inputs (air, sunlight, water, soil) and asked where the mass is coming from as an oak tree grows from an acorn and where energy is coming from. Students were asked to circle if most, some or none of the mass/energy came from those inputs.

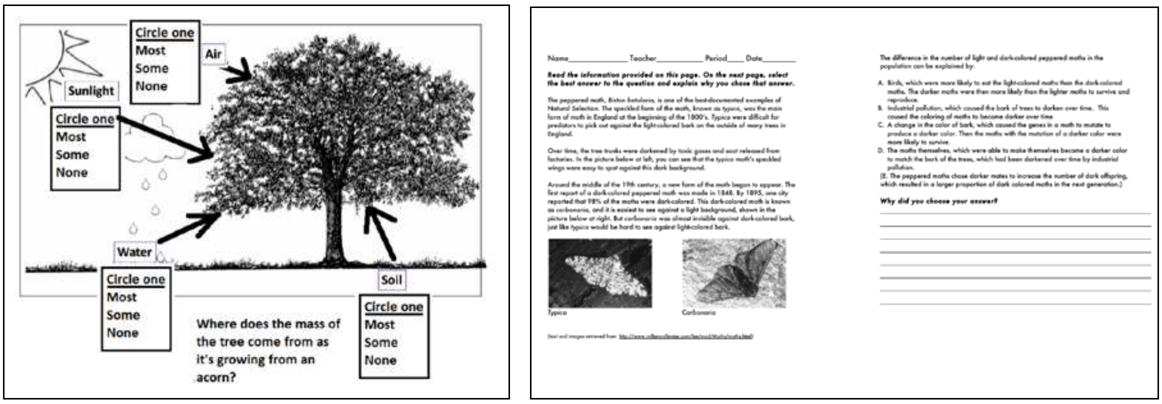

Figure 3. A task for matter and energy cycling, teacher-designed "Oak Tree" task on the left and a formative assessment task for natural selection unit "Peppered Moth" task (Furtak, 2012) on the right.

Teachers then enacted these tasks with students and brought student work samples back to a meeting to *Reflect and Identify Next Steps.* Margaret brought a copy of the Carbon Time progression to help her sort student work, noting that she had already tried to use it to make piles of student work but wasn't able to align the categories in the progression with the student responses to the Burning Match task. We encouraged her to work with her colleagues to develop their own system for making piles of student work that made sense to them. While one pair of teachers made just two piles – those that were right and wrong – the other groups made more descriptive categories, including "matter consumed," "matter transformed/converted," and "into air/smoke." They then discussed instructional supports that might be provided for the students in each category, drawing on the categories they had created. Later, when teachers interpreted student response patterns to the Energy and Matter in an Oak Tree task, teachers and facilitators created piles of student work again but did not reference or attempt to use the Carbon Time learning progression to do so. In discussing formative assessment design and enactment in one particular meeting, a facilitator referenced the learning progression saying that a written artifact can be compared back to the learning progression. Despite the challenge to use the learning progression to sort student ideas, teachers indicated that creating the piles and sorting student data was valuable for their practice. One teacher shared that she did not feel that the sorting process was valuable at first but that afterwards it helped her to better understand specific student responses so she could support her students.

Natural selection: The 'Elevate' learning progression

We began *Setting Learning Goals and Exploring Student Ideas* for the Evolution unit in the spring semester by introducing the natural selection learning progression at Meeting 8, and then supporting teachers in adapting their own local scope and sequences for the natural selection unit at Meeting 9. The teachers had multiple separate scopes and sequences they created as part of this process which, they later reflected in interviews, were likely influenced by the Elevate progressions. That said, like the Ecology planning process, teachers did not directly use the Elevate progressions to create their scope and sequences, but rather formed these on the basis of their prior instructional approaches and curriculum materials. Teachers discussed student ideas about how organisms change in response to the environment, a common misconception in this domain (Shtulman, 2006), but they did so prior to examining how these ideas were incorporated into the learning progression.

Teachers also explored student ideas about natural selection by analyzing student responses (collected from another school) to a formative assessment task developed as part of a previous study (Furtak, 2012), and watching a video of high school students discussing their responses to that task. Facilitators asked teachers to create a spectrum of student ideas from what they felt were more correct to less correct. In this conversation neither the facilitators nor the teachers readily referred back to the learning progression for this activity.

Next, as teachers and facilitators *Designed and revised formative assessment tasks,* they used a variety of resources including the Elevate progressions, state and district standards, activities they had used in the past, their textbook, and a concept map of the big ideas covered in the unit developed by one of the teachers. Teachers considered designing a sequence of formative assessment tasks around the Elevate progressions to help them decide where to put the tasks in the sequence of their unit, but ultimately did not end up creating any formative assessment tasks this way. After reviewing several possible tasks to use with the teachers in this phase, the facilitators selected a task from a prior study as it was relatively simple, they had student response data for it to examine, and could also share video of teachers using it with students. Ultimately, they used the task facilitators had provided them without changing it – the Peppered Moth, shown in Figure 1 - and another task, Climate Change Extinction, developed after teachers looked at the results of the Moth Task.

Similar to the carbon cycle unit, when *reflecting on enactment*, teachers analyzed student data from the Peppered Moth formative assessment by creating multiple piles of student responses based on student response data, not the learning progressions. Piles were related to students expressing ideas about organisms being able to change themselves, or ideas about differential reproduction. These ideas, which are related to the Elevate progressions, were developed from the task itself, but by explicitly using the Elevate progressions.

Cross-case analysis: Relative utility of progressions in supporting task design

Teachers described the learning progressions as a "menu" or something to provide "benchmarks" for the unit as they designed formative assessment tasks. While all of the teachers mentioned the Elevate progressions, only one mentioned the Carbon Time progression, likely because we interviewed teachers at the end of the year when they had just used the Elevate progressions. Ron felt the Carbon Time progression was less clear; when asked directly about the Carbon Time progression, Jim noted that there just hadn't been enough time to use it, saying "we weren't able to experiment with the carbon time stuff just because the time constraints are nutty."

Teachers explicitly pointed to the Elevate progressions as a source of big ideas. Erika reflected that, "We used the evolution one that you guys showed us, where it showed us how it would develop over time and I mean, really we just kind of made a list of what were the big ideas." Sarah also described the Elevate progressions as supporting her in thinking about student ideas and how these ideas progress through a unit, stating, "I think it's useful to know where the students should be and then where we can take them with that work, the learning progression like, what, how do they follow that and where should they be at the end so that we can go back and see what we need to know from them in the beginning and then base our curriculum on that, or what we're going to teach on that." However, teachers' descriptions of the learning progression as a resource for considering big ideas was somewhat vague. For instance, when asked about what features a teacher found more and less useful, Jim responded, "Well, the evolution [progressions], I don't have the specifics, I'd have to take that out of the Google Drive, but it was a good introductory start."

Ron suggested the Elevate progressions had influenced his classroom practice, noting that "I spent more time on the struggle for survival this year versus other years, basically making that connection between overproduction of everything from insects to elephants and that builds in a struggle for survival." In terms of how the Elevate progressions supported unit design and sequencing, Sarah said that it broke down "…what [students] would need to know first, like natural selection, and then they understand that and what they need to know about that to get to the end point." Ron mentioned the challenge of not having specific lessons to connect to the learning progression, noting that he felt the progression needed "…to be put in context of a lesson that would be delivered and tied to it so that there is a clear lesson formative matching. If you have the formative but there's no lesson attached to it, then you're going to have to cobble together a lesson."

Discussion

Taken together, our case analysis – while admittedly with one school and a small sample of teachers – suggests some areas in which the progressions were directly useful to teachers, and other areas in which they could have been used but were not. We first summarize these main conclusions, and then identify future areas for research.

Lack of alignment between progressions and local scope and sequence

The SEPUP curriculum in place at our partner high school was built on the concept of spiraling, where core ideas re-occur throughout a year of study, and are treated with increasing complexity as the school year progresses (Bruner, 1961). In this environment, teachers created scopes and sequences to guide their instruction that were more tied to the curriculum materials they were accustomed to using, rather than adapting them to the learning progressions. Since many learning progressions are developed with the intention of supporting a process of curriculum design, this finding may only be an issue when teachers are using resources developed with a learning progression to supplement other instructional resources created with other designs and progressions in mind. Ultimately, given the piecemeal approach that many high school teachers take when selecting materials from multiple sources to support their instruction of different core ideas, a lack of alignment – whether real or perceived - between teachers' current curriculum materials and those associated with learning progressions may ultimately limit the ways in which progression-based resources are adopted in classrooms.

Suites of tools to support teacher practice

We note that in both units we studied, the teachers used one formative assessment task that was provided to them as part the learning progression resources, and then adapted materials to create a second formative assessment task. In each case, the tools were taken up into classroom use without direct reference to the learning progressions, and the progressions were also not used directly to interpret student responses. Given perspectives about how teachers need suites of related tools to support their implementation of new instructional practices (Thompson, Windschitl & Braaten, 2013), this suggests that while learning progressions themselves may not always be directly useful to teachers, providing teachers with resources linked to the progressions might help to support them in instructional approaches related to the ideas the progressions contain. When teachers were sorting student responses to the Moth Task, for example, teachers created piles based on the student responses themselves, but these piles were directly related to the learning progression given the close link between the structure of the Moth task and two of the Elevate progressions.

Learning progressions as meditational tools for facilitators

Although the learning progressions themselves were not directly used in the ways we might have expected, we acknowledge that they did inform the ways in which facilitators described student thinking as a spectrum, pushing beyond binary framing of student ideas. Furthermore, the progressions guided the facilitators in selecting instructional resources to use to inform formative assessment task design (the Burn Match and Peppered Moth). In this sense, the tools mediated the work of the facilitators and the teachers, suggesting an additional use for these resources: as tools to guide the design of professional learning experiences for teachers.

Grain size

There were a number of key differences between the learning progressions, namely that the Carbon Time progression spanned multiple years of student learning, whereas the Elevate progressions represented student thinking as it might unfold within a unit of instruction in one year of a high school course. Teachers found the Elevate progressions more directly useful in informing their planning; however, this might be because the representation of the Elevate progressions was more closely related to the types of scope and sequences they used to plan units, rather than having such a zoomed-out view on student learning. Our study, while small and exploratory, suggests that the progressions that now underlie the NGSS may also be difficult to translate into direct action as teachers design and interpret tasks. Such progressions will need additional tools and resources such as sample tasks, rubrics, or other interpretive frameworks to be useful at the classroom level.

Conclusion and future directions for research

Ultimately, our study generates several questions about future directions in bringing learning progressions directly to teachers. First, it points to the importance of considering learning progressions as belonging to sets of resources, all of which might support teacher learning and task design. It also tempers our expectations around the extent to which learning progressions in and of themselves are directly useful for teachers, and suggests that future researchers may consider how they can inform the design of teacher activities in professional learning experiences. From this perspective, although learning progressions might continue to be developed, we may come to reposition them in the field – rather than an end in and of themselves – as a representation of cognition that then serves a foundation for the design of subsequent resources (e.g. Pellegrino, Chudowsky & Glaser, 2001), and then these sets of resources could travel to new contexts, rather than the progressions in and of themselves. Finally, in engaging in learning progressions research, our findings suggest that researchers need to consider the contexts, implications, and potential uses of the progressions they create in order to strive to produce research that has meaningful implications for use in guiding science teaching, learning, and assessment.

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