REFLECTIONS ON LEARNING PROGRESSIONS

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> CCII (Center on Continuous Instructional Improvement) views learning progressions as potentially important, but as yet unproven tools for improving teaching and learning, and recognizes that developing and utilizing this potential poses some challenges. (Corcoran, Mosher, & Rogat, 2009, p. 5)

Introduction

Learning progressions have captured the imaginations and rhetoric of school reformers and education researchers as one possible elixir for getting K-12 education "on track" (Corcoran et al.'s cited metaphor, 2009, p. 8). Indeed, the train has left the station and is gathering great momentum in the education reform and research communities. I am concerned that there is so much enthusiasm—and potential for internecine warfare in a competitive market for ideas—that I share CCII's view of the state-of-the-learning-progression as quoted above. Even more, I fear that learning progressions will be adapted to fit various procrustean beds made by researchers and reformers bringing the light of day to education reform. I believe that learning progressions and research on them have the potential to improve teaching and learning; however we need to be cautious because they are especially vulnerable to data fitting as captured by a recent cartoon in *Non Sequitur* (Figure 1). A moment's reflection leads to the recognition that there are promises and pitfalls associated with a learning-progression reform agenda. Moreover, I fear that the enthusiasm gathering around learning progressions might lead to giving heavy weight to one possible solution when experience show single solutions to education reform come and go, often without leaving a trace. As the saying goes, the best of intentions can go awry.

Figure 1. Procrustean fitting of data to (learning-progression) theory.

With this preamble, you can see why the conference organizers—Alicia Alonzo and Amelia Gotwals—invited me to keynote the conference *as a friendly curmudgeon* raising issues and

[1] I would like to thank Alicia Alonzo and Amelia Gotwals for inviting me to address the conference; it is an honor. I also wish to thank Amy Kurpius, Jeff Steedle, and Alicia Alonzo for their comments on earlier drafts of this talk. They made invaluable suggestions.

concerns about learning progressions to keep the train "on track." I come to you as a veteran of formative assessment, learning progressions, and cognitive research on learning and memory. I have learned firsthand how tricky it is to attempt to model cognition and the multitude of individual differences that arise therein. For example, Jeff Steedle's dissertation (2008; Steedle & Shavelson, in press) made it abundantly clear how fragmented students' knowledge structures are in explaining force and motion. Knowledge comes in pieces that seem to be cobbled together in a particular context calling for a particular explanation and the cobbled-together explanation may or may not align in a learning trajectory (e.g., diSessa, 1988). More problematic, imposing a particular learning trajectory on the data leads to misinterpretation and mis-prescription for teaching.

I have learned firsthand how appealing and (superficially) compelling formative assessment can be, especially when delivered by teachers who have their own conceptions of teaching and learning. Our research on formative assessment led to the following conclusion in a special issue of the journal, *Applied Measurement in Education*:

> After five years of work, our euphoria devolved into a reality that formative assessment, like so many other education reforms, has a long way to go before it can be wielded masterfully by a majority of teachers to positive ends. This is not to discourage the formative assessment practice and research agenda. We do provide evidence that when used as intended, formative assessment might very well be a productive instructional tool. Rather, the special issue is intended to be a sobering call to the task ahead. (Shavelson, 2008, p. 294)

And I have learned firsthand how learning progressions can derail the train by reinforcing naïve conceptions and by prematurely imposing a procrustean bed for instruction and cognition that may not be advantageous in the end. For example, our research on sinking and floating followed a middle-school science-inquiry unit (Pottinger & Young, 1992) sequenced in a manner consistent with scientists evolving explanations of sinking and floating: from mass to volume to volume and mass to density to relative density. One major, unintended consequence of the curricular learning-progression approach is that the unit especially reinforced the mass explanation of sinking and floating, making subsequent conceptual development and conceptual change quite challenging.

In the balance of this talk, I begin by presenting my naïve, simplified view of how the field of learning progression conceptualization and research is evolving along different strands. Given the possibility of fragmentation, the vision may say more about the perceiver than the perceived; I'll leave that to your judgment. I then take up the curriculum and instruction strand and follow it out. I also consider the cognition and instruction strand and do the same drawing out lessons and approaches for further research. Finally, I'll try to put the pieces together in summary.

Before proceeding, it seems appropriate to attend to definitional matters. As a number of us attending the conference had the great fortune to serve on the Science NAEP 2009 Assessment Framework, this seems one place to start as we looked into the future: "A learning progression is a sequence of successively more complex ways of reasoning about a set of ideas"; learners move from novice to expert after extensive experience and practice (NAGB, 2005, p. 93, draft document). We went on to say that learning progressions are not developmentally inevitable but depend on instruction interacting with students' prior knowledge and new-knowledge construction. Moreover, we recognized that there was no one "correct order" of progression. And we also noted that learning evolves in a succession of changes taking place simultaneously in multiple interconnected ways. Finally we warned that learning progressions are partly hypothetical and inferential since long-term longitudinal accounts do not exist for individual learners. I believe that this constituted a pretty good characterization of learning progressions and what was known at the time.

Corcoran et al. (2009, p. 8), reporting for a committee that some of you served on, provided a more recent but not inconsistent definition of learning progressions in science based on an NRC (2007) report: "… empirically grounded and testable hypotheses about how students' understanding of, and ability to use, core scientific concepts and explanations and related scientific practices grow and become more sophisticated over time, with appropriate instruction." They noted that the hypotheses described pathways students were likely to follow as learning progressed; the number and nature of such pathways being empirically testable and influenced by instruction. These learning progressions are based on "research … as opposed to selecting sequences of topics and learning experiences based only on logical analysis …."

There seems to be considerable overlap. Both definitions characterize learning progressions as sequence or growth of successively more complex ways of reasoning about a set of ideas. They both recognize the centrality of instruction in the evolution of the progressions. They both recognize that such growth is not simple but can take complex forms moving from novice to expert. And both definitions recognize the hypothetical character of learning progressions and the need for a strong research base on which to justify the use of such progressions.

It is the hypothetical and under-researched nature of learning progressions that causes great fear in me. Not only is it premature to move learning progressions into prime time as seems to be happening, it also places a great deal of weight on empirical research to establish these progressions, and when we think of each and every set of core ideas that might be the focus of learning progression research and subsequently incorporated into teaching and learning, the amount is staggering. Moreover, the policy and reform circus will have long ago pulled up tents and headed for another apparently greener pasture. Just what are we embarking on and recommending? Might it be premature? Or might we recognize the hypothetical, call for more research, but push ahead with practice and revision of progressions in the mean time? That's a question I pose to our community as we move forward.

Two Roads to Learning Progressions

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth.

Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that the passing there
Had worn them really about the same.

. . .

Somewhere ages and ages hence:
Two roads diverged in a wood, and I--
I took the one less traveled by,
And that has made all the difference.

--Robert Frost, *The Road Not Taken*

I, like the traveler in Robert Frost's poem, but in a more simple-minded way, see two roads… inter-related roads traveled by learning progression reformers and researchers (cf. Corcoran et al., 2009, who also seem to see these two roads). One seems more worn but as the traveler admitted, they both were really worn about the same… but that may make all the difference.

The first road I'll call the curriculum and instruction road; the second the cognition and instruction road. Fortunately we are more than one traveler and do not have to choose (or should not choose!) at a glance. If President Obama's stimulus package trickles down to us struggling researchers and reformers, perhaps we'll be able to pursue both to see if, in fact, one of the two roads makes all the difference, whether both do, or whether neither do.

The Curriculum and Instruction Road

The curriculum and instruction road may be characterized by the development of instructional units on, say, living organisms (Lehrer & Schauble, 2000) or sinking & floating (Shavelson et al. 2008), K-8 curricular specifications for, say, atomic structure (Smith et al. 2006), or even content specifications spanning K-12 science (Valverde & Schmidt, 1997). Examples from two such learning progressions are shown in Table 1 (from Corcoran et al., 2009, pp. 61-62).

To be sure, cognition is not left out on the curriculum and instruction road. Yet I believe that C&I progressions are based largely on logical analysis of content structure—perhaps a kind of spiral curriculum as envisaged by Jerome Bruner in *The Process of Education*. This logical content analysis is combined with what I call "psychologizing" as to how students might develop the ideas cognitively. (Incidentally, Bruner had a particular version of psychologizing in building curriculum—from enactive to iconic to symbolic.) Yet such psychologizing is always limited as becomes evident when widely varying students' cognition surprises the psychologizer as they "think aloud"!

Table 1. Example learning progression excerpts (Corcoran et al., 2009, pp. 61-62).

Focus Topic, Concept, or Practice	**Developers** *(In **Bold** are people on panel)*	**Subtopics**	**Grades**	**State of Work**	**Basis of Development of the Framework**	**Development Purpose**
Learning progressions presented and discussed at the CCII meetings.						
Tracing carbon in ecological systems (one of four strands of environmental literacy)	Mohan, Chen, and **Anderson**, 2009	1) Carbon (generating organic compounds, transforming organic compounds; oxidizing organic compounds), 2)Water, 3)Biodiversity, 4)connecting actions	Across Grades 4-12	A basic framework with achievement levels is in place for Carbon, with a set of psychometrically sound assessments that have helped to validate. Currently working on other subtopics but much more work is done on the carbon strand. Conducting classroom investigations to help validate the carbon strand. Validation not complete for any strand of this environmental literacy program, is far along for carbon.	Draws on research on student learning of the topics, but to a large degree is based on empirical work around assessments and interviewing students across many grades.	Understand how to help students develop deeper understanding of important concepts in environmental science so they can become environmentally literate citizens.
Particle model of matter	Merrit, Shin, Namsoo, and **Krajcik**	Structure and Behavior of Atoms and Molecules (includes particle concept, movement, and conservation principles).	One eight – ten week unit at the middle school level	Curriculum is developed and some assessments developed allowing for determination of achievement levels. Working on developing more psychometrically sound assessments to validate. Validation not complete.	Based on prior research on student learning of the particle nature matter, but also based on assessments linked to curriculum and taken by middle school students.	Understand how students use the particle model of matter to explain phenomena can develop over time so can inform curriculum development and instruction around this topic.

Perhaps an example of a learning progression that follows the curriculum and instruction road might be helpful here. In our research on the use of formative assessment in teaching about sinking and floating (e.g., Shavelson et al., 2008), we posited a learning progression that followed the series of investigations laid in *Foundational Approaches in Science Teaching* (Pottinger & Young; see Figure 2). The dependency of the learning progression on teaching and learning is evident in the performance of two students, one from a "successful" guided-inquiry teacher (Gail) and another from an "unsuccessful" open-ended discovery teacher (Ken). Gail's student appears to follow the learning progression; Ken's student does not. Rather, Ken's student is mired in the conception that heavy things sink and light things float. That is, the learning progression received empirical support when Gail taught with guided inquiry but not when Ken taught by discovery.

Figure 2.5 Development of Understanding of Why Things Sink and Float in Two Experimental Teachers' (Gail's And Ken's) Students

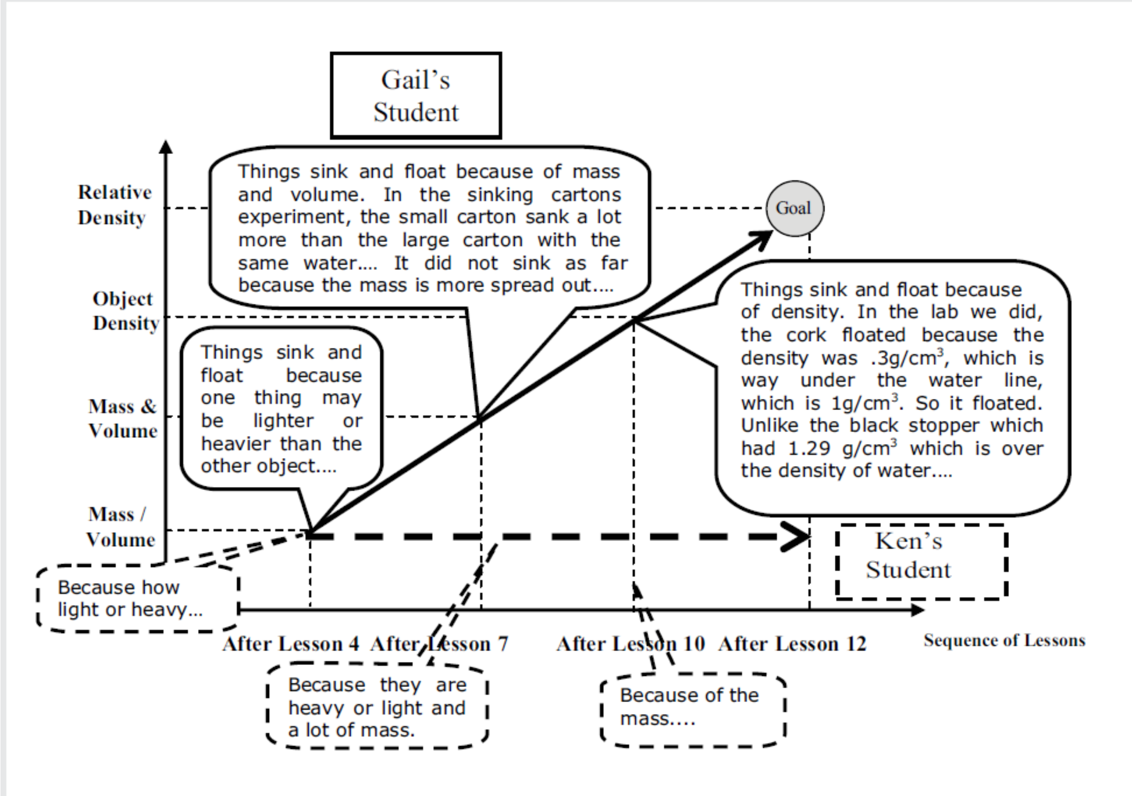

Figure 2. Learning progression for sinking and floating—two students, one studying with a "successful" inquiry-science teacher (Gail's student) and one from an "unsuccessful" discovery-science teacher (Ken's student) (Shavelson et al., 2008, p. 34).

With a few exceptions, learning progressions following the curriculum and instruction road have not been empirically validated, at least in the strong sense that each and every learning progression posited has been researched and replicated and now stand as validated in the Corcoran et al. definition of a learning progression. Indeed, our research suggests that context—in this case teacher and teaching method—will greatly influence the validity of a learning-progression interpretation of student performance.

This said, I believe that we need to follow this road to the development of learning progressions. Logical analysis and psychologizing can move us along the road; empirical research can help guide us. But given the immensity of the curriculum, how might we accomplish the kind of self-correcting research needed to fine-tune and validate learning progressions? I don't know, but I have a proposal—one that might surprise many of you. I believe the teaching experiments and action research with collaborating teacher and researcher teams just might amass the evidence and practical wisdom needed to study and refine learning progressions. I envision such teams working on particular progressions, learning what does and does not work, fine tuning the progressions, and making their findings available to others working on the same progression. In this way, we just might expand both our knowledge in developing and validating learning progressions and our practice in using them. If we get a critical mass of teams working on important learning progressions we might just jump start the research and development agenda and create enough replications to evaluate the validity and utility of proposed progressions. We would then be in a position to know if this is a road well taken or to a road that leads to great caution as we logically analyze and psychologize learning progressions, perhaps leading to new and improved methods of doing so; this seems a practical necessity.

The Cognition and Instruction Road

Just as the curriculum and instruction road starts out with a logical analysis of content, the cognition and instruction road starts out with a psychological analysis of cognition underlying content—what does it mean to understand core ideas in science? How can we use knowledge about cognition to build instruction that improves the chances of all students learning to high levels?

There is a long tradition in the psychological analysis of cognition related to subject-matter learning that includes early on David Ausubel, Robert Gagne, Jerome Bruner and Robert Glaser. The idea here is to map out the growth of cognition as a student learns about, say, force and motion. That is, what does the path look like as a student, over time, moves from naïve conceptions of force and motion to expert conceptions consistent with the understanding accepted by the scientific community? Most importantly, *what do the paths look like in between novice and expert* and how might they inform curriculum, teaching and assessment?

Most recently Mark Wilson and colleagues and Alicia Alonzo and Jeff Steedle have mapped out learning progressions from a cognitive perspective. A learning progression for force and motion—specifically for explaining constant speed—is shown in Table 2 (from Steedle & Shavelson, in press). The progression talks about what the student knows and can do when confronted by force and motion phenomena, more specifically when there is and is not a force present and when the object is and is not in motion. That is, the learning progression maps out a cognitive progression for "understanding" force and motion from naïve (level 1) to competent (level 4).

At issue with this kind of learning progression is whether it accurately reflects cognition. Put another way, do students actually grow their knowledge in this linear, progressive way? Put still another way, does the progression provide a valid and practically useful way of portraying the pathway of cognitive development? By valid I mean whether students' actually do grow their knowledge in this way. By useful I mean that if they do grow knowledge this way, can the progression inform curriculum development, classroom teaching, and assessment?

There is another way to conceive of the pathway from naïve to competent understanding of a core science conception. It builds on two principles in cognitive science. The first principle is that knowing and doing are embedded in a cognitive network. The second principle is that memory is reconstructive. Together these principles lead to the hypothesis that when confronted by a natural phenomenon and posed a problem, students will construct an explanation that is context dependent and draw on bits and pieces of knowledge embedded in a memory network to reconstruct their knowledge and provide an explanation. Note that if students at different places in the evolution from naiveté to expertise have bits and pieces of knowledge organized in a coherent linear manner, their cobbling together explanations would most likely follow the learning progression shown in Table 2, for example.

Table 2. Force and motion learning progression (Steedle & Shavelson, in press, p. 9)

Proposed Explaining Constant Speed learning progression

Level (Facets)	Description and Expected Responses to Item Types
4 (00)	When balanced forces act on an object, the object is either at rest or moving with a constant speed. When unbalanced forces act on an object, the object's speed changes *Balanced forces*: When balanced forces act on an object, it is either at rest or moving with a constant speed *No force*: After a force is removed, an object slows down because of friction, which acts in the direction opposite motion *Constant motion*: An object is moving with constant speed when forces are balanced *No motion*: An object remains at rest when a horizontal force is equal to an opposing friction force. The force of gravity is equal to the upward force for an object at rest on a surface
3 (30, 70)	When balanced forces act on an object, the object is at rest or slowing down. An unbalanced force in the direction of motion is needed to maintain constant speed. Speed is proportional to applied force *Balanced force*: When balanced forces act on an object, it is either at rest or slowing down *No force*: After a force is removed, a force continues to act on an object as it slows down *Constant motion*: A constant net force or unbalanced force or force of motion maintain constant speed *No motion*: *Same as level 4*
2 (90)	No motion implies that no force is acting on an object. Exception: gravity may act on objects at rest. Motion implies that a force is acting on an object *Balanced force*: *Same as level 3* *No force*: *Same as level 3* *Constant motion*: *No motion*: A horizontal force on an object that remains at rest is zero. No force or gravity only acts on an object at rest on a surface
1 (80)	If an object is pushed horizontally and remains at rest, there must be a greater force keeping the object at rest *Balanced force*: When balanced forces act on an object, it is moving at a constant speed *No force*: *Constant motion*: *No motion*: An object remains at rest when a horizontal force is not great enough to overcome a larger friction force, gravity, or the inertia of the object. The force of gravity is not equal to the upward force for an object at rest on a surface

But suppose their knowledge is not so orderly. Suppose they have bits and pieces of loosely related knowledge of force and motion in their cognitive networks, garnered from extensive personal experience and brief classroom encounters. In this case, their explanations will most likely be quite context specific; changing superficial characteristics of the problem would change their explanations in ways not explicated by the learning progression in Table 2. Progress just might not be nice and linear—although our statistical and qualitative modeling might force it, procrustean style, into something neat and linear! Rather progress from novice to expert might be better conceived as a wandering through a complex memory network of bits and pieces of information about force and motion; students might be nested in non-linear subnets for particular contextual representations of a force and motion problem.

If knowledge comes in bits and pieces, only when a high level of competence has been reached would this knowledge appear to be organized and coherent. Anything less than expertise would give rise to multiple “mental models” and explanations for the same underlying phenomenon by the same person under different contexts! And if this is so, prescriptions based on a linear learning progression might just not be accurate and if not accurate, probably not very useful.

Jeff Steedle in his dissertation research examined the extent to which students’ responses to force and motion test items fit a learning progression. He did this for three different learning progressions dealing with conceptions in force and motion, including constant speed as shown in Table 2. He used multiple-choice item data where the alternatives were accurate and naïve conceptions or “facets” of understanding from Jim Minstrell’s Diagnoser (Minstrell, 2000). In a Bayesian latent class analysis of the data comparing models based on the learning progressions and models based on “knowledge as pieces” in a cognitive network, he concluded (Steedle & Shavelson, in press, p. 15):

> Students’ actual response patterns aligned with the proposed learning progressions for two sorts of students: those whose understanding is (nearly) scientifically accurate and those [naïve students] who believe that velocity is linearly related to force. Learning progression diagnoses for these levels could be interpreted validly (with few caveats), but diagnoses for the other levels could not because students diagnosed at those levels are not expected to consistently express the ideas associated with their learning progression levels…. This suggests that it is not feasible to develop learning progressions that can adequately describe all students’ understanding of problems dealing with Explaining Constant Speed. Finally, an analysis of relationships between learning progression levels and facet classes indicated that the confirmatory [learning progression] model failed to make important distinctions between latent classes that the exploratory [knowledge in pieces] model made.

Steedle (Steedle & Shavelson, in press, p. 15) goes on to conclude that:

> Students cannot always be located at a single level of the learning progressions studied here. Consequently, learning progression level diagnoses resulting from item response patterns cannot always be interpreted validly. It should be noted that the results presented here do not preclude the possibility that some individuals systematically reason with a coherent set of ideas. These results do, however, provide strong evidence that there are few substantial groups of physics-naïve students who appear to reason systematically about the forces acting on objects with constant speed. Further, these results corroborate findings from other physics education research indicating that many physics-naïve students should not be expected to reason systematically across problems with similar contextual features.

There is, then, evidence gathered on the cognition and instruction road that would give us pause as we proceed in the pursuit of learning progressions. This evidence suggests pausing and re-thinking how we want to conceive of learning progressions. Indeed, the evidence supports the not-so-tidy definition of learning progressions used in the NAEP 2009 Science Framework--learning progression as a sequence of successively more complex ways of reasoning about a set of ideas; not developmentally inevitable but dependent on instruction interacting with students’ prior knowledge and new-knowledge construction; no one “correct order” for the progression but progressions evolving in a succession of changes taking place simultaneously in multiple interconnected ways; and partly hypothetical and inferential since long-term longitudinal accounts do not exist for individual learners.

Concluding Comments

I was asked to serve the role as friendly curmudgeon at this conference, raising issues and concerns as the learning-progression train gathers steam having already left the station. If I have accomplished anything it has been to be curmudgeon-like. My overriding concern is that a yet inadequately tested idea for improving curriculum, teaching and assessment is being moved into primetime prematurely. This is said with full recognition that the learning-progression idea has legs and if not pushed into and developed in practice, it will languish in researchers' arcane journals. Nevertheless, the potential is high to do more unintended mischief than intended good at this point.

We must, for example, guard against fitting our data to a preconceived notion of a learning progression. Rather, in a Popperian sense, we should seek disconfirmation and only when we fail should we move the progression into primetime. But even then we need to monitor how well the progression is working and agree to modify it as evidence demands.

We also need to make a concerted effort to amass evidence from the field that learning progressions embedded in curricular materials are operating as intended. I posed one possible approach that would move this agenda forward—that of teaching experiments and action research carried out by collaborating teacher-researcher teams. Such teams, on large scale, might amass the empirical evidence and practical wisdom needed to refine and improve learning progressions. Teams would work on particular progressions, learn what does and does not work, fine tune the progressions, and make their findings available to others working on the same progression. I trust you all here today will think of other ways to address this area of concern.

A concerted effort also needs to be made to insure that cognitive interpretations of learning progressions are accurate, useful, and lead to intended learning with minimal unintended consequences. Learning progress just might not be nice and linear. Rather, progress from novice to expert might be better conceived as wandering through a complex memory network comprised of bits and pieces of information; students might be nested in non-linear subnets for particular contextual representations of a problem. Steedle's research suggests a methodological approach for guarding against imposing theory on data but rather for testing theory—our notion of a particular learning progression—with data. Both substantive psychological theory building and research into learning progressions are needed urgently for the most important of science conceptions in the curriculum. A concerted research effort is needed. I again trust you all here today will think of other ways to address this area of concern.

One last curmudgeonly thought is in order. What we come up with as a learning progression research and development agenda for reform, *it must take into account the capacity of U.S. teachers to implement.* The four million teachers in this country are not, in general, like the teachers who volunteer to work with researchers to develop and test cutting edge ideas. They are well known to lack, on average, the critical content knowledge needed to use learning progressions and address the challenges that emerge when students do not nicely and neatly follow the prescriptions of the progressions and the textbooks. Whatever we do needs to take this reality into account and teacher professional development may not be extensive enough to address this challenge. So, finally, I trust you all here today will think of ways to address this area of concern.

In closing, I have discussed two roads taken in the pursuit of learning progressions. Truth be told, they don't diverge in a yellow wood nearly as much as I envision Robert Frost's roads diverging. Rather they continually intersect at the point of instruction. So the final challenge is to bring these roads together into a major highway of coherent research to undergird the policy engine that is now steaming down the track… can we even catch up before it derails for want of sufficient bedrock?

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