

Rethinking what is “developmentally appropriate” from a learning progression perspective: The power and the challenge

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ABSTRACT

Learning progressions have recently become increasingly visible in studies of learning and instruction in science. In this essay, I explore the power and considerable challenges in rethinking what may be developmentally appropriate for young children’s learning science from the perspective of learning progressions. In particular, I examine the issues of: a) the design of promising learning progressions within the vast design space of potential progressions; b) identification of cognitive resources relevant to a progression; c) analysis of effort / payoff for particular competencies at different points in the progression; d) attribution of cognitive limitations and achievements; e) coordination and collaboration needed to support the design, utilization, and refinement of the learning progression; and f) absence of straightforward correspondence between a learning progression and trajectories of different children’s knowledge-development.

KEY WORDS

Learning progression, science, young children

RÉSUMÉ

Les progrès d’apprentissage sont récemment devenus de plus en plus visibles dans les études de l’apprentissage et de l’enseignement des sciences expérimentales. Dans cet essai, j’explore la puissance et les défis considérables à repenser de ce qui est approprié au niveau du développement à l’appropriation des sciences par les jeunes enfants dans la perspective du progrès d’apprentissage. En particulier, je

examine les questions suivantes: a) la conception des progressions prometteuses d'apprentissage dans le vaste espace des progressions potentielles; b) l'identification de ressources cognitives pertinentes à une progression, c) l'analyse de l'effort / récompense pour des compétences à différents points dans la progression; d) l'attribution de limites cognitives et les résultats; e) la coordination et la collaboration nécessaires à l'appui de la conception, l'utilisation et l'amélioration de la progression de l'apprentissage, et f) l'absence de correspondance directe entre une progression de l'apprentissage et les trajectoires des différents enfants vers la connaissance-développement.

MOTS CLÉS

Progrès d'apprentissage, sciences expérimentales, jeune enfant

The idea of “learning progressions” has recently become increasingly visible in research in the learning sciences, especially research in scientific cognition and instruction. In the United States, recommendations to rethink children’s capabilities and the structure of the curriculum in terms of learning progressions constituted a core of the recent National Academy of Sciences report on how to improve K-8 science teaching and learning (Duschl, Schweingruber & Shouse, 2007). A soon-to-be-published issue of *Journal for Research in Science Teaching* is devoted to exploring the application of the construct to science teaching. The National Science Foundation has multiple funding initiatives intended to support research investigating learning progressions.

Across these documents, there appears to be considerable variability in conceptualization of the construct, with some interpreting learning progression as instructional plan and others more in terms of conjectured trajectories of children’s developing knowledge-structure to guide instructional design. This essay appropriates the later conceptualization, building on its articulation in the National Academy of Sciences report:

Learning progressions are anchored at one end by what is known about the concepts and reasoning about children entering school. At the other end, learning progressions are anchored by societal expectations (values) about what society wants middle school [or high school] students to understand about science... Learning progressions propose the *intermediate* understandings between these anchor points that are reasonably coherent networks of ideas and practices and that contribute to building a more mature understanding.

Learning progressions are descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time (e.g. 6 to 8 years). They are crucially dependent on instructional practices if they are to occur” (ibid, p. 214)

Among researchers conceptualizing learning progression as a pathway that might be strategic for students’ knowledge-construction, there is variability in the degree to which they assume that any learning progression could fully capture the actual developmental path of their understandings. I assume that knowledge-development is too varied and complex to closely accord with such a singular, linear form. Once again, my interpretation is aligned with the National Academy of Science report:

Learning progressions recognize that all students will follow not one general sequence, but multiple (often interacting) sequences around important disciplinary-specific core ideas (e.g. atomic-molecular theory, evolutionary theory, cell theory, force and motion). The challenge is to document and describe paths that work, as well as to investigate possible trade-offs in choosing different paths” (ibid, p. 221).

Assumptions of what is “developmentally appropriate” for young children, on the part of teachers, curriculum writers and policy makers, have had a strong influence on what science gets taught in the primary school. The learning progression perspective could have profound implications for rethinking what may be appropriate, within children’s reach. Indeed I view research grounded in a learning progressions perspective is key to rethinking children’s capabilities and to the reform of instruction that much more adequately supports the development of their thinking.

This essay explores the implications of the learning progressions perspective for what may be developmentally appropriate for young children in their science instruction. I first consider conceptualizations of the developmentally appropriate that have long influenced the design of young children’s science instruction and where these fall down, especially in their underestimation of children’s capabilities and unnecessary impoverishment of instructional opportunities. Then I examine both the potential power and substantial challenges of a learning progressions research literature to rethink what is developmentally appropriate.

WHAT'S SO DIFFERENT ABOUT TAKING A LEARNING PROGRESSION PERSPECTIVE ON WHAT'S DEVELOPMENTALLY APPROPRIATE?

Derivation of what is developmentally appropriate from age as a proxy of stage

Schemas for children's science education have tended to view developmental stage or, its proxy, age, as the basis on which to infer what is developmentally appropriate. From this perspective, the scope and sequence in curriculum documents and the cognitive demands at particular grade-bands are designed to correspond with the capabilities children have at different stages. Consider, for example, the conceptualization of the developmentally appropriate in what have been influential science curriculum policy documents in the U.S.:

Students should do science in ways that are *within their developmental capacities*... Describing, grouping, and sorting solid objects and materials is possible early in this grade range... Emphasis in grades K-4 should be on developing observation and description skills and the explanations based on observations [National Research Council, (1996); Emphases added].

Kindergarten through grade 2: In the earliest grades, students make observations, collect and sort things, use tools, and build things. They are, *for their developmental level*, doing science and using technology [American Association for the Advancement of Science, (1993); Emphases added].

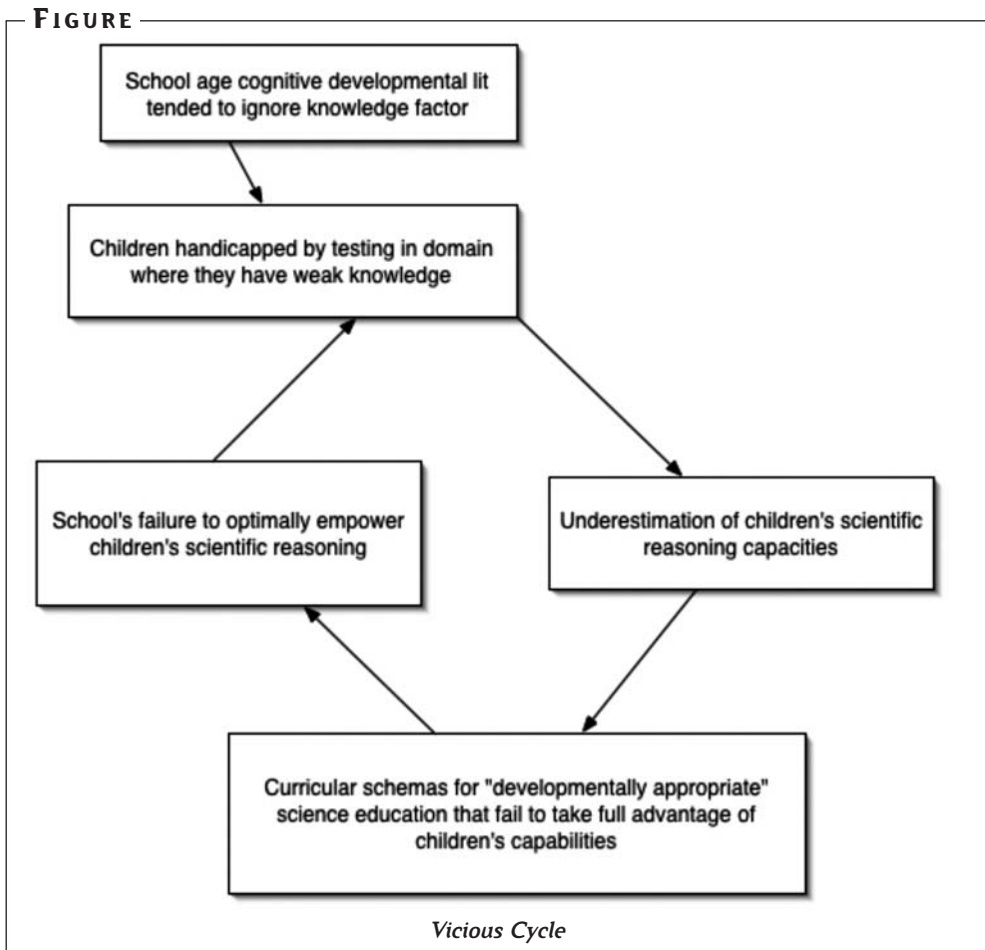
Each of these documents treats developmental stage as laying down constraints within which the curriculum needs to build. There are several fundamental problems with this model of the developmentally appropriate.

First of all, it assumes broad-based consistency in the adequacy of children's thinking within any given grade-band. However a close analysis of the cognitive developmental literature does not support this presumption. In the words of cognitive developmentalist John Flavell (1994), "virtually all contemporary developmentalists agree that cognitive development is not as general stage-like or grand stagelike as Piaget and most of the rest of the field once thought." (p. 574). Furthermore, Piaget himself did not assume children's thinking would reflect the same sophistication across all contexts; for example, identifying familiarity with the objects in whether or not they manifested competence in class inclusions problems (Inhelder & Piaget, 1964). The assumption that children's thinking within broad age-bands can be uniformly characterized, on the basis of common features of their "stage" is simply not supported by the developmental literature.

Second, the goals and scope of the cognitive developmental research make it ill-suited as a basis to infer the limits of what may be developmentally appropriate. The cognitive developmental research literature examines the nature of children’s thinking and how it changes over time largely apart from any intervention. Rarely does it consider capabilities children might achieve under more optimal learning conditions. It is an inappropriate base for considering what children might be able to attain under effective instructional conditions, as with a few notable exceptions this question falls outside the bounds of the discipline.

More subtle, there is reason to suspect that the school-age literature may have frequently underestimated the reasoning capacities that these children do have, even apart from any additional instructional opportunities. If children’s reasoning is investigated in contexts where they have impoverished knowledge, weak reasoning capabilities can be confounded with weak domain knowledge. While researchers in the preschool cognitive developmental literature have tended to be acutely attuned to this challenge in their design of experimental contexts, the school-age cognitive developmental literature has frequently been less so. In this vein, Carey (1985) criticized Piaget for using domains with substantial conceptual knowledge (e.g.; torque or density) in his investigation of children’s capacity to differentiate and systemically coordinate variables (Inhelder & Piaget, 1958). More generally, Brown (1990) identified differential sensitivity to the knowledge factor across the preschool and school-age cognitive developmental research communities as the basis for points of apparent superiority in the reasoning of the preschoolers. We have reason to suspect that the school-age cognitive developmental literature has tended to underestimate children’s reasoning competencies.

I contend that these factors, combined, have led to a vicious cycle perpetuating the underestimation of children’s capabilities and the impoverishment of children’s instructional opportunities. In short, the school-age developmental literature’s failure to fully acknowledge the impact of the knowledge factor on children’s scientific reasoning has resulted in underestimation of the power of children’s thinking. Instructional designers’ reliance on this literature has resulted in their underestimation of children’s scientific reasoning capabilities and, in turn, curricula that fail to take full advantage of children’s capabilities. These curricula fail to optimally empower children’s knowledge, which we know to be critical for the power of their scientific reasoning. Without an understanding of how domain knowledge impacts scientific reasoning, the children’s weak domain-knowledge can feed back into a circular confirmation of weak reasoning in the research laboratory and, given educators reliance on cognitive developmental stages to infer ceilings on children’s capabilities, an apparent rationale for unnecessarily restricted curricular aspirations. The cycle perpetuates impoverishment of instructional opportunity and learning that might well be within children’s reach.



In this vein, the curriculum policy document *Benchmarks for Scientific Literacy* includes a key caveat in its delineation of developmentally-appropriate science curricula. The document describes students' capabilities within each of four grade-bands across K-12. However, in its delineation of the grades 3-5 band (approximately 8-10 years of age), it notes that capabilities and limits may be a function of current instructional opportunities:

Research studies suggest there are some limits on what to expect at this level [grades 3-5] of student intellectual development. One limit is the design of carefully controlled experiments is still beyond most students in the middle grades. Others are that such students confuse theory (explanation) with evidence for it and that they have difficulty making logical inferences. *However, the studies say more about what students of this level do not learn in today's schools*

than what they might possibly learn if instruction were more effective [American Association for Advancement of Science, (1993), p. 10-11, Emphasis added].

I argue that we simply do not know what might be possible under more optimal instructional conditions, particularly under conditions of multi-year learning progressions and corresponding instructional support that more fully capitalize on children’s capabilities.

Developmentally appropriate as an “interplay of maturation, experience and instruction”

In contrast to the classic model of the developmental stages as essentially laying down the lines within which the instructional demands need to fit, an increasingly influential model views the developmentally appropriate as emerging from an interaction of maturation, experience and instruction. In the words of the National Academy of Sciences report:

What children are capable of at a particular age is the result of a complex interplay among maturation, experience, and instruction... What is developmentally appropriate is not a simple function of age or grade, but rather is *largely contingent on prior opportunities to learn* and not some fixed sequence of developmental stages (Duschl et al., 2007).

Although this model has only recently gained prominence in the science education research community, it builds on the seminal work of both Vygotsky and Brown, developmentalists who had deep interests in and theoretical commitments to the influence of instructional scaffolding on children’s competence.

Vygotsky (1978) clearly differentiated a child’s competence without any support from that he or she could achieve with the benefit of instruction. Although Vygotsky framed the significance of the distinction largely as a more sensitive measure of individual children’s development and their capacity for learning rather than its entailments for long-term instructional design, the distinction between competence with and without scaffolding was central to his theorizing.

Brown’s work more closely focused on the implications of the distinction for instructional design and the competence children might be able to eventually achieve. In Brown’s (1997) words:

I rely on establishing a *developmental corridor* within a school. Children remain in this corridor for several years, during which time they delve more deeply into the underlying principles of a domain... Each revisit is based on a deepening

knowledge of that topic, critically dependent on past experience and on the developing knowledge base of the child... Will 10-year-olds with prior experience in the program be capable of acquiring and using domain knowledge of considerably greater complexity than will 10-year-olds in the program for the first time? To the degree that FCL [Fostering a Community of Learners] is successful, I should be mapping a moving target.

Brown's construct of developmental corridor emphasizes the strong influence of instructional opportunities on development and the importance of instruction that systematically builds on and extends children's understandings of core ideas.

From this perspective, although maturation and developmentally-based constraints enter in, to a great degree what children can learn is a function of what they already know and its relation to the current instructional opportunities. A learning progressions approach is a logical entailment of this model of the interplay of development, learning and instruction.

THE CHALLENGES OF A LEARNING PROGRESSIONS PERSPECTIVE

Although there is considerable power in a well-developed learning progressions research literature, I contend that the challenges in pursuing this research genre are also substantial. Analyses of the challenges and the work needed to overcome them also elucidate the fruitfulness of the endeavor, and the particular advancements this work could support for both instructional design and developmental theory. In this sections below, I examine five challenges: a) the design of promising learning progressions within the vast design space of potential progressions; b) identification of cognitive resources relevant to a progression; c) analysis of effort / payoff for particular competencies at different points in the progression; d) attribution of cognitive limitations and achievements; e) coordination and collaboration needed to support the design, utilization, and refinement of the learning progression; and f) absence of straightforward correspondence between a learning progression and trajectories of different children's knowledge-development.

Design of promising learning progressions within the vast design space of potential progressions

If we can think outside the box of how a topic has been traditionally treated across the K-12 curriculum, the design space of how it might be strategically developed is vast. It is vast even assuming the end-point as given, defined by societal and disciplinary expectations about the nature of understandings of the targeted topic that students

should attain by the end of middle or high school. There are multiple ways that a learning progression could tap into the kindergartners’ knowledge base and thereafter build toward the targeted understandings. These choices have profound consequences, as early experiences and instruction function to both open up and constrain the nature of the subsequent learning. To varying degrees, we would expect that each step in the progression to open up some possibilities of conceptual advancements and delay the probable emergence of others.

Testing of the power and limitations of a learning progression is a huge endeavor, requiring considerable resources and time. Thus conjecturing a relatively powerful one is crucial. How can we design learning progressions that are particularly worthy of close study? How can we most fruitfully conceptualize the possibilities of the design space of science learning progressions? How can we capture the relation between the learning progressions and their respective choices and respective trade-offs?

Identification of relevant cognitive resources relevant to a progression

The rich cognitive resources with which young children begin the primary school constitutes one key constraint in the design of relatively powerful multi-year learning progressions. We need to closely examine what understandings and reasoning competencies most children of this age do have that could serve as relevant resources on which to ground the learning progression targeting such core topics as atomic-molecular theory, evolutionary theory, or force and motion. Given these resources, where is a strategic place to begin? There are multiple places that learning progressions sharing a common end point can begin, in correspondence with the different ways the progression aims to capitalize on the resources with which children start school. Nevertheless identification of these resources is challenging in and of itself.

Take, for example, K-12 learning progressions with the end-goal of a robust understanding of evolution. Some competencies that the developmental literature attributes to five year-olds can be easily identified as potentially relevant resources to leverage early on in the progression; e.g. some rudimentary understanding of the distinction between the animate and inanimate, *albeit* with errors of categorization (Hatano, Siegler, Richards, Inagaki, Stavy & Wax, 1993; Richards & Siegler, 1986), and the differentiation of indetermined and determined events (Fay & Klahr, 1996; Kuzmak & Gelman, 1986). However, particularly at this early age-level, other ways of thinking that appear far removed from normative ways of reasoning might also function as potentially relevant resources. For instance, Astuti, Solomon and Carey (2004) conclude that by age five children have developed the assumption that “each species has an underlying internal essence, which is inherited from biological progenitors” (ibid, p. 4). While this assumption fails to acknowledge the variability so fundamental to understanding a species and the process of natural selection, it does reflect some

rudimentary conceptualization of heredity on which instruction could build. Similarly, Keleman, Widdowson, Posner, Brown and Casler (2003) documented the increasing propensity across the preschool years to “view structures as designed for functions” in inferences about animal behavior, a way of thinking they have termed teleo-functional reasoning. While any teleological reasoning will fall short of a biologist’s perspective, the fact that five years-olds reason in these contexts in terms of structure and function can be viewed as a fruitful preconception.

In short, analysis of relevant reasoning resources of children is nontrivial. The choice of which of these resources to use to ground the learning progression and further refine to position the subsequent advancements is challenging, yet consequential for the power of the interim steps the progression as a whole.

Analysis of effort / payoff for particular competencies at different points in the progression

Design of learning progressions needs to be grounded not only on what children *can* achieve at different ages, but also the amount of instructional time and resources that are needed to achieve particular outcomes at that point. Is the outcome worth the expenditure of time and instructional support? Assuming the competence needs to be incorporated at some point in the learning progression, when is it most strategically addressed?

Some capabilities may be within the reach of children of a given age but strategic to delay in the learning progression, as they may be reached much more easily at a subsequent age. Consider, for example, the practice in Sweden of largely delaying reading instruction until children enter compulsory schooling at age seven (Lundberg, 1991) and the huge devotion of instructional resources and time devoted to teaching reading in the US at increasingly early ages. Indeed, schooling for five year olds in the United States is increasingly devoted to fundamentals in the teaching of reading such as phonics (Russell, in press; Shepard & Smith, 1988). In reading, mathematics or science, just because it is possible to design experiences and instruction sufficient for children of a given age to reach a given level of competence does not mean it is strategic to do so. Above and beyond knowledge of the plasticity in children’s capabilities and what it takes for them to achieve different forms of competence, in framing the learning progression we need to consider what is most strategic to support when.

Attribution of cognitive limitation and achievements

The learning progression perspective presumes that children will be able to attain much greater competence than currently achieved, given instruction that takes advantage of the knowledge with which they start school and maximally leverages their

knowledge to build increasingly powerful understandings. The question of how to attribute either newly observed competence or enduring shortcomings is far from straightforward and yet key to the learning progression research enterprise and its entailments for engineering instruction.

Brown, Metz and Campione (1996) argued, “Of considerable theoretical interest to developmental psychologists and of practical interest to designers of science curricula are answers to the question: what, if any forms of knowledge and process are immutable in the face of carefully tailored instruction?”. While existence proofs of children of a particular age manifesting a particular competence reveals it is within their reach, it is insufficient to inform instructional design. In those cases where we do achieve robust competence, to what do we attribute it?

Although extremely difficult to determine, knowledge of the necessary and sufficient conditions to support the competence are much more helpful to instructional designers – and of great interest to developmentalists interested in the interplay of development and context. In an innovation that introduces multiple facets of systematic change, such as Brown and Campione’s *Fostering a Community of Learners*, identification of the conditions sufficient for the success poses daunting challenges. The difficulty is compounded in multi-year interventions, corresponding with multi-year learning progressions (Brown’s, 1997) capitalization on naturally occurring variations in the instruction corresponding with the progression suggests one tactic in this regard).

Attribution of cognitive shortcoming introduces other challenges. When children fall short of understandings targeted in a learning progression, to what do we attribute the shortcoming? Is it a robust developmental constraint for children of this age? Or is the shortcoming attributable to suboptimal learning progression, or at least suboptimal vis à vis this particular understanding? Or is the shortcoming attributable to the instructional opportunities designed to support the learning progression? Differentiating among these possibilities is of great importance, for the action one needs to take: reworking the progression, refining the instruction or simply delaying trying to teach the idea.

Nature of the coordination and collaboration needed to support the design, utilization, and refinement of the learning progression

Learning progressions require that teachers be keenly attentive to children’s understandings and how they may change under conditions of a new instructional history. To the extent to which teaching at prior grade levels has more effectively leveraged their understandings, the children will now be capable of wrestling with more advanced ideas. Consider again Brown’s (1997) description of the “moving target” of the child’s competence, from the perspective of demands on the classroom teacher:

I rely on establishing a *developmental corridor* within a school. Children remain in this corridor for several years, during which time they delve more deeply into the underlying principles of a domain... Each revisit is based on a deepening knowledge of that topic, critically dependent on past experience and on the developing knowledge base of the child... *Will 10-year-olds with prior experience in the (FCL) program be capable of acquiring and using domain knowledge of considerably greater complexity than will 10-year-olds in the program for the first time? To the degree that FCL (Fostering a Community of Learners) is successful, I should be mapping a moving target* (Emphases added).

To take full advantage of students' increased capabilities, teachers need to understand how the understandings with which children now enter their classroom have changed, how these understandings relate to the learning progression, and how they could change their instruction to capitalize on these new capabilities in ways that strategically contributes to advancement on the progression. Any teacher who teaches as they have taught before essentially disrupts the progression.

The implementation of a learning progression is inherently an enterprise of coordination. Cross-grade collaborations in the form of teacher learning communities (e.g. Lehrer & Schauble, 2005; Little, 2003; Little, Hawley & Rollie, 2007; McLaughlin & Talbert, 2001) can support examination of the development of children's understanding vis à vis the learning progression at large and support teachers' rethinking situating of learning that is now possible at their own grade-level. These collaborations could be invaluable in understanding how the instructional history of one's students has changed and the new capabilities it has supported.

In addition to the much needed effective coordination and collaboration among teachers, this research genre requires others as well. Scientists play a key role in the design of the learning progression, supporting the team in parsing key facets of the targeted knowledge and its application in making sense of the natural world. Cognitive developmentists provide expertise in the range of potentially relevant resources on which to build at the beginning and the other parallel developments on which the progression could draw at later points. Experts in instructional design and assessment are also central players in developing the pedagogy and evaluating its outcomes. In short, learning progressions research requires collaboration at the level of the school sites and interdisciplinary teams that design the progression. The coordination and collaboration of all of these groups are crucial for the design, implementation and refinement of the learning progression.

No simple correspondence between a learning progression and trajectory of any child’s learning

Learning progressions are a powerful tool for conceptualizing how to capitalize on the knowledge with which children enter school and build increasingly powerful knowledge, leveraging prior knowledge toward more powerful ways of thinking. These schemas in turn powerfully constrain and shape the focus and sequencing of instruction. Thus we would expect them to have substantial impact on how students’ understandings emerge.

However, for several reasons, it is deeply problematic to assume that children will develop their expertise in straightforward correspondence with the progression. First of all, while the learning progression schema focuses and informs the sequencing of instruction, it does not specify pedagogical practices. Second, even assuming identical instruction, there will always be wide variability in what different children — with different knowledge, abilities, backgrounds, and interests— learn from the same instruction. More fundamental, the research literature closely examining the nature of children’s cognition indicates that it is much more complex, varied and contextually sensitive (e.g. Metz, 1998; Saxe, 1992; Siegler, 2006, 2007) than could possibly be represented — or desirable to represent— in a learning progression.

In conceptualizing the complexity of students’ various trajectories of development and learning vis à vis the instructional opportunities we provide, I find fruitful the parallels that Lehrer, Strom and Confrey (2002) have drawn to analysis of contingencies in biology:

Like evolutionary biologists and practitioners in some other disciplines, we are collectively confronted with the need to account for phenomena that are contingent and historical (Mayr, 1991, 1997)... Rather than corridors or trajectories, we prefer the metaphor of webs of development (Fischer & Bidell, 1998) that emerge in the interactive constitution of design spaces (Dawkins, 1996). In biology, design space refers to resources (i.e., affordances) and adaptive pressures (i.e., constraints) that constitute a landscape for potential growth and development of a population of organisms (e.g., Niklas, 1997). In education, design spaces arise from specification of prospective design elements like the affordances and constraints of tasks or tools, and the adaptive pressures wrought by the goal structures of tasks, teachers’ recruitment, selection and enhancement of student contributions, and the like (Lehrer, Strom & Confrey, 2002, p. 395).

The metaphor of webs of development is particularly powerful for conveying variability in the paths by which different children’s knowledge actually develops and the

consideration of the more nuanced interplay of children's development in interaction with fine-grained features of the learning environment.

The web metaphor — and the nature of the analysis it implies— has less utility for conceptualizing how children's understanding of a topic might develop over a scale of multiple years, the scale needed for the framing and structure of instructional opportunity across children's schooling. Although the web metaphor captures the numerous complex conceptual divergences and convergences that actually occur in relation to the numerous potentially influential facets of a particular learning environment (even within a single point in time), it is not tractable to analyze the interplay of students' thinking and learning environment at this grain size across multiple years of schooling. While it may be useful to conduct some case studies of student' learning at this grain-size at strategically selected points in time, is it not feasible to anticipate students' paths of learning at this grain size, nor is it feasible or even desirable to plan for instruction at this level of complexity. A learning progression — not a web— can serve as powerful tool in rethinking how children might more powerfully construct understandings of key science topics, guide instruction in accordance with the schema, and function as foil in analysis of the paths that children actually traverse under these conditions.

CONCLUSIONS

The idea that content needs to be “developmentally appropriate” has long concerned teachers of young children, science curriculum designers and curriculum policy makers. Ideas about the reasoning or understanding that are developmentally appropriate have frequently been based on children's age, as a proxy for their developmental stage.

This model of the developmentally appropriate falls down on a number of grounds. First of all, it is out of *sinc* with current developmental research, as well as close readings of the original research on which it is purportedly based. Children's thinking cannot be simply characterized by common, universal strengths and weaknesses. Furthermore, children's capabilities and the trajectory of their development is more plastic than the original model assumed. Rather than stage alone, an interaction of maturation, experience, and instructional history and current instructional opportunities (together with individual differences in aptitude, background, interests and motivation) constrain the path and power of children's learning and development.

Given the substantial influence of instructional opportunities, it becomes clear that children's knowledge of the same topic could evolve through many different trajectories, some much more powerful than others. Thus it behooves us to consider what pathways we anticipate would be relatively efficacious and to try to build

instructional opportunities to support learning accordingly. Although we would not expect that children’s actual development would simply align with the trajectory we posit, the learning progression schema constitutes a powerful constraint on how we engineer learning opportunity. The learning progression, in turn, constitutes a foil against which we can compare the pathways children actually traverse as they construct their understandings under instructional conditions designed to support the learning progression. We also need to compare competing learning progressions, in terms of how children construct the targeted understandings, as well as the depth of understanding of the topic that students’ eventually achieve at the endpoint of the schooling informed by the progression.

While students will traverse different paths in developing their understandings under conditions of the same learning progression, so we would expect their paths to vary under *any* instructional history. Indeed we could expect more influence over the actual path of development in a learning progressions-engineered instruction, given its emphasis on systemic knowledge building, keen attention to the moving target of students’ emergent understandings, and instruction that capitalizes on these varied capabilities.

Approaching curriculum design and its revision from the perspective of how it supports a learning progression represents a radical shift from current practices, especially in the United States. International comparisons of science curriculum objectives and materials (e.g. Valverde & Schmidt, 2000) reveal that the US is a relatively extreme case of wide inclusion of many topics and failure to build adequate connections. Equally troubling, a study conducted by the American Association for Advancement of Science found that the big ideas were essentially lost in most science curricula (Roseman, Kesidou, Stern & Caldwell, 1999). Considering science curricula from the perspective of how they could support learning progressions would force a serious attention to rethinking science content within and across grade levels in terms of systematic knowledge-building and a rethinking of what children do know and might know under more optimal learning conditions.

At this point the research literature is inadequate to design optimal learning progressions — particularly ones on a scale of 8 to 12 years of schooling — with any degree of confidence. As we have little knowledge of how the students’ knowledge might develop under other conditions, the pathway we construct becomes in part a product of our imagination, albeit informed and constrained by the extent literature of scientific cognitive development, conceptual change, innovative teaching experiments, etc.

The challenges are nontrivial, but the potential gains are substantial for both instructional design and theorizing about the interaction of development, learning and instruction. Approaching science instruction in terms of how it could more systemically develop students’ understanding constitutes a much needed

transformation, particularly in the United States. We have much to gain from a learning progressions research literature that rigorously compares the relative power and trade-offs of different learning progressions for the same topic. A research literature evaluating competing learning progression and, ideally, competing instructional instantiations of the most promising progressions, has the potential to substantially transform what we find to be “developmentally appropriate” for students of different ages and the pedagogy sufficient for their support.

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