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LEARNING PROGRESSIONS IN SCIENCE EDUCATION: TWO APPROACHES FOR DEVELOPMENT

This paper presents a review of the literature on Learning Progressions. Two approaches to Learning Progressions are identified, named, and presented: the escalated approach and the landscape approach. The first approach constructs a progression in terms of levels, being its extremes the *lower anchor* and *upper anchor*, and having a strong empirical component in the depiction of the progression. The second approach have a stronger analytical component to define and construct the progression, presenting connections among elements of the progression by levels and *threads*, while resting mainly in previous research for validating its analysis of progress on learning. Similarities, main features, and the principal identified rationale of each of the approaches are discussed. Research pieces representing the approaches are briefly shown as examples. Also a discussion on how the differences between the approaches can affect learning progression research, the advantages and disadvantages of using learning progressions, and its potential future implications are presented.

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Introduction

Advances in research about how people learn are increasingly intended to be connected to the practices of teaching (Bransford, Brown, & Cocking, 2000). The work on learning progressions (LeaPs) is a promising line of research because of its potential to build a bridge between research on learning and school classroom practice. Being a relatively new term, many definitions of the term are buzzing around. Regardless the different definitions being found in the literature, LeaPs are a useful tool for describing the steps in people's learning regarding an idea in a specific context. In this paper, a literature review on LeaPs in science education is the basis for recognizing two approaches for developing LeaPs. The purpose of this paper is to contribute to a definition of the term 'Learning Progression' and to present a useful framework to characterize the way in which researchers have used the term.

The literature on conceptual change provides an initial idea of how the term LeaPs has been used in the field. Claesgens, Scalise, Draney, Wilson and Stacy (2002) developed a project called *Living by Chemistry* (LBC) for the secondary school level. This project proposed to frame the 'big ideas' of chemistry for measuring individual's conceptual change over time and informing patterns and characteristics of the conceptual "change space" in the domain. The purpose of the project was to bring conceptual change theory into practice in the teaching and learning of chemistry. The framework was called *Perspectives of Chemists*, and its purpose was to "provide a coherent assessment frame, specified by a set of progress variables, that mediates between the level of detail in secondary science curricula and the contents of applicable standards documents." The authors attribute to this multidimensional construct the capacity of "mapping individual students performance to reveal a picture of conceptual change in the domain over time." The framework is focused on describing the progression of student understanding. This study represents an example of an initial work introducing the idea of LeaPs and providing some of the constitutive elements of them. Another example is provided by Brown (1996, cited in Catley, Lehrer, & Reiser, 2004), who introduced the term *developmental corridor*, or a pathway of learning across school-grades and age. It suggest that early in school ages concepts are introduced and progressively refined, elaborated and extended throughout the school history.

In the next lines, an intended chronological report informs how the term LeaPs has been evolving in the literature. Masters and Forster (1996, as quoted in Hess, 2008) stated LeaPs as "a picture of the path students typically follow as they learn…a description of skills, understandings, and knowledge in the sequence in which they typically develop." Wilson and Berthental (National Research Council, 2006) defined LeaPs as "descriptions of successively more sophisticated ways of thinking about an idea that follow one another as students learn: they lay out in words and example what it means to move toward more expert understanding." Roseman, Caldwell, Gogos & Kuth (2006) describes them as a "sequence of ideas" which goes from primary grades until high school. Smith, Wiser, Anderson and Krajcik (2006) defined LeaPs as "descriptions of successively more sophisticated ways of reasoning within a content domain based on research syntheses and conceptual analyses." Duschl, Schweingruber, and Shouse (NRC, 2007) defined LeaPs as "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)." Stevens, Shin, Delgado, Krajcik, and Pellegrino (2007) defined LeaPs as "a strategic sequencing that promotes both branching out and forming connections between ideas related to a core scientific concept." Flowers, Browder, Wakeman, & Karvonen (2007, cited by Hess, 2008) define progress as "a description of students moving from generalizing their responses across people or setting to generalizing their understanding of concepts." Other similar definitions are provided by Merrit, Krajcik, and Shwartz (2008), LeaPs are "increasingly sophisticated ideas" that comes from simple to complex understanding; and by Mohan, Chen, and Anderson (2008), LeaPs are ways of thinking that follow one another advancing to higher grades of sophistication. Alonzo and Steedle (2008) defined LeaPs as "ordered descriptions of students' understanding of a given concept."

The definitions imply the word *progression,* that is an underlying learning sequence that increases in sophistication of thinking, whether advancing toward expert knowledge or generalizing conceptual understandings. Common features of LPs are: they are research-based accounts of how learning typically develops; imply a sequential increment in defined levels (bands) of learning, being the extreme levels the "anchors" (Mohan et al., 2008); need assessments in order to illustrate learning; occur throughout a defined time span; and are framed by 'big ideas' or domains that interconnects elements from different disciplinary sources. Another implicit remark can be made regarding the context in which they occur, for some authors the definition involves the school or classroom setting (Masters & Foster, 2006; Roseman et al., 2006; Flowers et al., 2007; Alonso & Steedle, 2008), whereas for others it does not (Anderson & Krajcik, 2006; Duschl et al., 2007; Stevens et al.; Merrit et al., 2008; Mohan et al., 2008).

An operational definition of LeaPs that will be used in this paper considers the elements described in the paragraphs above. LeaPs are the description of the typical successive and interconnected steps in a person's thinking skills and knowledge that start from simple to complex understandings, advancing toward more sophisticated ways of thinking. They are flexible, research-based, and occur in a defined time span and in a specific and defined context within a specific topic or content domain.

Despite the apparent convergence in its definition, researchers use different approaches for developing LeaPs. The literature suggests two approaches to the process of developing LeaPs. On the one hand an approach with a strong empirical component; on the other hand another with a strong analytical or rational component. I have called these approaches the ‘escalated’ and the ‘landscape’ approach. Below, both approaches are presented, providing examples of research pieces as illustrations, and briefly discussing their design process. Then, a general discussion on the differences and their implications for research is presented, as well as advantages, disadvantages and future directions of the topic. Additionally, an example of a “mixed” approach is briefly discussed.

Two Approaches for Learning Progressions

As said above, two design trends for LeaPs can be identified, whether by the process of constructing them or because of the final features that the sketched progression presents. In the following sections, both approaches to LeaPs and their main features are described: the escalated approach and the landscape approach.

Escalated Approach to Learning Progressions

The term *escalated* was constructed for the purpose of this paper. It uses the idea of escalation as advancing or raising another to higher levels. In addition, the term escalation also refers to an increase in intensity, as in an escalating conflict. In the theory of conceptual change, learning can be triggered when a cognitive discrepancy (conflict) exists between what is perceived (known) about natural phenomena and the scientific explanation of those phenomena (Driver, Asoko, Leach, Mortimer, and Scott, 1994). Thus, the term escalation can also refer to the increasing cognitive conflict that can trigger changes in conceptual understanding.

The escalated approach to developing LeaPs is to define mostly a linear, escalating description of students’ understandings about a topic over a time span, from eight weeks (Merri et al., 2008) to eleven school years (Mohan et al., 2008). It has a set of levels, with the extremes named *Lower* and *Upper* A*nchors* (Mohan et al.., 2008). Between these anchors are one or more *intermediate levels*. Transition between levels is based on evidence that accounts for *learning performances*. All of the LeaPs using this approach frame a main domain or *Big Idea* –a powerful way of thinking about the world (Smith et al., 2006). One important feature of the escalated approach is its initial research-based analytical component that hypothesizes the progression, followed by a strong empirical base to trace the development of students’ ideas. The following paragraphs describe some examples of research pieces that can fit into this model.

Smith et al. (2006) detailed the process of building a LP for matter and atomic-molecular theory. Big ideas, in this work, were organized around three key questions a) what are things made of? b) what changes and what stays the same?, and c) how do we know? The big ideas have two parts, one likely to be developed in elementary school and the other one for middle and high school. Six big ideas responding each question are: a1) Matter and material kinds, a2) Atomic-molecular account of matter and material kinds; b1) Conservation and transformation of matter

Table 1.

Questions associated with ‘big ideas’ as described by Smith et al. (2006)

Questions	Associated big idea for elementary school	Associated big idea for middle and high school
a. What are things made of?	a1. Matter and material kinds	a2. Atomic-molecular account of matter and material kinds
b. What changes and what stays the same?	b1. Conservation and transformation of matter and material kinds.	b2. Atomic-molecular explanation of conservation of matter and material kinds
c. How do we know?	c1. Epistemology	c2. Epistemology of the atomic-molecular theory

and material kinds, b2) Atomic-molecular explanation of conservation of matter and material kinds; c1) Epistemology, c2) epistemology of the atomic-molecular theory (see table 1 for clarity). For every big idea they defined components and three levels or ranges that will account for the increasingly sophisticated ways of thinking about those components. The ranges match a group of school grade level bands, the first ranges from K to 2nd grade, the second from 3rd to 5th grade, and the third from 6th to 8th grade. For determining what learning performances are expected as evidence of learning, the authors drew the progression based on existing research about students' misconceptions regarding the topic. The authors acknowledge that standards are mostly brief statements of propositional knowledge rather than a source of operational definitions of understandings, which need to be developed for creating assessments. They claim that research on learning can be used as a foundational strategy for developing elaborated standards, including in this strategy "a) organizing standards around 'big ideas', b) connecting standards to empirical evidence about children's learning, and c) connecting children's knowledge and practices." 'Big ideas' should be a powerful way of thinking about the world—being central to their discipline—, and should structure a LeaP —or be understood in progressively more sophisticated ways as students gain cognitive abilities—. They also direct attention to some themes about LeaPs, stating that LeaPs depend on instruction; however are not developmentally inevitable; that there is no single or "correct" order in LeaPs, and that the pathway could be influenced by previous and current instruction, and individual differences; learning takes place in multiple interconnected and simultaneous ways; and all the suggested LeaPs are inferential and hypothetical.

Mohan, Chen, and Anderson (2008) worked on LeaPs of students' understanding about Carbon Cycling in Socio-ecological systems. Their work is part of a bigger project on environmental literacy, having developed LeaPs for water cycling, biodiversity in environmental systems, and for practices in environmentally responsible citizenship (Anderson, 2008). The study was a three-year research designed to capture how students advance in their understanding about carbon cycling and climate change when taking required science courses from upper elementary through high school. To accomplish their purpose, the researchers developed an iterative method which started with the development of an initial hypothetical learning progression that defined two extremes, the *Upper* and *Lower Anchors*, and its intermediate *transitional levels*. The Lower Anchor is defined as what is known about students' reasoning in specific concepts when entering school. The Upper Anchor is defined as the expectations that society has (e.g. science standards) about students' knowledge and understandings when they finish formal education, meaning high school or college. After having defined their framework and sketched progression, the researchers developed assessment instruments and apply them to students. Using the results of those assessments and clinical interviews, the investigators revised the progression they have developed and modified it, leading to new assessment instruments and modifications of the described progression. Then they repeated the cycle completing three of them after their initial pilot work. The participants of the study were upper elementary, middle and high school teachers and students from three different locations: Michigan, Korea and California. In Michigan they had 9 teachers and 280 students from grades 4^{th}, 6^{th} 7^{th}, 8^{th}, and high school. Eighteen high school students also participated in clinical interviews. In Korea the participants were one teacher and 20 American sixth graders. In California 14 middle school students were interviewed.

Merrit et al. (2008) proposes a LeaP regarding the Particle Model of Matter for sixth graders. The purpose of the study was to describe the changes in students understanding of the Particle Model of Matter during the implementation of an eight-week model-based curriculum. The researchers started by developing a learning progression according to prior research and science logic. Pre- and post- tests were designed in order to monitor students' performance. They continued by applying the eight-week unit called "How can I smell things from distance," which is part of the *Investigating and Questioning our World through Science and Technology (IQWST)* project (Krajcik, McNeill & Reiser, 2008), and gathering data about a) how students construct and change models of the nature of matter during that time span, and b) activity sheets they could collect (43 total). The next step was analyzing students' pre- and post- tests, the 43 activity sheets, and the models constructed by students at three different moments during the development of the unit: in lessons one, five and fifteenth. The participants of the study where two teacher's sixth grade classes from a U.S. Midwestern school district in a large Midwestern college town (total 57 students).

In each of these cases an initial research-based LeaP was sketched framed under a big idea, defining lower and upper anchors, and intermediate levels. Then, instruments for assessment were developed for gathering evidence of learning. Data from assessments were used to refine the initial sketch of the LeaP. This cycling process is more useful to inform students learning without considering standards sequence aims as a limitation. In consequence, it would inform about how students demonstrate their progressing level of understanding in their contexts of learning. This process was also put in practice by Alonso and Steedle (2008), who worked developing a LeaP in force and motion with special focus on the use of ordered multiple choice items and open ended items for assessment. They worked using the iterative process described above: starting with a preliminary research based learning progression, creating assessment items to evaluate students' levels in the progression, administering those items to students, and revising the progression based on the students' responses. Figure 1 shows a graphical representation of the iterative process.

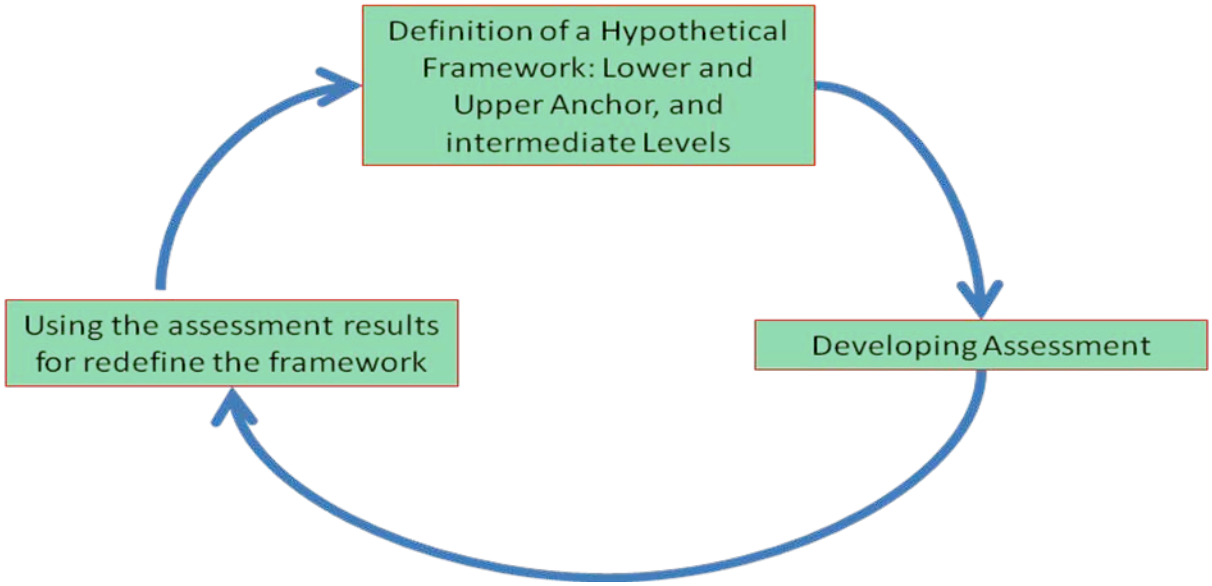

Figure 1. Iterative process focused on description of students learning progress according to the escalated model of LeaPs.

Looking across the papers presented in this section, an evolving process can be seen. First, Smith et al. (2006) used existing research on student learning for building their LeaP, while acknowledging the limitations and flexibility of them. Second, Mohan et al. (2008) moved forward, using their own assessment instruments to reveal what the evidence that depict the LeaP is. Third, Merrit et al. (2008), while in a shorter time span, designed their LeaP in the context of a teaching experiment. Finally, Alonso and Steedle (2008) depicted a clear and explicit example on how to create assessment linked to the iterative process that allows creating LeaPs using the escalated approach. Figure 2 provides a visual representation of the resulting approach.

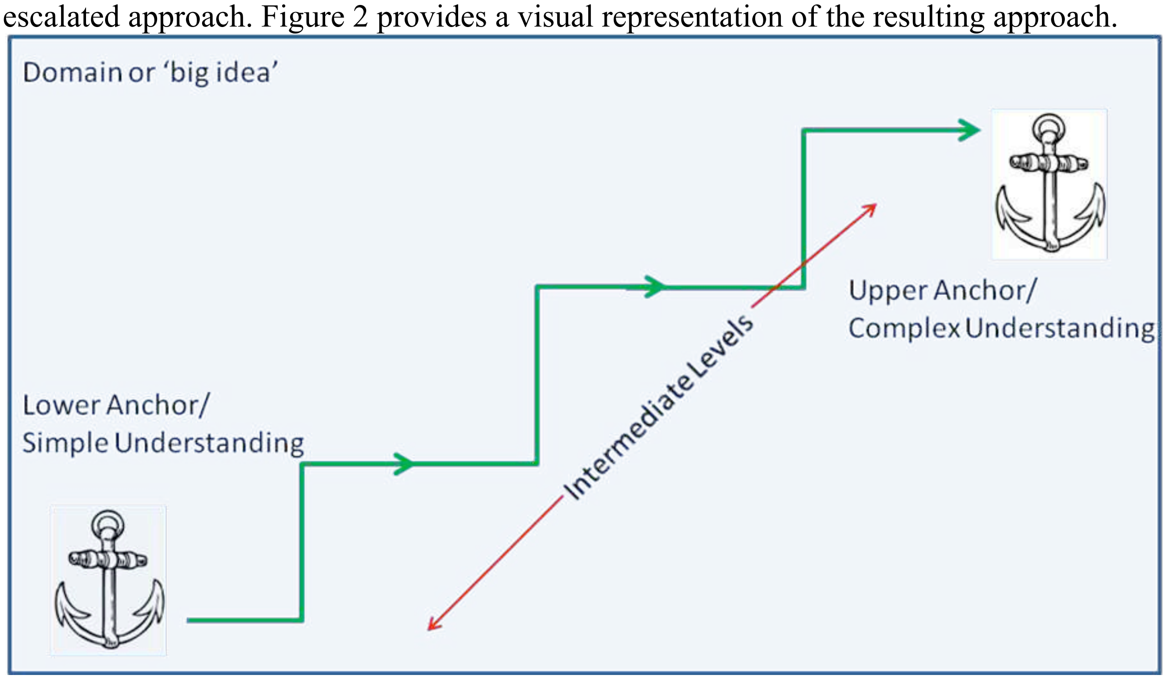

Figure 2. Visual Representation of the escalated approach to Learning Progressions.

Landscape Approach to Learning Progressions

The word 'landscape,' as the previous term escalated, was constructed in order to describe another approach to LeaPs development. The idea behind this term is that a landscape provides a rich and connected set of elements that will shape a general situation. At this point it is useful to stress that a main reason for the distinction of both approaches is their process for generating LeaPs and the product they lead to.

The landscape approach preserves the framework of having standards or societal expectations organized around big ideas, which would cluster standards and allow a coherent development of core concepts. *Project 2061's Atlas of Science Literacy* (AAAS, 2001 & 2006) is a centerpiece for the development of the work that fits into the landscape approach. Different from the escalated approach, the landscape approach presents connections among different content domains by describing threads that relate phenomena, observations, or skill sets. These threads show connections necessary for students to advance to higher levels or bands of learning. This approach has a strong analytical component for developing the progression, and the work that has been done suggest that research is intended to validate how the progression should go, and detect elements to support further learning in that direction. Below, some examples of LeaPs using the landscape approach are presented

Catley et al. (2004) reported on the construction of a learning progression for understanding of evolution, identifying 'big ideas' or core evolutionary concepts. They were: diversity, structure-function, ecology/interrelationships, variation, change, geological processes, forms of argument, and mathematical tools. As seen, the concepts look across different content-domains. The authors suggested that focusing standards around 'big ideas'—central conceptual structures—permits the elaboration of clusters of standards adhering to those big ideas rather than isolated standards. After identifying the core concepts, the authors looked for research that reports on students' learning regarding those core concepts. Finally they developed a 'cartography' that charts the development of the key concepts and the learning performances associated to their progression across grade level bands.

As said above, the American Association for the Advancement of Science has developed *Project 2061*, and as part of it they have focused on creating connections between science standards and the progression of learning. Roseman et al. (2006) depicted a learning progression linking biology and chemistry in the topic called Molecular Basis of Heredity using *Project 2061'*s Atlas (AAAS, 2001). The study was intended to improve the coherence of the progression presented in the AAAS Atlas regarding molecular basis of heredity by reordering the ideas presented in it. In doing so, the researchers have worked in four stages. First they defined the learning goals embedded in the ideas that composed the progression. Second, they clarified the meaning of every idea. Third, they identified commonly hold ideas that students have using both bibliography and interviews and questions to students. Fourth, in a parallel work, the researchers a) developed assessment for monitoring students' learning paths, and b) identified phenomena that are intended to help students learn.

In a work dealing with a similar topic, Duncan, Rogat and Yarden (2007) purposed to describe progressive levels of understanding for core concepts in modern genetics. They targeted students from grades 5^{th} to 10^{th}, drawing students learning from literature reports. For creating the LeaP they used standards and previous work on genetics, instruction and materials, previous progressions or sequences of learning, and students' prior knowledge. The researchers identified eight core ideas and organized them in two questions: how do genes influence how we, and other organisms, look and function? Why do we vary in how we, and other organisms, look and function? The final product describes what students should be able to do at different school grades.

Hess, (2008) in the context of assessment proposed the following iterative process to develop LeaPs, based on the so called *Interrelated Guiding Principles of LeaPs.* First, a literature review on cognitive, content specific, and action research should be done. Second, connecting the content and processes by finding its connection threads will allow going to the third step, which is to articulate the landscape. Fourth, well developed formative assessment in different forms will help monitor students understanding and refine or validate the LeaP. Figure 3 shows the graphic representation of the process.

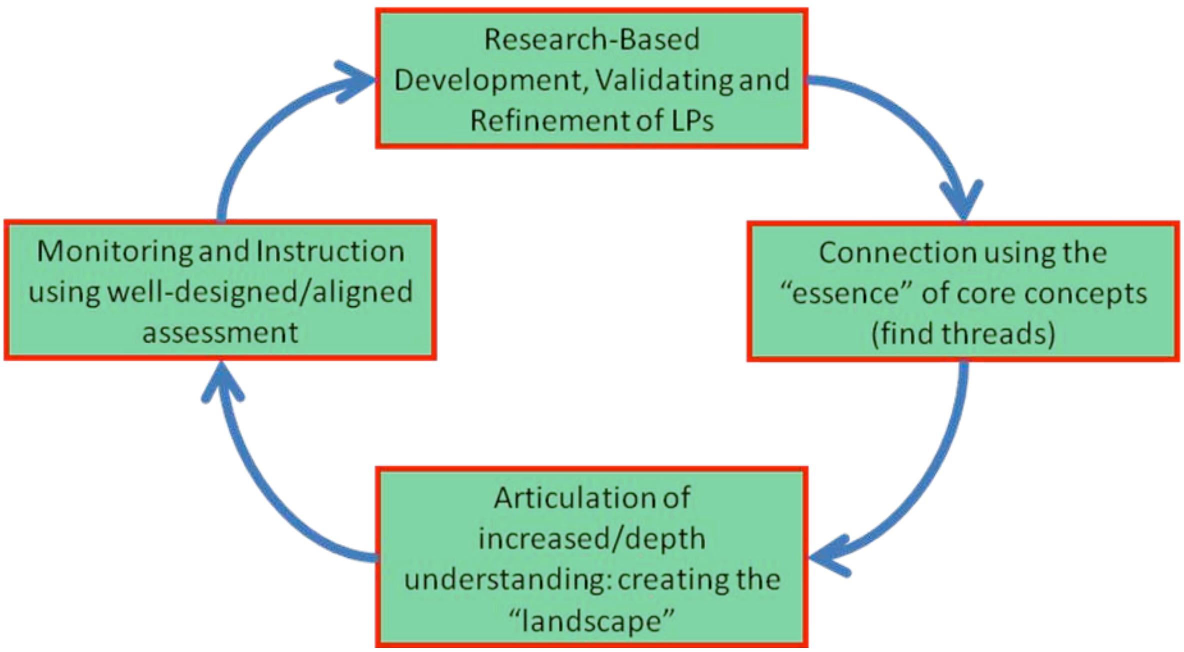

Figure 3. Iterative process focused on developing, refining and validating LeaPs.

This iterative process in the landscape approach is different from the one in the escalated approach because its usefulness relies more on the validation of the learning sequence or progression proposed. It emphasizes the idea of using LeaPs for instruction and assessment purposes more than just describing students' knowledge.

Summarizing, the landscape approach begins by defining the knowledge and practices students need to know and manage, and then identifying the supporting ideas that will help students reach the desired level of understanding. After that, the ideas (content and skills) are related using threads that create a web representing the progression. The evidence obtained is gathered mainly to support the organization of the progression and to monitor students' progress within it. As seen in the examples, the landscape approach preserves the framework of having standards or societal expectations organized around big ideas that would cluster standards and allow a coherent development of the core concepts. The connection among different content-domains are linked between threads that relate phenomena or represent a skill set needed in order to advance to higher levels or bands. Learning performances are present in the approach as a crucial part for describing the levels or bands. Figure 4 shows a graphic representation of the final progression that could result from the landscape approach to LeaPs.

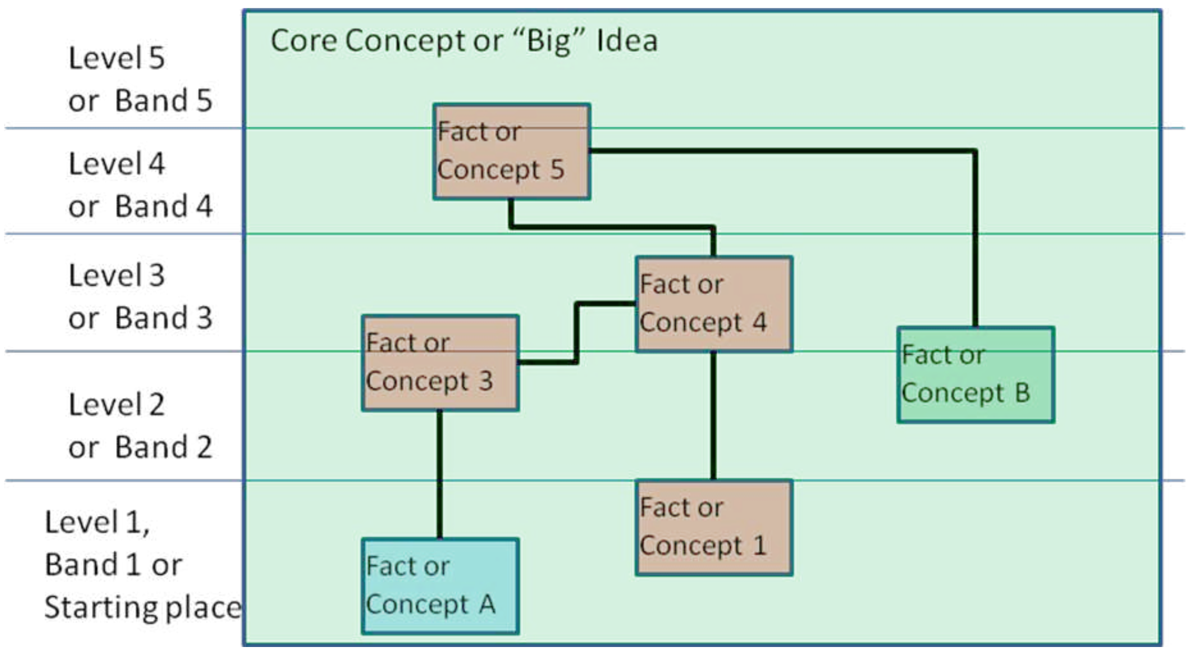

Figure 4. Visual representation of the landscape approach to Learning Progressions.

Other Considerations Regarding Learning Progressions

The purpose of this section is to provide additional information about the use of the term LeaP. First, an example of what could be considered a "mixed" approach to LeaPs will be presented. Second, a recent report on the development of a LeaP will be shown because of its particular focus on patterns of progression. Then, a brief discussion on associated terms regarding LeaPs will be provided. Afterwards, a discussion on the use of the term "progress map" is presented.

"Mixed" Approach to Learning Progressions

Stevens et al. (2007) report on their "work in progress" towards developing and validating a sequence behind a LP for students' understanding of the nature of matter as it relates to nanoscale science. The work informs both the curricular organization and instruction by providing insight into how students connect ideas from other science disciplines with a core scientific concept. The authors conducted and reported semi-structured interviews with middle school, high school, and undergraduate students to measure their conceptual understanding of the structure, properties and behavior of matter in order to test the aspects of a hypothetical progression. The interviews considered some tasks that were gathered as evidence. Also the elaboration of models of matter was used as evidence. They rated and coded students' ideas regarding different models or concepts that are directly related to the understanding of the nature of matter as also relate to nanoscience. As a product they created a LeaP that consisted on levels and singular ideas representing students' understanding. The singular ideas were interconnected in a tridimensional network that has threads connecting topic-topic ideas and level-level ideas.

The final product is a progression that looks like one produced from a landscape approach. However, it has elements that allow describing how students connect the specific content or knowledge to understand the particle model of nature more than validating the hypothetical progression, increasing the empirical component of the LeaP development. For that reason, the approach taken by the researchers on this project is called here ‘mixed’ approach.

Patterns in Learning Progressions

In a recent work, Tai and Sheppard (2009) described their work on developing a LeaP for students’ understanding of combustion. They used a cross-age design and a questionnaire having knowledge and cognitive abilities questions applied to 1,237 Taiwanese students from grades sixth trough twelve and university students. Based on the responses, the researchers found six patterns of progression in students’ understanding of combustion, called 1) gradual increase, 2) stepwise increase, 3) persistent misunderstanding, 4) early misunderstanding, 5) varied misunderstanding, and 6) reverse-V understanding. The patterns are the interpretation of the graphics resulting from plotting students’ grade level against percentage of correct answers in the questionnaire. The researchers focus on analyzing the age-related and non-age-related patterns, but the authors do not present a LeaP. Furthermore, they use the term *conceptual trajectories* as synonym to LeaPs. This last point is discussed in the next section.

Associated Terms in Learning Progressions

LeaPs development implies assessment design in order to obtain evidence of learning. The term *learning performance* has been mentioned in this paper and associated to LeaPs, and its meaning involves “types of tasks or activities appropriate for classroom or assessment settings through which students enact their understanding of big ideas and scientific practices” (Smith et al., 2006). Another term that can be associated in this topic is *progress variables*, which “summarize the important strands of student development that are intended by the curriculum developers” (Wilson & Draney, 1999) or “define the intended content of a specific curriculum up to a level of detail that would allow, say, biweekly tracking of student progress through the curriculum” (Wilson & Sloane, 2000). It is important to consider those elements very carefully when designing a LeaP because they are central for defining students learning as outcomes that can be informed from classroom teaching formative assessment practices; therefore being helpful for linking LeaPs and teaching practices.

Conceptual trajectory is another term, used by Driver, Leach, Scott, & Wood Robinson (1994) in reference to cross-age curricular studies. Drawing from an evolutionary perspective, learning in a domain can be seen as a “progress through a sequence of conceptualizations which portray significant steps in the way knowledge within the given domain is represented” (Driver et al., p. 85) which is called *conceptual trajectory*. In Driver et al.’s words, the conceptual trajectory does not describe individual pathway in reasoning, but indicate broadly “the nature of the changes in reasoning which may be demonstrated by students in particular curricular settings.” This term, as said before, has also been used as synonym with LeaPs (Tai & Sheppard, 2009), which may led to confusion about how to use the term LeaPs. However, there is some research associated with the term, which may be worth to compare and contrast to the increasing body of research that has been associated with LeaPs.

Progress Maps and Learning Progressions

It was mentioned some sections above that the landscape approach to LeaPs involves a process that was intended to validate a progression more than describe students' understanding over time. This emphasis is probably linked to the development of *progress maps*. The maps, aligned with curricula standards, would define what students should know and be able to do, so they are not strictly descriptions of what students actually develop in the contexts of classrooms. LeaPs are intended to be a description of what really the learning sequence (rational or empirical) is towards more sophisticated ways of knowledge, whereas progress maps are intended to describe how to illustrate an intended sequence of learning.

Progress maps is a term that provokes confusion because of its relation to the topic. Masters and Forster (1996) discussing on developmental assessment stated that "a progress map describes the nature of development in an area of learning and thus serves as a frame of reference for monitoring individual growth." Pellegrino, Chudowsky and Glacer (2001) understand progress maps as models of learning which intention is to serve as a basis for the design of both large scale and classroom assessment. "Progress maps provides a description of skills, understandings, and knowledge in the sequence in which they typically develop—a picture of what it means to improve over time in an area learning" (Pellegrino et al., p. 190). Wilson and Bertenthal (NRC, 2006) define a progress map as "a continuum that describes in broad strokes a possible path for the development of science understanding over the course of 13 years of education. It can also be used for tracking and reporting students' progress in ways that are similar to those used by physicians or parents for tracking changes in height and weight over time" (p. 78).

The similarities between the two terms, 'Learning Progressions' and 'Progress Maps,' are evident and create confusion about the terminology that needs to be addressed. For the case of this paper, a main difference would be made between what is understood of learning progressions and progress maps: learning progressions are descriptions of learning as it typically develops while progress maps are descriptions of what is the learning that is expected to be developed among students. In other words, LeaPs answers the questions about what is the learning path students (typically) follow, whereas progress maps answers the question about what is the learning path students should follow (according to a major curriculum or standards development).

The difference (and confusion) stated above has been confirmed in at least one practical example. The Chilean government asked the Australian Council for Educational Research for a consultancy in order to develop 'performance standards' (Forster, 2007). The products of that consultancy were the 'Progress Maps or Learning' (MINEDUC, n.d.). Even though the underlying assumption about progress map was that it "describes the knowledge, skills and understandings developed by students within a learning area in the sequence in which these typically or normally develop," the actual progress maps describes the sequence students should follow according to the Chilean curricula standards. The Chilean progress maps are still under development.

Discussion

The convergence regarding a definition of LeaPs does not provide a common view in the design of a progression, which can constitute a conflict among researchers and the way LeaPs are developed. Researchers acknowledge the impact that LeaPs can have in curriculum development and teaching practices (Merrit et al., 2008; Catley et al., 2004; Mohan et al., 2008, Duncan et al., 2007), although different approaches could also result in different impacts of LeaPs. Four differences among the escalated and landscape approaches that could impact research in LeaPs are: the starting point for the progression, the assessment design, the flexibility of the produced LeaP, and how they answer the question: what progresses in a LeaP? Also, a general discussion on the advantages and disadvantages of LeaPs will be presented.

First, according to what has been examined in this paper, the escalated approach presents a more exploratory nature about how learning evolves in students, prioritizing classroom contexts and using evidence of student learning to inform the developing learning progression. Different from the escalated approach, the landscape approach starts by developing the logical LeaP, and then mostly validating the progression based on student data (using interviews, assessment, or bibliography). The escalated approach offers a more useful way to characterize students' learning progressions within the context of the current curriculum, whereas the landscape approach is more useful to characterize an expected rational progression in learning.

Second, developing LeaPs involves assessment design in order to obtain evidence of learning. From the different approaches, it could be important to determine what grain size will be the optimal for gathering learning evidence. Again, the first step in the development of LeaPs could define what assessment will be more suitable. In the escalated model, for example, a fine grain assessment could be more illustrative of learning because it will be focused on individualized learning, which is useful for an approach that starts on the classroom setting. Within the landscape approach a bigger grain size would be more illustrative of the learning path because it provides evidence across grades and content-domains, giving to the approach an opportunity to link expectations to standards development. Assessment is central for intermediate levels to be defined and characterized. The grain sizes to which devote the LeaPs development efforts will also play a role in the applicability of the progression. Whereas a bigger grain size could inform curriculum and standards development, a finer grain size could help enhance teaching practices.

A third point I would like to discuss is the likeness of the progression of being flexible. The definition of LeaPs provided in this paper refers to flexibility, which is framed under two presuppositions. First is the flexibility of the process of creating a LeaP, which in both approaches offers the possibility of refinement. The second presupposition is the accommodation of LeaPs to cultural and contextual differences among students. However, the degree of flexibility varies. The escalated approach would be more flexible because of its descriptive nature and the landscape approach would offer less flexibility because of it more expectations-guided nature.

The differences among both approaches, taken to an extreme, could also portray differences in what progresses in a LeaP. On the one hand, an extreme escalated approach with a strong empirical component could portray a progression on students' learning just based on the evidence possible to gather and the conversations possible to have in a research setting. Under that assumption, this approach can provide a progression on students' learning. On the other hand, an extreme landscape approach with a strong analytical component may portray how ideas are interconnected and progress logically. Assuming that, what progress are the logical development of concepts or ideas, and not the actual understanding of those concepts ideas. This is not to say that the landscape approach has less value in order to create LeaPs, but is a different manner to look at how scientific ideas develop.

Being a promising construct, learning progressions have the advantage of informing and embedding a collection of elements that interrelate in the classroom context, such as individual and social cognitive development, formative assessment, curriculum development, and instructional approaches. Being a research-based description, it also permits the link between research in (science) education and classroom practice in a more integral way, informing about cross-cultural similarities in the progression, as well as differences.

However the above, it has the disadvantage of being a new line of research with different interpretations. Schweingruber (2006) points several questions regarding Smith et al. (2006) study: "How to select the big ideas? How much does instruction matter? What the course students would follow in the absence of adequate instruction is? Are all learning performances equally important for later learning? What kinds of knowledge and skills do individual items tap into?" These questions represent the probable paths that LeaPs researchers will try to answer in order to strengthen the field and its applicability to classroom practice. Another disadvantage pointed by Schweingruber is the complex scenario that arises from uneven research base on children's learning. Regarding that complexity, another point is necessary to consider. Different frameworks have not been included in the discussion of LeaPs, for example the *Funds of Knowledge* framework (Gonzalez, Moll & Amanti, 2005), which provides a more complex view about how students' learning occurs in acknowledgment of the quotidian resources they have available at their households. If we agree on a descriptive nature of LeaPs, the idea of fitting students into "boxed" levels in a progression may seem awkward to researchers that work under the Funds of Knowledge framework. The complexity of learning paths arising from looking at learning from Funds of Knowledge lenses may portray LeaPs as fixed and then diminish its potential descriptive quality.

The Future: Possible Impacts of Learning Progressions

Learning Progression could impact educational world of research, practice and policy in different manners.

In research the current developed LeaPs could be used for testing teaching experiments in order to determine what kind of teaching approaches, lessons, or experiences are the most effective to move students learning, as informed by LeaPs design, towards more sophisticated ways of thinking. Cross cultural research could be developed in order to inform differences and similarities among the same LeaPs in different contexts. Mohan et al. (2008) proposed the Learning Progression hypothesis, or "the optimism that, in some content domains at least, the base of research on science learning is reaching the point where it may be possible to bridge the gap—to develop larger-scale frameworks that meet research-based standards for theoretical and empirical validation." They attribute testing this hypothesis an implication of the learning progression research development. Another point necessary to draw upon is the necessary conversation among researchers that have used the term Learning Progression, as well as others that may have similar or different uses and conceptions. For example, the use of the term conceptual trajectories (Driver et al., 1994), discussed above, maintains similarities with the common features of LeaPs depicted here. A quote from their paper says:

> [W]ithin many specific domains in science, characteristic conceptual trajectories in students' reasoning can be identified. It is suggested here that knowledge of these trajectories can be drawn on planning and sequencing the curriculum so that instructional materials can interact with and address the conceptions that students are likely to have at different points in their schooling. (p. 85)

For classroom practice, it could be predicted that LeaPs development will create a database of classroom assessment instruments that will be aligned to learning performances that inform students' "location" in the progression. If research advances to inform what teaching approaches are most effective in levering students' understandings, it would be beneficial for teaching practice, teacher training, and for the development of curricula. Kennedy, Brown, Draney, and Wilson (2005) reported that learning goals, instruction, and assessment activities can be aligned through the use of progress variables. That finding could be important for current classroom assessment practices because learning goals could be defined by the development of LeaPs. It also could lead to help teachers use students' evidence of understanding a given concept to make instructional decisions (Alonzo & Steedle 2008).

Regarding educational policy, the LeaPs are powerful for re-envisioning standards, large scale and classroom assessment, curricula, and instruction grounded in current research on science learning (Schweingruber, 2006). Developing future standards based on LeaPs could give a more accurate account about what research says regarding students learning and how that links with the expectations posed by societal institutions. For example, Krajcik, Shin, Stevens, and Short (2009) have proposed the necessary requirements in order to link LeaPs to inform K-12 coherent curriculum development. In another example, progress maps in Chile, despite their alignment with the definition of LeaPs, could be taken as an initial effort in order to promote a shifting toward more research-based classroom practice.

Conclusion

Learning Progressions are descriptions of the sequence of learning as typically develop towards more sophisticated ways of thinking during a defined time span, context and framed topic. Despite the apparent convergence toward a common definition of LPs, there seems to be two lines or approaches for development of a learning progression present in the literature: the escalated and the landscape approach. Both approaches give an account of LeaPs, however they consider different starting points. Differences between the two approaches could impact the way LeaPs informs students' learning, the development and use of assessment, and the flexibility of the design. LeaPs are a promising line of research that could influence educational research, classroom practices and educational policy, but that also needs to be a topic of more conversations among researchers in order to agree on what constitutes LeaPs and how to include different frameworks of learning in their discussion.

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APPENDIX

Suggested Websites

American Association for the Advancement of Science. Project 2061 Connections. http://www.project2061.org/publications/2061Connections/

American Association for the Advancement of Science Project 2061, Michigan State University, Northwestern University, University of Michigan. Center for Curriculum Materials in Science. http://www.sciencematerialscenter.org/

Berkeley Education & Assessment Research Center. University of California Berkeley. http://bearcenter.berkeley.edu/

Center for Highly Interactive Classrooms, Curricula & Computing in Education. University of Michigan. http://hi-ce.org/

Environmental Literacy. Michigan State University. http://edr1.educ.msu.edu/EnvironmentalLit/

The National Academies, Board on Testing and Assessment, Center for Education. http://www7.nationalacademies.org/bota/State_Science_Assessment_Commissioned_Papers.html

The National Center for the Improvement of Educational Assessment. http://www.nciea.org/