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Learning progressions: An overview and how-to guide for researchers in physics education

I. Testa(1), S. Galano(1), U. Scotti di Uccio(1), I. Marzoli(2), G. Giuliana(2), D. Catena(3), S. Leccia(4) and E. Puddu(4)

(1) *Università di Napoli Federico II - Napoli, Italy*
(2) *Scuola di Scienze e Tecnologie, Università di Camerino - Camerino, Italy*
(3) *Università di Udine - Udine, Italy*
(4) *INAF OACN - Napoli, Italy*

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Summary. — Learning progressions are a well established model in science education research to represent the learning process. It lies at the heart of the learning progressions the idea that students develop their knowledge of a subject from naïve conceptions and, through a series of intermediate stages of increasingly sophisticated understanding, come to master a scientifically correct body of knowledge. Starting from a learning progression, it is possible to develop entire curricula and large-scale evaluation tools based on empirical data. We will present a review of the literature on learning progressions and discuss possible implications for research in physics education and teaching practice.

1. – Introduction

In the early years of the twenty-first century, the critical analysis of school curricula in the United States and in the United Kingdom revealed that they were extremely fragmented, composed of learning units mostly unrelated to each other [1-3] and, therefore, unsuitable for promoting meaningful learning [4]. To overcome this issue, action was taken with the involvement of several researchers in the fields of education, psychology and pedagogy. The commitment of researchers and institutions led to the publication of the *Framework for K-12 Science Education* [5, 6] and the *Next Generation Science Standards* [7, 8], which represent a synthesis of what students should learn in terms of contents, skills and competencies to master the knowledge needed to face future scientific and technological challenges. In this context, the concept of learning progression has been introduced in educational research as a key tool to ensure the horizontal and vertical coherence of the new curricula, particularly in the field of science. In the following sections we will examine, without claiming to be exhaustive, the main characteristics of the learning progressions, illustrate some of the main findings of educational research in this area and discuss the implications that learning progressions can have for teaching practice.

2. – What is a learning progression?

The term learning progression was first used in the National Research Council report *Taking Science to School: Learning and Teaching Science in Grades K-8* [1]. In that report, learning progressions are defined as a sequence of increasingly sophisticated and complex ways of thinking about a particular topic that follow one another over a long period of time. We will refer to learning progressions by adopting this definition. However, it should be kept in mind that in the scientific literature there are several definitions of learning progressions, which alternatively emphasize their main features. In particular, the following four main aspects characterize the learning progressions [9]:

- Learning progressions should describe the learning of the so-called *big ideas* [10-15], *i.e.*, concepts and topics that constitute the founding nuclei of the various disciplines and that represent a common core across several subjects. In this regard, learning progressions describe the logical sequence of ideas and concepts presented during the teaching-learning process [1, 16]. In particular, learning progressions are anchored, on the one hand, to what students know about a certain concept or topic at the beginning of their education and, on the other hand, to what they are expected to know and to be able to apply in a certain area of knowledge at the end of the school cycle. The starting point is often referred to as *lower anchor*, while the final level that students are expected to reach is called *upper anchor*.

- Learning progressions are an *experimental output*, as they are developed and revised on the basis of the results of previous research and experimental evidence [17].

- Learning progressions describe the *evolution* of knowledge and understanding possessed by a learner towards a deeper, more sophisticated, broader and more articulated knowledge. In other words, learning progressions describe how students should progress along subsequent levels of scientific knowledge [18-21].

- Learning progressions complement and intertwine with evaluation tools and processes, which must be aligned and consistent with the learning progressions. In particular, learning progressions describe and interpret how students perform [22-24]. As such, learning progressions may also affect the development and revision of school curricula [1].

Overall, with the steadily development of research studies in the field, learning progressions became a general theoretical framework that includes a cognitive model of learning, the principles underlying students' assessment, the structure and organization of school curricula at various educational levels and the teaching materials that may help students progress across the learning progression levels [25, 26].

3. – What progresses in learning progressions?

On the basis of what has been pointed out in sect. **2**, we can graphically represent a learning progression as in fig. 1, *i.e.*, a sequence of successive levels of knowledge, from the lowest one, *i.e.*, the lower anchor, to the highest one, *i.e.*, the upper anchor. Each

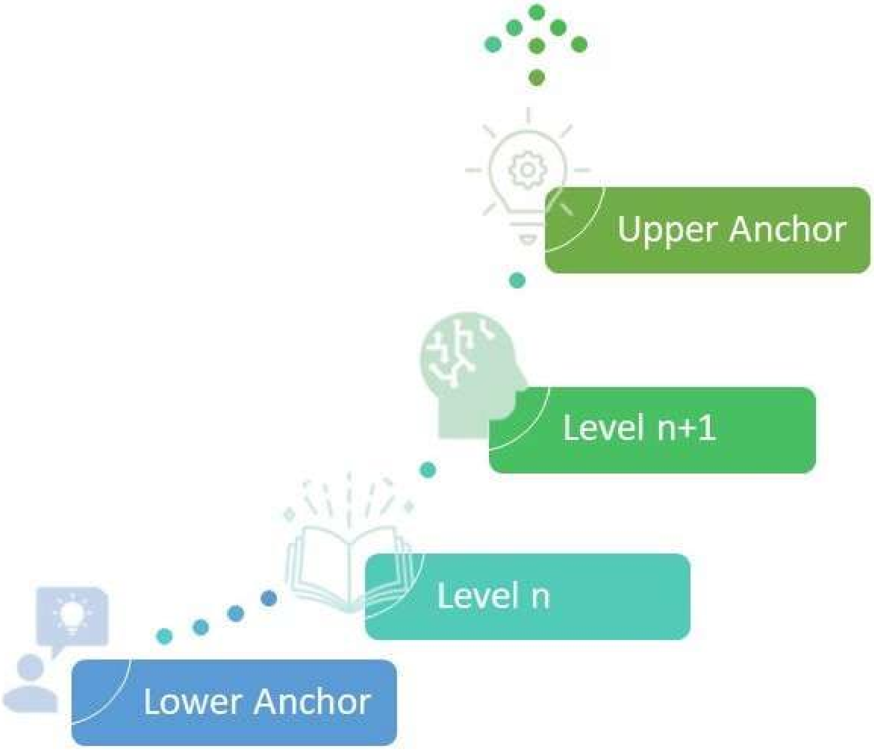

Fig. 1. – Schematization of a learning progression. The lowest level of the learning progression, *i.e.*, the *lower anchor*, represents the naïve and erroneous explanations that students initially use to explain the topic/subject of the learning progression. The highest level of the learning progression, *i.e.*, the *upper anchor*, represents the set of ideas, scientifically correct theories and knowledge about the subject matter of the learning progression. Starting from an erroneous or partially erroneous view, students progress in their learning path, through a series of increasingly sophisticated levels of understanding, towards the scientifically correct view of a given topic.

level of the learning progression is described by the so-called *progress variables*, which define knowledge, skills and competences related to a particular topic that a student at that level of the learning progression is expected to achieve. Examples of progress variables are the capability to apply the concept of energy in everyday contexts or the capability to design an experiment. Figure 1 represents an extremely simple and basic case of learning progression, which targets a single big idea [27]. Moreover, such a model of learning progression is overly linear and sequential and is, therefore, unable to capture the complexity of the dynamics that takes place in the learning process [28, 29]. To address this limitation, we can refine the model of a learning progression as in fig. 2. First, learning progressions can address different number of levels and target different, but

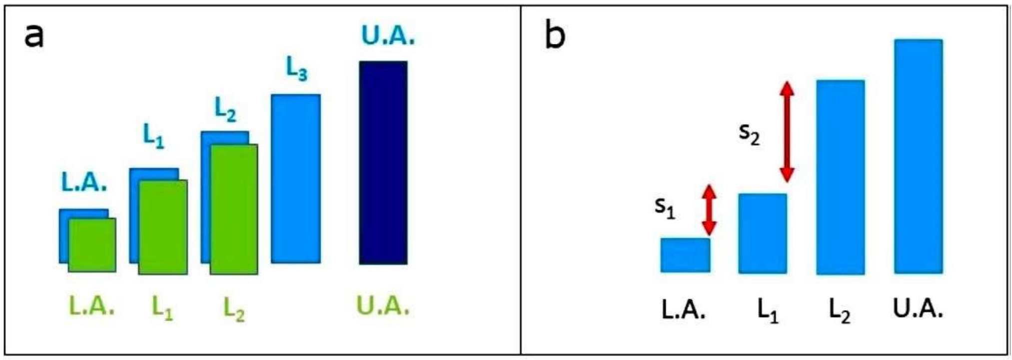

Fig. 2. – (a) Representation of a multidimensional learning progression. A multidimensional learning progression is a representation of the learning process of complex topics. Students are expected to learn a number of correlated topics (dimensions), for each of which one can build a distinct learning progression. To reach the upper anchor, students must progress along all the levels that describe the different dimensions of the main learning progression. There is no limit to the number of levels of each learning progression. (b) Representation of a generic learning progression in which the gaps in knowledge, skills and competences between any two successive levels are not necessarily equal.

related, dimensions of the same big idea [30]. Second, the levels of a learning progression may be unevenly spaced. In other words, a pupil may progress quickly and easily between certain levels of the learning progression, whereas it may require much more time and effort in terms of study and deepening their knowledge and skills to progress from one level to the next. This feature of the learning progressions is called *grain size* and determines how distant the learning progression levels are between each other or, in other words, how much the description of the progress variables differs between two consecutive levels. An example may help the reader familiarize with the concept of grain size of a learning progression. Let us imagine that we want to design a learning progression that describes how much students should learn about a particular topic (*e.g.*, force and motion) in a school year. In this case, the levels of the learning progression will need to provide a fairly detailed description of what teachers and students will have to do, so that the learning progression will probably contain a great number of levels in terms of knowledge and skills. The planned learning progression in this case will have a *fine grain*. If, on the other hand, our aim is to design a learning progression, which describes the development of knowledge about a given subject over several school grades (*e.g.*, physics in upper secondary school), the learning progression levels are likely to contain a broader description of what students should learn, limiting the scope to major objectives and expected performances. The planned learning progression in this case will have a *coarse grain*.

Finally, we point out that learning progressions seldom prescribe a precise temporal sequence of the expected levels of performance, since they are limited to describing *how* knowledge and understanding of a particular topic are hypothesized to develop. This aspect, as we shall see, has several implications for curriculum development and school practice.

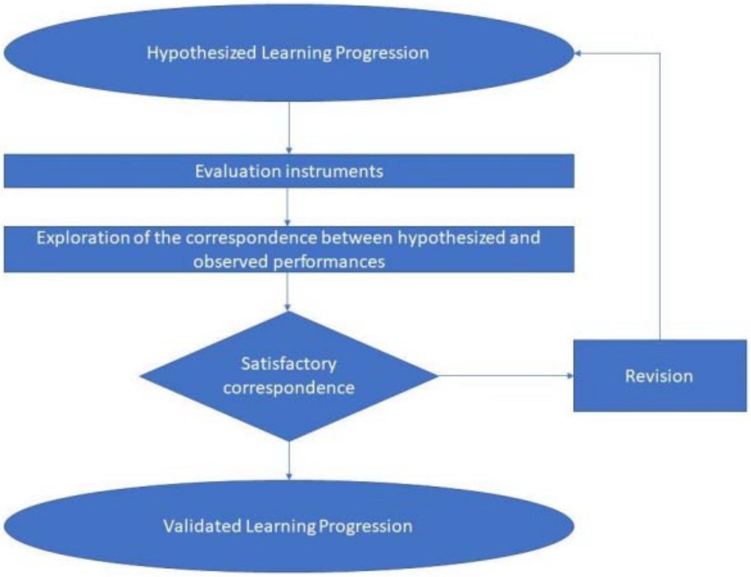

Fig. 3. – Representation of the design and validation process of a learning progression.

4. – The development-validation-revision cycle of a learning progression

The process of developing and validating a learning progression is a cyclical research process, which can be schematically represented as in fig. 3 [31, 32]. For the development of a new learning progression, a first version of the learning progression (*hypothesized learning progression*) is hypothesized, starting from the existing scientific literature, available empirical data and the organization of school curricula. The first step in defining the hypothesized learning progression is to identify and describe the lower and upper anchors. The upper anchor usually coincides with a description of the scientifically correct knowledge of the topic of the learning progression or, in any case, with a description of how much a student is expected to know and understand about that topic at the end of a school cycle or of a teaching intervention. The lower anchor represents the lowest level of understanding required to students and often coincides with a naïve, intuitive and scientifically incorrect view about the targeted topic. When dealing with topics such as forces, energy, water cycle, basic astronomical phenomena, . . . , lower anchors are built on a large and consolidated scientific literature [32]. In other cases, defining the lower anchor can be more complicated, especially when dealing with big ideas, such as the atomic structure of matter, which are not directly experienced by the students. In these cases, the researcher should collect new data through interviews or open-ended questionnaires, in order to build, on the basis of the collected evidence, suitable descriptors of the lower anchor. For the definition of the intermediate levels of a learning progression, the researchers usually refer to the experimental evidence emerging from a first sample of students, but also from the analysis of school curricula. In usual research practice, it is reasonable to assume that the sequence with which a given subject is treated in the school curriculum is a determining factor in defining how the students' knowledge about that particular topic should progress. We report in table I an example of learning progression related to the phenomenon of seasons, which we have developed starting from the sequence of the Italian secondary school curriculum. The lower anchor corresponds to the widespread belief that seasonal changes are due to periodic variations of the distance between Earth and Sun. According to the hypothesized learning progression, one has to take into account the tilt of the Sun's rays (level 1), the Earth's revolution about the Sun (level 2), the tilt of the Earth's rotation axis (level 3), and, eventually, its constant direction during the revolution (upper anchor). This hypothesized learning progression was tested against empirical evidence, collected through questionnaires, drawings, and interviews. Hence, we were compelled to revise the hypothesized learning progression to reflect the actual students' achievements. Notably, in order to understand why the Sun's rays have a different angle of incidence over the year, it is necessary first to acknowledge the tilt of the Earth's rotation axis relative to the orbit plane. Then, the revised level 3 of the learning progression is reached, when one becomes aware of the constant direction of the Earth's rotation axis. Finally, the new upper anchor includes the Earth's revolution about the Sun. Once the hypothesized learning progression has been constructed, the researchers should develop suitable tools that allow to evaluate to which extent the hypothesized sequence actually corresponds to the actual progress made by the students towards the upper level of the targeted big idea [27, 30]. These tools can be qualitative [10, 31], quantitative [27, 28] or mixed. The chosen measurement instrument, if not already validated, should be appropriately validated [29, 30] to make sure that it is fit for purpose. In the case of a qualitative assessment tool, researchers proceed to collect data through think-aloud students' interviews. Then they manually explore whether the reasoning, which emerges from the collected data, may correspond to a learning progression level [31]. When researchers use a quantitative tool, such as a multiple-choice questionnaire, the students' responses are analyzed through statistical methods. We will discuss in sect. **7** how to relate assessment tools and learning progressions.

5. – Examples of learning progressions

As pointed out in sect. **2**, learning progressions describe students' learning process of big ideas in science. As such, learning progressions target very different fields and knowledge areas. Table II reports a not exhaustive list of learning progressions. The table

TABLE I. – *Development of a learning progression about seasonal changes* [27].

Level	Hypothesized learning progression	Final learning progression
Lower anchor	Seasonal changes are due to the Earth-Sun changing distance	Seasonal changes are due to the Earth-Sun changing distance
1	The change of seasons is due to the tilt of the Sun's rays changing throughout the year	The change of seasons is due to the tilt of the Earth's axis of rotation relative to the plane of the orbit
2	Level 1 + Earth's revolution around the Sun	Level 1 + tilt of the Sun's rays changing during the year
3	Level 2 + tilt of the Earth's axis of rotation	Level 2 + constant direction of the Earth's axis of rotation
Upper anchor	Level 3 + constant direction of the Earth's axis of rotation	Level 3 + Earth's revolution around the Sun

shows that the research field has been very active in developing and validating learning progressions centered on a wide set of big ideas. For instance, Neumann and colleagues [32] developed a learning progression on energy, a crosscutting concept that is commonly exploited in all scientific disciplines (biology, chemistry, physics, engineering, geology, . . .) to explain ad interpret a broad set of phenomena. To date, other examples of learning progressions address the following big ideas: particulate nature of matter [33, 37], the Earth system [38], nutrition [39], quantum mechanics [40], the water cycle [41], genetics [26, 42-48], evolution [49], hydrogeological phenomena [50], celestial motions [30, 51, 52] and the forces [53-57]. However, big ideas are not limited to cross-cutting concepts but they can also include cross-cutting methodologies adopted in science. Authors have also developed learning progressions on scientific modelling [58-62], argumentation [26,63], the use of scientific evidence for decision-making [64], quantitative reasoning in the scientific field [65], errors in science [66] and scientific communication [67]. Jin and colleagues [68] analyzed over 150 learning progressions and classified them in three broad categories that reflect different views of the learning process: enrichment, transformation and integration of knowledge (see table II).

The knowledge enrichment process refers to a view according to which students already have some knowledge, which is, at least, partly correct but still incomplete. Therefore, students proceed on their path towards learning a given big idea by enriching their existing ideas, until they master an increasingly complex and sophisticated understanding of the targeted big idea. According to this view of the learning process, the levels of the learning progression somewhat follow the same logical structure of organized scien-

Table II. – *Examples of learning progressions categorized according to the view of the learning process* [68].

Knowledge enrichment	**Knowledge transformation**	**Knowledge integration**
Energy [32, 69-71]	Energy in socio-ecological systems [79-84]	Energy [88]
Concept of substance [72]	Atomic and molecular matter and theory [14]	Particulate nature of matter [10]
Structure of matter [73]	Concept of matter [33, 37]	Force and motion [53-57]
Hydrogeological phenomena [50]	Structure of Matter [83]	
Food chains [36, 74]	Water in socio-ecological systems [41]	
Ecology [29]	Ecosystems [84]	
Complex reasoning on the topic of biodiversity [36]	Natural selection [85, 86]	
Genetics [42-48]	Evolution [49]	
Tides [75]	Human nutrition [39]	
Acids and bases in chemistry [76]	Apparent motion of celestial bodies and moon phases [51, 52]	
Thermo-chemistry [77]	Basic astronomical phenomena [35]	
Stellar structure and evolution [30]	Solar system formation [87]	
Buoyancy [78]		
Quantum mechanics [40]		

tific knowledge, since they feature ideas, concepts and principles of increasing complexity. This is a fairly common approach, used especially for those learning progressions that deal with big ideas about which the students do not have any experience on a daily basis, such as quantum mechanics [40], stellar structure and evolution [30] and genetics [42-48].

The knowledge transformation process is informed by the Conceptual Change (CC) theory of learning. In the 'standard model' of CC [89], students enter a learning environment with a set of initial ideas that are used to provide some explanation of natural phenomena. These ideas may be consistent or inconsistent with scientific theories. In the latter case, such initial ideas are referred to as misconceptions, preconceptions, alternative ideas or naïve conceptions, and are generally less powerful than scientific theories [90]. According to the standard model of CC, on their way to the upper anchor of the given learning progression, through specific instruction, students 'abandon', 'build on' or 'substitute' the initial views to arrive at a more coherent framework that incorporates scientifically correct ideas and explanations. In the standard model of CC, the focus is on individual scientific concepts and how they relate to scientific knowledge, and less on a broader structure of knowledge that can include productive ideas on which to build meaningful knowledge (as it is the case of the knowledge enrichment process). We remind here, for the sake of completeness, that to address such limitations of the standard model of CC, broader theoretical perspectives have been developed to provide some mechanism underlying the emergence of students' ideas, such as the 'mental models' theory [91] or the 'p-prims' framework [92-94]. Building on both the 'standard model' and subsequent broader theoretical perspectives of CC, the learning progression framework focuses on students' initial ideas and attempts to describe, through the different levels, the subsequent steps taken by students to arrive at a scientifically sound idea.

The last, and least common, of the learning theories, which informs learning progressions, is that of knowledge integration [88]. According to knowledge integration, learning occurs through one or more of the following mechanisms: a) learning a certain subject is based on recognising false ideas and building on students' productive ideas to construct new knowledge, which leads to the formation of more sophisticated and increasingly correct ideas from the scientific point of view; b) as a result of the development of new knowledge, links are formed between relevant and significant concepts that are different from each other; c) when a student reaches the scientifically correct understanding of a given topic or of a certain idea, a virtuous process is triggered whereby the student is able to recognize the same idea in different contexts.

The main difference between knowledge enrichment and knowledge transformation or integration is that the last two contemplate the possibility that knowledge does not solely develop by adding new information, to what already possessed, but it may also mature through the assimilation of theories and ideas, which are incorrect or partially correct.

6. – How to use learning progressions to improve the teaching practice

How to apply the learning progression framework as a guide to reform the school curricula is still an under-researched topic. Researchers, in most cases, only refer to school curricula as the starting point of the learning progression design process. Only few studies have been carried out to critically compare the existing curriculum and the validated learning progressions in order to obtain a revised version of the curriculum. For instance, Forbes and colleagues [50], after validating a learning progression on hydrogeological phenomena, introduced a short teaching unit on modelling into the curriculum activities usually implemented by teachers. Differently, Plummer and Krajcik [51], starting from the data collected in a previous study, first developed a short curriculum unit on celestial motion, then tested it with students and finally, based on the data collected to evaluate the effectiveness of the teaching intervention, developed a learning progression.

Another under-researched issue, which influences and complicates the process of the learning progression/curriculum alignment, is that, unlike the usual school curricula, the levels of a learning progression do not contain a time frame. On the contrary, the organization of most school systems envisages a precise temporal arrangement of educational activities, which are almost always organized into school grades (*e.g.*, pre-school, primary, secondary school, . . .) sometimes separated by examinations. Moreover, the curriculum documents of the different disciplines contain indications on what knowledge, skills and competences students should possess at the end of each year or, at least, at the end of each school cycle. To address this issue, one possible solution is to re-organize curricula in levels of knowledge rather than in school years.

Alternatively, researchers might want to focus on building learning progressions with a very fine grain in order to have a very detailed description of the progress variables, so to make them directly usable by teachers in their everyday practice. Songer and colleagues [95], for instance, first developed a learning progression, whose progress variables described the learning of biodiversity and the development of the ability to elaborate evidence-based explanations [95, 96]. Starting from this learning progression, the researchers developed a teaching-learning sequence whose activities were aimed to help students progress along the levels of the learning progression. The effectiveness of the teaching-learning sequence was assessed through the analysis of interviews and answers to open questions. Similarly, Todd and Kenyon [46] developed a teaching-learning unit based on the inquiry methodology to help students progress along a learning progression centered on the big idea of genetics. The researchers investigated the implementation of the educational intervention by a group of teachers, testing its effectiveness through a multiple-choice questionnaire administered before, during and after the implementation.

To give a more precise idea of such a process, let us return to the example of the change of seasons, a relevant dimension of a wider learning progression focused on familiar astronomy phenomena (seasons, moon phases and eclipses) at secondary school level [27, 35]. We started the process of developing the hypothesized learning progression by looking at the conceptual sequence presented in secondary school curriculum and usual textbooks. In this sequence, emphasis is put on winter/summer solstices and spring/autumn equinoxes and on the shape of the Earth's orbit, which is presented as strongly elliptical in textbook images [97, 98]. Kepler's laws and the precession of the equinoxes are also addressed. However, we soon realized that this sequence can be potentially misleading, as it may reinforce the idea that the Earth-Sun distance changes significantly over the course of the year, thus leading to seasonal changes (the so-called 'distance misconception') [99-103]. A further potential incorrect idea, which can be caused by the textbook conceptual sequence, is that seasonal changes are due to the change in the direction of the Earth's axis, because of the emphasis on precession motion. Therefore, we decided to investigate whether usual textbook instruction could help or hinder students' progress along the levels of the hypothesized learning progression, developed from the curriculum materials, by administering a questionnaire to a wide sample of Italian students. We found that students did not reach the upper levels of the learning progression, since they were not able to grasp the relationship between the constant direction of the Earth's axis during the motion of revolution and the different angle of incidence with which the Sun's rays hit the Earth surface during the year. A further difficulty was to relate both orbital motion and the tilt of Earth's axis to seasonal changes. Hence, we decided to develop a suitable teaching-learning sequence to address these issues [27]. Starting from the naïve idea that the distance between the Earth and the Sun could be a potential factor that determines the change of the seasons, students are encouraged to prove that this effect is decisive in relation to other factors that could play a role in the phenomenon of the seasons, in particular the change in the angle of incidence of the Sun's rays. By modelling the Earth-Sun system with the aid of an incandescent lamp (the Sun) and a solar panel (the Earth's surface), the students experimentally determine the mathematical law describing how the energy received by the surface of the Earth from the Sun's rays depends on the distance of the Earth from the Sun (the inverse of the square of the distance) and on the angle of incidence of the Sun's rays on the Earth's surface (the cosine of the angle). By applying the derived laws to the real system, the students are asked to estimate the percentage change in the energy received by the Earth during the year at a given location as the Earth-Sun distance changes between aphelion and perihelion and as the angle of incidence of the Sun's rays varies over the year. By comparing these two measurements, students are able to demonstrate experimentally that the effect of the Earth-Sun distance is negligible with respect to the tilt of Earth's axis. Students are, therefore, driven to develop and verify the consequences of a false hypothesis, which is itself part of the learning progression as lower anchor, in order to be involved in a cognitive conflict that allows them to progress towards the upper anchor (see table I).

Finally, a further possible strategy for the construction and validation of a teaching-learning sequence, based on a learning progression, consists in integrating the process of development and validation of the teaching intervention with that of the learning progression. Our group adopted this methodology focusing on stellar structure and evolution as big idea [30, 104] building, at the same time, the hypothesized learning progression and a teaching-learning sequence. Then, both the hypothesized learning progression and the teaching-learning sequence went through an iterative cycle of implementation-assessment-revision to better align the teaching-learning activities with the learning progression levels.

Unfortunately, the number of teaching modules developed from validated learning progressions is still relatively small. As also pointed out in [68], there is not a sufficient number of studies related to the development and validation of teaching-learning sequences, based on a given learning progression. Several studies [51, 52, 104, 105] report supporting evidence that students engaged in activities informed by the theoretical underpinning of learning progressions, achieve significant improvements on all the progress variables that describe the levels of the learning progression. However, there are also studies that show that students make significant progress only on some of the progress variables and not on others [50, 58]. Hence, more research on this issue is warranted, as results are often contradictory. For instance, the study in [106] showed that less than 10% of the students, who participated in the educational activities developed on the basis of a learning progression, made significant progress on the levels of the learning progression itself.

7. – The use of learning progressions to improve educational assessment

Learning progressions can play a key role also in the design of effective assessment tools. In this review, we will restrict our attention to formative assessment [85, 107-109], namely the continuous process that involves the analysis of students' learning outcomes in order to ascertain the level achieved by the students and how to help them attain the desired objectives. Several studies have shown that formative assessment has positive effects on student learning [110], promoting the active participation in the learning process of both teachers and students [111,112]. According to the adopted definition of formative assessment, learning progressions can play a key role in supporting teachers in all phases of the formative assessment process. The upper anchor of a learning progression provides guidance in choosing learning objectives. In addition, by providing a description of students' learning levels, learning progressions represent a privileged tool for assessing the level of knowledge and skills achieved by the students. Finally, as seen in sect. **6**, learning progressions can serve as a guide for the construction of educational activities useful to support students' learning after the analysis of intermediate learning outcomes. However, how to correctly locate students at a given level of a learning progression can be a rather complicated issue from the methodological viewpoint. We will, hereafter, refer to a widely used analysis to address this issue. We refer, in particular, to Rasch analysis [113-115]. This type of analysis is often preferred to other methods of statistical analysis in learning progression research because, amongst many other advantages, it allows the construction of a so-called Wright map. The Wright map is a graphical representation of both student ability and item difficulty (see, for example, fig. 4). The questionnaire items are plotted from top to bottom in decreasing order of difficulty (*i.e.*, more difficult items are plotted at the top of the graph and easier items at the bottom). Students are displayed in decreasing order of ability, *i.e.*, more able students are displayed at the top of the graph and less able students at the bottom. If an item is on the same horizontal line as a student, this means that the student has a 50% chance of answering the item correctly, whereas if the student is above (below) a given item, this chance is greater (less) than 50%. If the items have been designed to correspond to the target indicator of a particular level of the learning progression, the Wright map makes it possible to check experimentally whether the students are aligned with, above or below that particular level. For example, looking at fig. 4, if questions Q4 and Q16 target the descriptors of the upper anchor of a given learning progression, we see that only a few students have already reached that level, while most students are still in the intermediate levels. On the other hand, if questions Q3, Q5, Q10, Q13 and Q15 target the descriptors of the lower anchor, we can safely conclude that all students in this sample have already passed the lower anchor. Note, however, that if Q7 targets the descriptors of a particular intermediate level of a learning progression, while Q9 targets the descriptors of a higher level, one should revise the learning progression levels and their descriptors, since Q7 is a more difficult question than Q9 according to the Wright map. The cycle of revision and validation of a learning progression does not end until the hypothesized levels describe with sufficient accuracy the actual knowledge of the students.

8. – Future steps for didactic research and educational practice in the field of learning progressions

Research activity in the field of learning progressions has been more active than ever in recent years and has led to many advances in the understanding of the processes that describe the development of learning and knowledge building. Much progress has also been made in the study of methodologies, the development and validation of educational interventions based on learning progressions and their effectiveness in supporting students in their learning pathways. However, research activity has concentrated mainly on some areas related to learning progressions and neglected others. In particular, little we know about teachers' use of learning progressions in their classroom practice. By their very nature, learning progressions should be a tool for teachers to design both educational

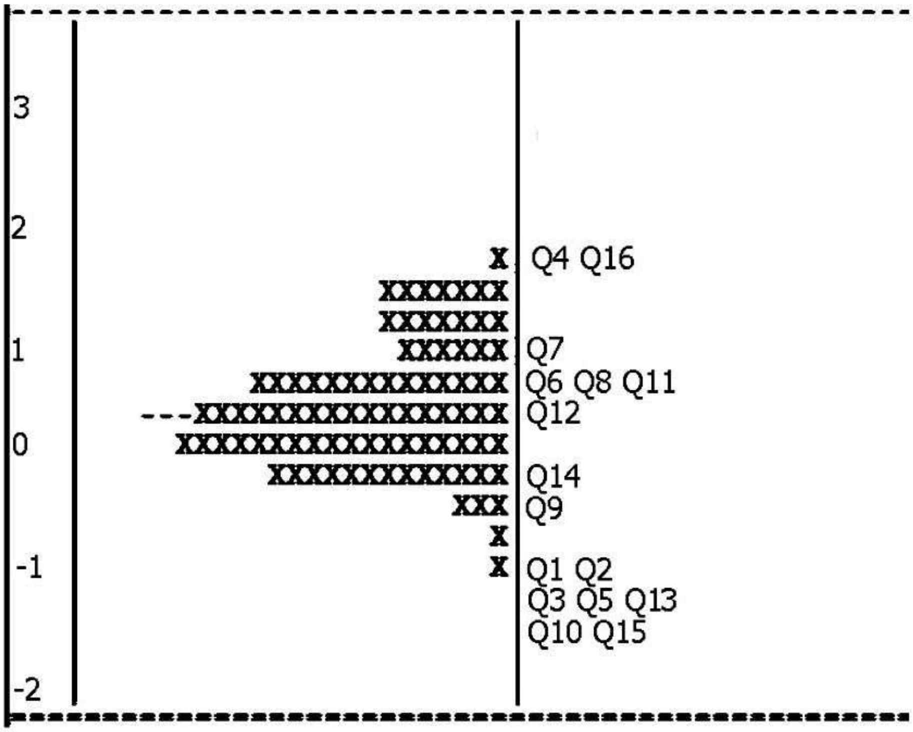

Fig. 4. – Example of Wright map for the learning progression in table I [27].

pathways and assessment instruments. For this to happen, however, more attention needs to be paid to the implementation of teacher training courses that focus on the use of learning progressions. It follows that, without suitable professional development courses, the results of educational research are unlikely to have a significant impact on everyday school practice. At the same time, it will be necessary to deepen the studies that investigate the ways in which teachers use learning progressions in their classroom practice and evaluate the impact of such use on their students' learning. Finally, much research needs to be carried about the use of learning progressions to assess curriculum instruction over different school grades.

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