

Precursor models of the Physical Sciences in Early Childhood Education students' thinking

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Abstract: *The current study presents the basic characteristics of the effort to develop a trend for Early Childhood Science Education, in the context of which it is attempted to construct precursor models in young children's thinking, schemes of understanding natural phenomena whose characteristics are compatible with those of Natural Sciences models that are used in schooling. General trends of research and teaching strategies for bringing young children closer to the Physical Sciences, specific issues of scientific models in education context as well as fundamental issues of structure and operation of precursor models in early childhood are also discussed.*

Keywords: *Precursor models, Physical Sciences, Early Childhood Education*

Πρόδρομα μοντέλα των Φυσικών Επιστημών στη σκέψη των μαθητών της πρώιμης παιδικής εκπαίδευσης

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Περίληψη: Στην εργασία αυτή παρουσιάζονται τα βασικά χαρακτηριστικά της προσπάθειας για την ανάπτυξη μιας τάσης για τη διδασκαλία των Φυσικών Επιστημών στην πρώιμη παιδική ηλικία, στο πλαίσιο της οποίας επιχειρείται η κατασκευή προδρόμων μοντέλων στη σκέψη των μικρών παιδιών, δηλαδή σχημάτων κατανόησης των φυσικών φαινομένων των οποίων τα χαρακτηριστικά είναι συμβατά με αυτά μοντέλων των Φυσικών Επιστημών που χρησιμοποιούνται στη σχολική εκπαίδευση. Συζητούνται επίσης οι γενικές τάσεις των στρατηγικών έρευνας και διδασκαλίας για την προσέγγιση των μικρών παιδιών στις Φυσικές Επιστήμες, συγκεκριμένα ζητήματα των επιστημονικών μοντέλων στο πλαίσιο της εκπαίδευσης, καθώς και θεμελιώδη ζητήματα της δομής και της λειτουργίας των προδρόμων μοντέλων στην πρώιμη παιδική ηλικία..

Λέξεις κλειδιά: *Πρόδρομα μοντέλα, Φυσικές Επιστήμες, Εκπαίδευση στην πρώιμη Παιδική ηλικία.*

Introduction

The issue of the initiation of Early Childhood Education children into the concepts and phenomena of Physical Sciences has been raised for the last fifty years in different scientific fields and epistemological contexts. Pedagogy, Psychology trends oriented towards learning, and, in recent years, Science Education, either at the level of research or at the level of implementation of educational activities, study the conditions that encourage an initial organized contact of children with the world of Physical Sciences. However, the multiple paths mentioned above create a complexity of approaches. This complexity needs to be organized in a way that allows multiple paths to be integrated into specific research and teaching contexts in order to be productive.

Following a classification introduced three decades ago and still enriching over time, research and formulation of educational activities from Physical Sciences in Early Childhood

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Education that goes beyond a simplifying empiricist perspective, is mainly linked to three dominant theoretical frameworks (Ravanis, 1994, 2005, 2017):

1. The first framework is related to the pedagogical traditions developed within the context of Genetic Epistemology; that is, the research trend that emerged in line with the perspective of Piaget's legacy (Kamii, 1982; Kamii & Lee-Katz, 1982; Kato & Dykstra Van Meeteren, 2008).
2. The socio-cognitive framework that follows, was formed based on theories that underline the importance of cognitive development and highlight the obstacles in young children's thinking and ways of overcoming these obstacles through teaching interactions. These aspects laid the theoretical foundations for the development of modern Science Education (Christidou & Hatzinikita, 2006; Kalampos & Ravanis, 2019; Kalogiannakis et al., 2018; Kambouri, 2015).
3. The third framework includes a range of pedagogical approaches. These approaches underline the critical role of a holistic perspective in understanding the development of young children focusing on the dialectic interrelations between enactive, affective, and intellectual factors. These are Socio-cultural and Cultural-historical approaches that are mainly based on the broader theorizations of Vygotsky's legacy (Fleer, 2017; Fragkiadaki, 2020; Pantidos, 2017; Plakitsi, 2011; Vidal Carulla & Adbo, 2020).

However, despite the common orientation, within each framework, there is a wide variety of theoretical tools, methodological approaches, and research options. Agreement within the different traditions is not a given, although these differences enrich all three frameworks. Thus, within the socio-cognitive framework, a cluster of researcher uses the concept of precursor model, that is an entity as conceptualization that is formed in young children's thinking and has specific characteristics. After discussing in a schematic level the issue of the formation of scientific models in children's thinking, some basic features of this conceptualization as well as an example of its implementation will be illustrated.

Models as a notion in Science Education

The transition from pure Sciences and/or scientific disciplines towards the attempt to formulate educational material for teaching them, always raises significant problems. That is because of the formation of pure Sciences and teaching Science are two completely different social practices that are developed under different necessities and conditions. The younger the students we focus on are, the more complex these problems are.

From a purely cognitive point of view, perhaps the most important issue we encounter in learning Physical Sciences is the mental representations of students, that is, the entities of their thinking based on which they form the natural phenomena and their interpretations. What it is well known after many years of research, students' naïve mental representations often differ to a great extent from the scientific knowledge we formulate for teaching. Thus, in the context of Science Education, a constant priority is the identification of children's representations and the effort to transform them. However, knowledge in Physical Sciences is not a sum of mental representations but distinct sets of abstract tools of the intellect such as theories or laws, with internal structure, organization, specific concepts, symbolism, and fields of application. Models are a type of these sets as they are constructed entities that are placed between theoretical constructions and reality in order to offer structured 'local' solutions in the representation, the formation, and the understanding of the phenomena.

Since models are basic tools for the development of scientific thinking, they also obtain a special interest in education. However, although the structural and functional characteristics of a model undergo (or rather should undergo) the necessary transformation in order to adapt

to the capabilities of children of different ages and their educational needs, without a doubt, the orientation of teaching practices in constructing models in children's thinking increases the difficulties and complexity. The attempt to form scientific models in children's thinking requires pathways that are usually demanding and long-lasting, as it is held back by several obstacles. Often the mental pathways children have to take to shift from their individual constructions towards scientific models are so demanding that the chances of a successful outcome of the relevant teaching processes are low.

Discussions about the role of models in teaching and learning but also about the processes of forming models in thinking have been an important area of research in Science Education (Cheng, Wu, & Lin, 2019; Hasni, 2010; Potvin et al., 2020). Despite the different approaches, it seems that a model from the Physical Sciences area, modified for education, allows for three distinct functions (Genzling & Pierrard, 1994):

1. *Description*. The level of description, at which the models allow us to select the efficient and appropriate illustrations of the phenomena. The description of systems, relationships, and their transformations in science teaching does not coincide with mere observation. That is because first the observation and then the description require and presuppose the use of criteria that only one model can offer.
2. *Explanation*. The level of explanation in which the utilization of the elements and the relations between elements of a model allows us to create causal relations and to interpret the observed processes and the results produced.
3. *Prediction*. The level of prediction at which models allow thought to use and combine elements to successfully expand into new but relevant topics and areas of application. The use of the specific elements and interrelations of a model leads thought to the formation of a creative ability to deal with new problems and phenomena by formulating hypotheses, creating correlations, and abstract reconstructing of the observed events.

The ability of children to use all three of these functions indicates the successful construction of a model from the Physical Sciences. In such a context, important questions arise both about the process towards the acquisition of these functions as well as the gradual appropriation of them. This discussion gains a new dimension in the light of the concept of the precursor model which at the same time gives the possibility of capturing the state of children's thinking of children as well as its developmental perspective.

This discussion is of particular interest to the thinking of young children as approaching Physical Sciences at the level of Early Childhood Education becomes extremely complex due to the cognitive limitations of children. It is obvious that at the ages of 4-8 years it is not possible to talk about the formation of models and modelling. However, any attempt to introduce young children to Physical Science does not make sense to be limited to a sequence of experiences and fragmentary images of the physical world. Thus, within the socio-cognitive trend, several research and teaching approaches are oriented towards the need for the formation of entities in young children's thinking that intervene between the naïve mental representation and the models; namely, schemes of thinking that may facilitate the attempts of mental construction of the real models. These entities are recognized as precursor models.

The precursor models in Early Childhood Education

The concept of precursor model was firstly proposed by Weil-Barais & Lemeignan in France (Weil-Barais, 2001; Weil-Barais & Lemeignan, 1990) and stemmed from a strong theoretical environment that made use of important concepts for learning such as the concepts of 'reflective abstraction' (Piaget 1977), 'zone of proximal development' (Vygotski, 1934/1962) and 'knowledge in action' by Vergnaud (1987). The concept acquired empirical content for the first

time in an extensive research on the way that students aged 16-18 construct basic concepts in mechanics (force, energy, quantity of movement) (Lemeignan & Weil-Barais, 1993). But what exactly are precursor models? These are mental formations compatible with scientific models since they are constructed a precursor model on the basis of certain elements included in the scientific models, have a limited range of application and prepare children's thought (Lemeignan & Weil-Barais 1993). 'These precursors are cognitive constructions (concepts, models, procedures, etc) generated by the educational context. They constitute the moulds for subsequent cognitive constructions, which without their help, would be difficult, or impossible' (Weil-Barais 2001, p. 188).

In precursor models the elements as well as the relationships between them are compatible with those of the scientific models that are commonly used in the learning and teaching processes of Physical Sciences. At the structural and functional level, they bring into communication the individual constructions of children's thinking about natural phenomena with the school knowledge and can act as the base for a process towards the elaboration of more complex models. But what are the resources used by the scientific community to develop the structure of a precursor model in a way that is explicit? Since at the core of the discussion lies a cognitive entity that should be transformed in order to be compatible with the Physical Sciences we teach in school, it is obvious that we are referring to three concurrently exhibited dimensions: children's thinking along with naïve mental representations and various obstacles, teaching practices and elements of scientific knowledge as it is transformed for school purposes. Although these three elements always coexist, their significance differs and should therefore constitute subject for future research and elaboration.

The idea of utilizing precursor models in Early Childhood Education was firstly introduced in the 2000s (Ravanis, 2000, 2005). Even through its limited application to older students, this concept seemed dynamic and provided a way out of the apparent weakness of a small number of studies which had already begun to appear in the study of mental representations of children aged 4-8 for concepts and phenomena of Physical Sciences. Indeed, these researches, despite their indisputable descriptive interest, did not lead to fruitful prospects as on the one hand they yielded results similar to those conducted with students of Primary Education and on the other hand their attempts to transform these mental representation for the given age spectrum were extremely discrete, isolated from the wider proposed models and totally absent from the contexts of early childhood curricula. With regard young children, a distinct problem was the absolute need to address the particular issues that arise from the limitations of their thinking, that is, to activate interpretive theoretical tools of science that deal with the developmental characteristics of children's thinking. Undoubtedly, this issue should also count for older children as the developmental characteristics of their thinking undoubtedly affect learning issues, nevertheless we shall not expand here as this goes beyond the scope of our study.

In the case of young children, it is impossible to focus on the issues of initiation in the Physical Sciences if we lack the ability to interpret their way of reasoning that stems from the prologue nature of their mental composition. Let us give two relevant examples in order to illustrate the importance of a deeper understanding and treatment of the special difficulties that count for young children.

- Whenever we find out that kindergarten children cannot realize the fact that different kinds of propagated entities such as light, heat or sound, are able to travel through space from the sources of production to the potential 'receivers', it should not just attributed to ignorance or misunderstanding of phenomena. Instead, it should be ascribed to constraints of their intellect that we should be able to interpret in order to integrate them into specific teaching and learning activities plan.

- In cases where research ends up to 'successful' teaching interventions such as the transition from naive mental representations to others compatible with scientific knowledge, a general framework statement is quite often formulated that this study lies in the boundaries of the 'zone of proximal development'. Such a general statement has no specific content regardless of the age of the students that were applied. However, it is inconceivable when it counts for young children as at this age the 'zone of proximal development' has a strictly specific content. Indeed, 'zone of proximal development' combines the structural and functional characteristics of children's intellect along with the knowledge from the Physical Sciences that interests us. Putting it differently, if we assume that we work with young children in the 'zone of proximal development' regarding the natural phenomena of clouds and rain, our object of work should not only count for the concepts of condensation-liquefaction as it would be with the older students, but also the pre-logical reasoning that young children often illustrate about the origin and composition of clouds.

At the same time, while from a functional point of view the models allow descriptions, explanations and predictions, as already mentioned, the precursor models that are developed for young children may incorporate only some of these functions mainly confined on the notions of description and prediction. Such a function is perfectly compatible with the concept of the precursor model as it concurrently exhibits a static and dynamic character since it captures a state of thought which incorporates the seed of evolution.

Let us now look at a typical example that illustrates many of the issues raised earlier. As it is well known, the interaction between two tangential bodies sliding relative to each other can be described as the resultant force of the force parallel to the common surface, called sliding friction, and the vertical force between the surfaces of the bodies which are in contact. The development of the friction force depends on a number of factors such as the pressures exerted or the degree of grinding of the metals, the presence or absence of air between the surfaces, the elastic or plastic nature of the materials, the speed of the moving bodies etc. The model used in education neglects a number of these variables and correlates the development of sliding friction force with the following two factors: the vertical force that is developed between the tangential surfaces that are moving relative to each other and the nature of these surfaces. In cases where the problem is limited to the movement of an object on a fixed horizontal plane, the vertical force exerted from the surface on the body is equal to the weight of the object and therefore the weight of the moving body can be considered as a factor.

The attempt of constructing a precursor model in the thinking of preschool children about sliding friction encounters a significant difficulty from the outset. Literally, we try to work with children on conceptualizing the development of a force whose creation conditions or developmental causes are neither visible nor tangible. Undoubtedly, we are well aware that the construction of the concept of force in young children's thinking is extremely difficult even in the case of simple forces and from this point of view the task seems problematic. However, what we are trying to do with a precursor model is not to build integrated concepts but reasoning schemes that prepare for the construction of real models. Therefore, instead of trying to approach friction as a force that depends on two factors, we try to process with young children the effects of the change of these two factors on the movement of an object in the horizontal plane which depends exclusively on friction. That is why the attempt to construct a precursor model of approaching phenomena in children's thinking is directed towards the mental construction of: (a) The estimated weight of the moving body on a quality scale 'lighter-heavier' and (b) The nature of the tangent surfaces, valued on a quality scale 'smoother – rougher', as factors that affect the obstruction of the free movement of an object on a horizontal surface which can be related to the distance traveled by the body. By adopting this

perspective, we lead to the development of a precursor model for sliding friction which allows the mental processing of the functional consequences of the change of two factors in the body motion, without referring at all to the concept of sliding friction force.

The relevant activity was based on playful procedures for both sliding and rolling friction. Children are invited to make predictions and estimates for the travelled distance that a vehicle is up to cover when it is launched in a steady manner either sliding or rolling on a fixed platform. Having the ability to change the roughness of the aisle in which the vehicle moves using plastic carpets or rugs, as well as the weight of the vehicle load by adding or removing objects, we lead children to compare the travelled distances covered by vehicles of different weights on different carpets. Thus, they gradually form in their thinking the conditions under which the movement of a body can be either facilitated or impeded (Ravanis, Koliopoulos & Hadzigeorgiou, 2004; Ravanis, Koliopoulos & Boilevin, 2008). Having recognized the factors that are involved in the study of friction in the school context from an early age (5-6 years old), we can reasonably assume that these children construct a precursor model that would enable them in the future to conceptualize the concept of friction on its all structural and functional characteristics.

Discussion

The research and development of precursor models in Early Childhood Science Education creates an interesting perspective as it takes us from the territory of naive mental representations to a range of structured knowledge that prepares young children to encounter in their future schooling with models of Physical Sciences. It is certainly a learning and teaching orientation that makes sense to be implemented on a larger scale with older children who would be able to construct a complete precursor model.

However, during the last twenty years, a real research and teaching trend has been developed at the level of young children, which has given interesting results in distinct fields and subjects. Research data on different concepts such as floating and sinking (Canedo-Ibarra et al., 2010), air (Lorenzo Flores, Sesto Varela, & García-Rodeja, 2018), inheritance (Ergazaki et al., 2015), the shadows (Delserieys et al., 2018), water state changes (Kambouri-Danos et al., 2019), suggests that it is possible to work with young children going beyond a traditional approach of presenting experiences from the physical world to a direction of rational elaboration of causes and effects and construction of fixed reasoning schemes, to the possible extent due to the constraints imposed by their development.

Undoubtedly such a research and teaching perspective on the one hand has still a long way to go in order to constitute a strong proposal and on the other hand owes to be able to provide answers to a number of serious questions such as the potential relationship with early childhood curricula or important affective aspects of children of this age. However up to date research findings and related teaching activities create a fertile ground for continuing the effort along this path.

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