

Precursor Models in Early Science Education: a multimodal perspective

ALMA ADRIANNA GÓMEZ GALINDO

Cinvestav Monterrey
Mexico
agomez@cinvestav.mx

ABSTRACT

This paper analyses the importance of modelling and the use of multimodal languages in the construction of precursor models in early science education. Drawing on a semantic view of science, it explores how the coordinated use of various semiotic registers—words, drawings, and physical models—enables students to transition from everyday explanations towards more complex school scientific models. It is argued that scientific language should not be presented as a finished technical structure, but as a system of meaningful relationships that is negotiated and constructed within the classroom. Through practical examples concerning the nervous system among students of different ages, this work illustrates how external representations allow for the materialisation of abstract entities and non-observable processes. The paper concludes that multimodality facilitates children's ability to make sense of scientific phenomena in a natural and gradual manner, ultimately enabling informed decision-making.

KEYWORDS

Precursor models, multimodality, scientific language, external representations, primary education

RÉSUMÉ

Cet article analyse l'importance de la modélisation et de l'utilisation des langages multimodaux dans la construction de modèles précurseurs dans l'enseignement des sciences précoces. S'appuyant sur une vision sémantique de la science, il explore comment l'utilisation coordonnée de divers registres sémiotiques — mots, dessins et modèles physiques — permet aux élèves de passer des explications quotidiennes à des modèles scientifiques scolaires plus complexes. On soutient que le langage scientifique ne doit pas être présenté comme une structure technique achevée, mais comme un système de relations significatives négocié et construit en classe. À travers des exemples pratiques concernant le système nerveux chez des étudiants de différents âges, ce travail illustre comment les représentations externes permettent la matérialisation d'entités abstraites et de processus non observables. L'article conclut que la multimodalité facilite la capacité des enfants à comprendre les phénomènes scientifiques de manière naturelle et progressive, permettant ainsi en fin de compte une prise de décision éclairée.

MOTS- CLÉS

Modèles précurseurs, multimodalité, langage scientifique, représentations externes, enseignement primaire

INTRODUCTION AND PURPOSE

Nowadays, there is a consensus that modelling is a central theoretical-methodological proposal in teaching and learning processes (Adúriz-Bravo, 2022). However, difficulties have been identified in constructing theoretical models with students due to their abstraction, counter-intuitive nature, and complex relationship with phenomena (Weil-Barais, 2022). Specifically, the precursor model proposal provides a transitional structure that mobilises students' starting ideas, considering their age, knowledge, and abilities, as well as curricular requirements. In this way, a feasible and fruitful modelling process is proposed for the gradual development of an understanding of models that are more complex and closer to those of scientists.

Within this framework, the construction of models is considered, from a branch of the philosophy of science, the central activity of the scientific endeavour. From a semantic perspective, models are simplified constructions of reality that mediate between reality and theory (Giere, 1992). From this viewpoint, it is assumed that models are abstract and generate external representations—that is, ‘observables’ in a broad sense—which allow for the communication of the ideas that students construct through natural language, images, or 3D models (Buckley, 2000). These expressions are created with a particular purpose and in a specific context; therefore, when integrating these communicative modes into modelling, the objective is to represent abstract entities and highlight their relationships within a school explanatory model that draws on ideas from the reference scientific model.

Starting from this basis, students can begin to construct precursor models from a young age which, although partial, have the potential to develop throughout their schooling. It is relevant to initiate this process early, given that the complexity of the final models requires a progression hypothesis. This trajectory allows students to generate sense and meaning for these ideas and, ultimately, enables them to use these models in their decision-making.

As noted in other papers in this issue, precursor models prove to be both a didactic and epistemic tool that promotes the mobilisation of students' ideas to generate the foundations for understanding school scientific models. The value of these models as transitional structures has been discussed by Ravanis and Boilevin (2022), who highlights their capacity to enable children to identify relevant aspects of phenomena and establish causal relationships. According to Weil-Barais (2022, p. 32), these models link the behaviour of phenomena with theoretical ideas through a system of symbolic relationships; thus, “precursor models can indeed lay claim to introducing children and teenagers to the game of science”.

Considering these ideas, this text addresses the incorporation of scientific language in precursor models and the way in which students construct a system of relationships with sense and meaning. In this regard, the following questions arise: Is it possible to find a language that also acts as an intermediary in the construction of abstract ideas and that, at the same time, links to empirical experience to achieve an understanding of nearby phenomena? That is, how can we build a language that links their experiences with theoretical ideas—a characteristic of scientific thinking—at ages when students are even developing their mother tongue?

Following Lemke (1990), we understand that scientific language undergoes a historical process of negotiation before establishing itself as universal. It passes through stages in which it is initially used to negotiate meanings through social interaction and debate; only when consensus is reached does it become a convention that generates thematic patterns. These patterns consist of semantic relationships that become fixed and universally accepted. Thus, for Lemke, scientific language is not just a list of concepts or ‘terms’, but a network of meaningful relationships. For example, it is not merely a matter of using words like ‘force’ and ‘mass’, but of understanding the relationship established between the two. Students must grasp how they form a logical, networked structure to make sense of the natural world. Lemke points out that

words may vary, but relationships must be maintained to build the network that defines the scientific model.

Drawing upon this premise, we propose that, during the construction of precursor models, we seek to incorporate terms meaningful to students that allow them to establish the relationships that give sense to 'scientific facts'. The objective is for students to construct theoretically interpreted facts (Izquierdo-Aymerich & Adúriz-Bravo, 2003).

Considering the above, in this work I explore the possibilities and limitations that may arise when constructing precursor models by incorporating scientific language as a system of meaningful relationships for young children. This process starts from the use of the students' own vocabulary and considers the achievement of consensus and conventions in the classroom. I seek here to prioritise the significance of relationships over the 'words' or 'terms' used in science, considering scientific language as a dialogical construction subject to debate, and not as a technical structure presented in a standardised and authoritative way that leaves no room for negotiation.

MULTIMODAL LANGUAGE AND THE CONSTRUCTION OF PRECURSOR MODELS

Scientific language and school science language involve various semiotic modes. In this section, I organise the argument into three parts, each dedicated to a specific medium and, above all, to its role in the generation of meaning and the establishment of relationships between ideas and experiences for the construction of precursor models. The resources analysed are words, drawings and physical models and I conclude the text with a section on the coordinated manner in which these three resources are used in the processes of model construction, as well as the role of teachers as mediators in such construction.

The role of terms and verbal discourse in the meaning-making process of precursor models

Following Lemke (1990), scientific language as a specialised register can be far removed from students' initial ideas and their colloquial language, which—especially in young pupils—is used to understand their world. Along these lines, Barnes (1976) distinguishes between exploratory talk (messy, flexible, in the child's own words) and presentational language (the final scientific term). Both authors agree that the early introduction of scientific language can constitute an obstacle rather than a facilitator of children's learning.

In line with the above, for Vygotsky (1978), language is initially constructed on a social plane; this implies that meanings are negotiated, and spheres of use and relationships are defined before being internalised. Within this framework, the Zone of Proximal Development is where a child can venture with the help of an adult to incorporate new language, situated close to their everyday language. It should be remembered that for Vygotsky, language is the fundamental tool for cognitive and social development; therefore, it is essential to analyse how scientific language is incorporated into schools from an early age.

From this perspective, it can be argued that, in many instances, formal scientific language is not within the student's Zone of Proximal Development. In this sense, incorporating modelling processes implies creating situations in which colloquial or everyday language acquires new meanings and is negotiated through interaction, giving rise to new relationships and interpretations. Once these meanings have been constructed, new (scientific) terms are introduced. Consequently, the proposal defended in this paper is that the scientific term or word is integrated into the modelling at a later stage, rather than at the beginning of the process.

An example of this was found when working on the nervous system and the five senses as the means by which our bodies sense environmental stimuli and respond. With pupils aged

4 to 6, we worked on the precursor model of ‘irritability’ in living beings (Gómez-Galindo, 2009). A central element was recognised that the five senses have a connection to the brain, such that it is the latter that processes the information captured by each sense and generates responses. When establishing relationships between the senses and the brain, the children mentioned the only communication system they recognised in their own bodies; thus, they explained the proposed experiences with the idea that ‘here are little tubes full of blood that connect the senses and the brain’. The transcript of this conversation is presented below:

Teacher.- But then, if the smell first arrives through the nose, and your brain told you it was incense, then must there be a way in which the nose communicates with the brain?

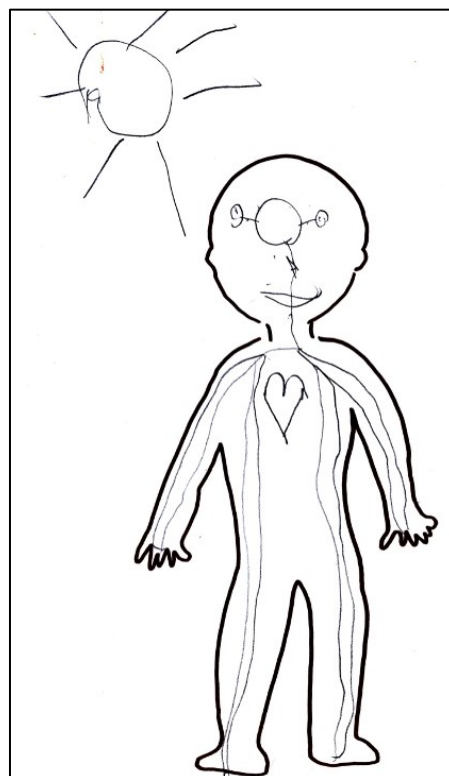
Alicia.- Yes, they are connected.

Teacher.- How?

David.- Through little tubes full of blood.

The previous interaction provides an example of what, according to Gutiérrez (2008), constitutes a Third Space. In this space, a discursive hybridisation occurs; that is, different ways of speaking coexist: that of the student—from their everyday experience—, that of the teacher—who integrates the scientific perspective—and an intermediate space where both interact. Initial linguistic flexibility is, therefore, a priority to accommodate the students' words as a tool for mediation and genuine recontextualisation (Wickman, 2006), allowing the student to construct their own structure of meanings.

FIGURE 1



‘Little wires’ connecting the brain and senses

Note: We observe the lack of connection to the heart, as the students construct a communication system alternative to the one initially proposed as ‘little tubes full of blood’.

In this interaction, a Third Space emerges in which students make sense of their previous experiences, including school-based ones, to explain a new phenomenon. Here, the teacher's task is not to correct and introduce 'correct' ideas, but to allow for the reframing of discourse. To this end, through classroom work, the teacher proposed new experiences aimed at helping students construct a second communication system in their body, distinct from the 'little tubes full of blood'. As a result, one student noted: 'they are like little wires that connect the brain and the senses'. This idea, presented as an analogy by saying 'they are like', proves to be quite powerful as a mediator and was promoted by the teachers.

Thus, the idea was gradually negotiated and adapted by the students. In Figure 1, we identify the representation of this communication, in which these 'little wires' even go around the heart. It is pertinent to note that these students clearly recognised that those little tubes full of blood were connected to the heart, which functioned as a pump to circulate the blood. In this way, this representation is significant in relation to their way of giving meaning to the established relationships.

Based on this representation, the meaning-making process develops throughout all activities, becoming more complex through new analogies; for instance, when a student points out the communication between a sense, such as touch—a pricked finger—and the brain: 'it is as if the finger sends a little letter to the brain... through the little wires'.

Furthermore, students organise their ideas by generating new interpretive frameworks. In this regard, a student who still uses the idea of 'little tubes'—though no longer the idea that they are full of blood— noted during an activity where they were blindfolded and a grain of salt was placed on their tongue: 'The grains of salt go to the brain through the little tubes. The brain says, "Ah! It's salt!"... and then it sends them back to the tongue, and the tongue takes them to the tummy'. This fragment, as well as the one about the letter sent by the finger to the brain, provides a guide for continuity towards levels of greater conceptual abstraction.

We identified that students require other ideas to understand this process: the conversion of a stimulus into an electrical impulse. This idea, characterised by high complexity and abstraction, was addressed with 11-year-old pupils and is presented in the section on the use of physical models.

By contrast, in this case, with pupils aged 4 to 6, we worked on building consensus around the term 'little wires' (*cablecitos*), subsequently introducing the term 'nerve fibres'. In this instance, this Third Space functioned as a bridge for the introduction of scientific terminology.

Taken together, the examples presented demonstrate how the science classroom can be understood as a Third Space in which scientific meanings are not introduced directly but are progressively constructed through the interaction between the students' everyday language and teacher interventions. In this process, analogies and emergent expressions serve as bridges between both registers, facilitating reframing of discourse. From this perspective, the use of scientific language is not proposed as a starting point, but as a moment of stabilisation within the modelling process, occurring once students have begun to construct shared meanings.

The role of drawings and physical models in the meaning-making process of precursor models

These forms of expression, such as 'little wires' (*cablecitos*) and their subsequent transition towards 'nerve fibres', are not limited to oral language but extend to other external representations, particularly drawings, in which students materialise and reorganise these relationships (Gómez & Sanmartí, 2008). In this sense, the construction of meaning in the science classroom is not reduced to verbal language. Authors such as Ronald Giere, from the semantic perspective that underpins scientific models (Giere, 1988), point out the importance of diverse external representations—not only words or texts, but also drawings, graphs and

physical models, as well as interaction with others—as key pieces in the construction of scientific knowledge (Giere & Moffatt, 2003).

From this perspective, interest in external representations has been widely addressed within the field of science education. Furthermore, the creation of drawings is an activity that young children perform naturally and is regularly encouraged both at school and within the family. Similarly, the construction of physical models remains relatively present throughout primary and secondary education. However, both physical models and drawings are often gradually set aside in schools, giving primacy to written text. Within science education research, various authors from different theoretical perspectives have drawn attention to the importance of multimodal language in science teaching (Kress et al., 2001). Multimodality includes not only written and oral text, but also drawings, physical models, and symbols, where each semiotic resource can provide differential but coordinated aid in the meaning-making process of scientific ideas (Gómez-Galindo, 2009).

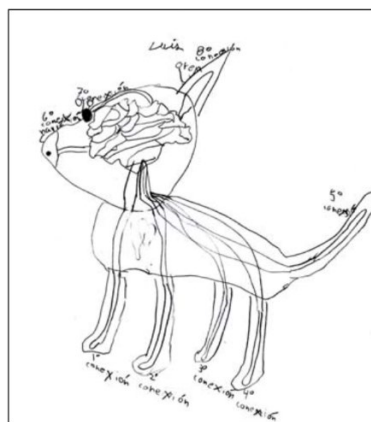
In the case I have been exemplifying, drawings also fulfil the function of providing a visual representation of the relationships between ideas and experiences. Students represent situations associated with the activities performed. With 6 and 7-year-old pupils, we continue to work on the aforementioned precursor model but integrating the capacity of other living beings to sense stimuli¹. We use the example of a dog. As can be seen in Figures 2 and 3, students establish relationships between experiences and theoretical ideas.

FIGURE 2



Photograph of students working on the irritability model in animals

FIGURE 3



Drawing representation showing how sensory organs and the brain are related in animals

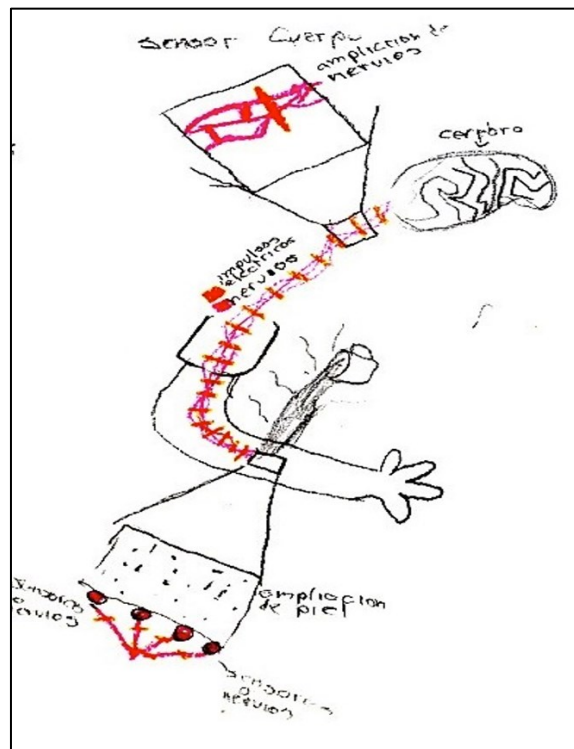
¹ A description of the activities can be found in Gómez-Galindo (2007).

Furthermore, the pupils provided written explanations, referring to the dog by the name Whiskers (*Bigotes*): ‘Whiskers’ brain is connected to all parts of his body; when he sees a disc, the eye sends a signal to the brain through the little tubes, and the brain sends a message to the feet and the mouth to catch the disc.’²

As previously mentioned, relationships become increasingly complex as precursor models are worked on in school. We might say that the transition from precursor models to school scientific models is more akin to a scale of greyscale than black and white; that is, the boundaries between them are gradually blurred. Rather than an obstacle, this represents a point of strength for precursor models, as it resonates with the natural way in which children make sense of the world and construct knowledge. All of this occurs in a gradual manner—not necessarily linear or continuous, but with a complexity that remains a subject of extensive research.

This complexity is evident in the drawings produced by 11-year-old students, who introduce abstract entities into the topic by using the concept of ‘electricity’ to refer to ‘nerve impulses’ (Figure 4).

FIGURE 4



Drawing by an 11-year-old student on the sense of touch

Note: Hot water is seen falling on the arm. The student uses a zoom effect to represent a ‘skin enlargement’ where ‘sensors or nerves’ are located; ‘electrical impulses’ and ‘nerves’ are drawn in red on the arm, and upon further enlargement, the ‘nerve magnification’ and the ‘brain’ are shown.

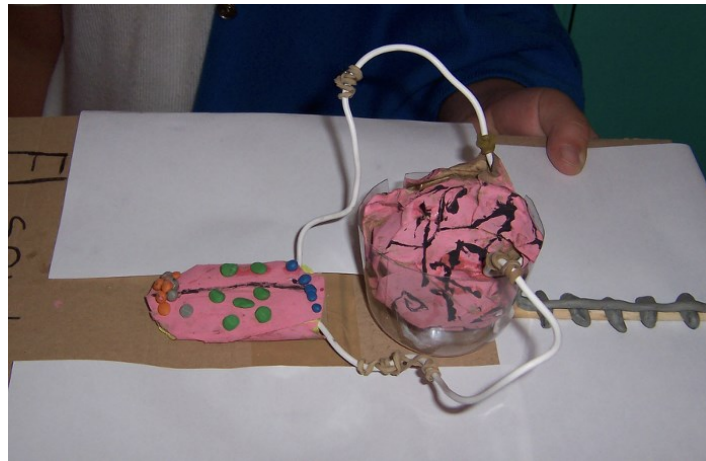
What is notable about the representation in Figure 4 is how the student associates the ideas of the model with the specific event of a cup of presumably hot water falling on an arm.

² It is worth noting that the students still use the term ‘little tubes’ (*tubitos*), as the transition to ‘nerve fibres’ is occurring gradually, much as it did in the history of science.

This exemplifies the theoretical explanation of a real-world phenomenon and the creation of a school scientific explanation. We can identify this complexity in the drawings produced by 11-year-old students, who introduce abstract entities into the topic. For instance, they use the concept of 'electricity' to refer to 'nerve impulses', as shown in Figure 4. In this representation, the drawing no longer merely shows visible organs; instead, it incorporates non-observable physiological processes, marking a transition towards a more advanced scientific model.

Turning to physical 3D models, these allow for a three-dimensional representation in which other types of relationships can manifest. In the case of the work carried out, a key point was that the materials used by the students should connect analogically with the ideas they sought to represent. Thus, analogies, as a highly potent learning resource (Gómez-Galindo, 2009), support the meaning-making process and the establishment of relationships within another semiotic register. An example of this can be seen in Figure 5, in which the physical model developed by 11-year-old students shows a series of analogies; for instance, the use of electrical wires to connect the sense of taste with the brain. The students used rubber bands to represent the electrical impulse travelling through the nerve fibres.

FIGURE 5



Physical model using electrical wires and rubber bands to represent the connection between the sense of taste, the brain, and nerve impulses

Thus, the use of drawings and 3D physical models allows precursor models to cease being merely isolated ideas and become meaningful explanations. By combining these resources, students manage to materialise not only what they see but also what they imagine is happening, such as the abstract processes of the nervous system. Ultimately, it is this variety of external representations that facilitates children making sense to scientific phenomena in a natural way and at their own pace.

FINAL REFLECTIONS: INTEGRATING SEMIOTIC RESOURCES FOR MEANINGFUL MODELLING

Ultimately, this work allows me to reflect on the fact that the construction of precursor models is not limited to the acquisition of concepts; rather it lies in the students' ability to make sense to their experiences through interaction with peers and teachers, and the coordinated use of different external representations that also serve as spaces for negotiation. These representations allow ideas to be materialised and, consequently, improved through

socialisation. This process helps in bridging the gap between initial ideas and school scientific models, providing students with the necessary elements for informed decision-making.

In doing so, we prioritise the network of relationships over isolated terms and allow scientific language to be a living, dialogical tool. However, this multimodal approach poses significant challenges that still require further exploration. It is pertinent to ask: how can teachers manage the tension between the expressive freedom of exploratory language and the need to reach the scientific conventions required by the curriculum? A difficulty not addressed here is the risk that the diversity of semiotic resources might lead to cognitive overload if precise teacher coordination is lacking. It remains, therefore, to investigate the pedagogical criteria that allow for identifying the moment when a drawing or a physical model ceases to be a support and becomes an obstacle, if it fails to integrate effectively into the thematic pattern that defines the scientific model. In this regard, teacher mediation remains the fertile ground where the 'shades of grey' between the everyday and the scientific must be carefully navigated.

Ultimately, the value of the precursor model lies in its ability to respect the child's starting point while providing a clear trajectory towards more complex ideas, proving that even the most abstract scientific concepts have their roots in these early negotiated meanings.

ACKNOWLEDGEMENTS

The author is responsible for the original ideas, the conceptual framework, and the didactic and empirical examples presented in this paper. Technical assistance for the translation from Spanish and stylistic editing into British English was provided by an AI-assisted academic tool.

REFERENCES

- Adúriz-Bravo, A. (2022). What is a precursor model? In J. M. Boilevin, A. Delsérieys, & K. Ravanis (Eds.), *Precursor Models for Teaching and Learning Science During Early Childhood* (pp. 221-239). Springer. https://doi.org/10.1007/978-3-031-08158-3_12.
- Barnes, D. (1976). *From Communication to Curriculum*. Penguin Books.
- Buckley, B. C. (2000). Interactive multimedia and model-based learning in biology. *International Journal of Science Education*, 22(9), 895-935. <https://doi.org/10.1080/095006900416848>.
- Giere, R. N. (1988). *Explaining Science: A Cognitive Approach*. University of Chicago Press.
- Giere, R. N. (1992). *Cognitive Models of Science*. University of Minnesota Press.
- Giere, R. N., & Moffatt, B. (2003). Distributed cognition: Where the cognitive and the social merge. *Social Studies of Science*, 33(2), 301-310.
- Gómez Galindo, A. A. (2007). ¿Cómo conocemos el mundo?: Los órganos de los sentidos y el sistema nervioso. In *Praxis. Educación primaria, orientaciones y recursos* (pp. 1-21). Wolters Kluwer Educación.
- Gómez Galindo, A. A. (2009). Analysis of the use of drawings and scale models in the construction of multi-modal explanations by primary students when studying the sense of sight. In M. Hammann, A. J. Waarlo & K. Boersma (Eds), *The Nature of Research in Biological Education: Old and new perspectives on theoretical and methodological issues* (pp. 167-184). CD-β Press.

- Gómez Galindo, A. A., & Sanmartí, N. (2008). Transformation of everyday language into scientific language in primary school children's explanations. In M. Hammann, M. Reiss, C. Boutler & D. Tunnicliffe (Eds), *Biology in context: Learning and teaching for the twenty-first century* (pp. 181-190). Institute of Education, University of London.
- Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the Third Space. *Reading Research Quarterly*, 43(2), 148-164.
- Izquierdo-Aymerich, M., & Adúriz-Bravo, A. (2003). Epistemological foundations of school science. *Science & Education*, 12(1), 27-43. <https://doi.org/10.1023/A:1022698205904>.
- Kress, G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal teaching and learning: The rhetorics of the Science classroom*. Continuum.
- Lemke, J. L. (1990). *Talking Science: Language, Learning, and Values*. Ablex Publishing.
- Ravanis, K., & Boilevin, J.-M. (2022). What use is a Precursor Model in early Science teaching and learning? Didactic perspectives. In J.-M. Boilevin, A. Delserieys & K. Ravanis (Eds), *Precursor Models for teaching and learning Science during early childhood* (pp. 33-49). Springer. https://doi.org/10.1007/978-3-031-08158-3_3.
- Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.
- Weil-Barais, A. (2022). What is a precursor model? In J.-M. Boilevin, A. Delserieys & K. Ravanis (Eds), *Precursor Models for teaching and learning Science during early childhood* (pp. 11-32). Springer. https://doi.org/10.1007/978-3-031-08158-3_2.
- Wickman, P. O. (2006). *Aesthetic experience in Science Education: Learning and meaning-making as boundaries of discipline*. Routledge.