

Facilitating the construction of Precursor Models through Early STEAM Education

MICHALIS IOANNOU

Department of Educational Sciences
and Early Childhood Education
University of Patras
Greece
michalissioannou@yahoo.gr

ABSTRACT

This article examines the development and construction of precursor models through STEAM education in Early Childhood Science Education settings. More specifically, it discusses and analyzes the connections of precursor models in activities that follow the Engineering Design Process and link thermal phenomena and other Science concepts with everyday situations and challenges that young children are called upon to solve. It appears that through appropriately designed STEAM activities - utilizing physical experiments, digital experiments-games, drawings, and music-movement games - children are able to construct, initially, precursor models for individual phenomena, such as melting or condensation, and subsequently to construct wider precursor models, directly connected to nature and their experiences, for the water cycle. In this way, the connections between individual precursor models become evident, as does their utilization by children in order to synthesize and construct more complex and elaborate precursor models.

KEYWORDS

Precursor models, STEAM, Engineering Design Process, water state changes, Early Childhood Science Education

RÉSUMÉ

Cet article examine le développement et la construction de modèles précurseurs via l'éducation STEAM dans les contextes de l'éducation scientifique de la petite enfance. Plus précisément, elle discute et analyse les liens des modèles précurseurs dans des activités qui suivent le Engineering Design Process et relient les phénomènes thermiques et autres concepts scientifiques aux situations et défis quotidiens que les jeunes enfants doivent résoudre. Il semble qu'à travers des activités STEAM conçues de manière appropriée – utilisant des expériences physiques, des expériences numériques – des jeux, des dessins et des jeux de mouvement – les enfants soient capables de construire, au départ, des modèles précurseurs pour des phénomènes individuels, tels que la fonte ou la condensation, puis de construire des modèles précurseurs plus larges, directement liés à la nature et à leurs expériences, pour le cycle de l'eau. Ainsi, les liens entre les modèles de précurseurs individuels deviennent évidents, tout comme leur utilisation par les enfants afin de synthétiser et construire des modèles de précurseurs plus complexes et élaborés.

MOTS- CLÉS

Modèle précurseur, STEAM, Engineering Design Process, Changements de l'état de l'eau, éducation scientifique de la petite enfance

INTRODUCTION

Early Childhood Science Education (ECSE) studies often focus on children's ideas and thinking about various scientific concepts and phenomena (Bar, 1989; Chachlioutaki et al., 2016; Ioannou et al., 2024; Savva, 2014). Lately, research in ECSE highlights not only the transformation and the evolution of children's mental representations but also with the construction of precursor models in children's thinking (Ravanis & Boilevin, 2022). Also, in Early Childhood Education it seems that STEAM education is gaining more and more attention because it can be combined with non-STEAM disciplines such as Literature (Ioannou, 2023). STEAM is primarily described as an educational approach that emerges from the disciplines of Science, Technology, Engineering, Arts, Mathematics (Bybee, 2010; Sousa & Pilecki, 2015). The essential perspective of STEAM education is to approach these separate disciplines as a whole (Breiner et al., 2012). It appears that STEAM education, and ECSE in particular, facilitate children to understand the world around them, while simultaneously, acquiring essential skills through utilization of pre-existing mental representations in order to construct their scientific knowledge (Kastriti et al., 2022). An important tool of STEAM Education in Early Childhood Education is the Engineering Design Process, an approach to engineering through a design and problem-solving process (Ioannou, 2023).

Children are familiar with various scientific phenomena about water state changes such as evaporation of the water, melting of the ice and other similar phenomena about water (Ioannou et al., 2023, 2024, 2025; Kaliaspos et al., 2024; Kambouri-Danos et al., 2019). Based on these data in the literature, it seems that research focuses on two points of view, one about the individual state changes of water and one about the water cycle in nature (Ioannou et al., 2023).

Water state changes belong to a broader field of thermal phenomena in early childhood. Children, from a young age, are familiar with water and with phenomena such as evaporation of water and melting of ice. The present article takes into account that research is divided into two approaches to water in early childhood, the point study of matter state changes (Åkerblom et al., 2019; Bar, 1989; Kambouri-Danos et al., 2019; Karlsson, 2017) and the study of the water cycle in nature (Ahi, 2017; Bar, 1986; Christidou & Hatzinikita, 2006; Karlsson, 2017; Malleus et al., 2017; Saçkes et al., 2010; Savva, 2014). A significant research interest emerges, therefore, focuses on thermal phenomena and water state changes.

Despite the difficulties in learning and understanding of several science notions by young children, Early Childhood Education offers interesting experiences about thermal phenomena and could approach scientific knowledge with appropriate teaching methods (Ravanis, 2017). Moreover, previous research on the same area reveals that children could be able to construct a precursor model about the water state changes (Kambouri-Danos et al., 2019; Ravanis et al., 2022).

PRECURSOR MODELS AND STEAM

Children's mental representation of science concepts and phenomena of the physical world are of great importance, as they highlight the fundamental challenges children face, thus enabling systematic design of their transformation in order to approach scientific knowledge (Ergazaki, 2022; Ravanis, 2020). Children interpret the behavior of objects and materials, recognize properties, make predictions, and construct thought about the world around them through cognitive tools they build themselves (Ravanis, 2024). Although models in the didactics of natural sciences constitute a fundamental tool of scientific thinking, their transformation is necessary in order to meet children's educational needs according to their age. A gap is thus

identified between the personal mental constructions of young children and scientific models. This gap is bridged by Precursor Models—cognitive entities established in children’s thinking between personal constructions of reality and scientific knowledge, or more precisely, school scientific knowledge (Ergazaki, 2022; Ravanis, 2020).

The complexity of this area of study leads to the observation that effective science teaching has three fundamental dimensions: a) the thinking of the students (barriers and difficulties), b) the objects that emerge from the natural sciences as they are appropriately transformed for each level of education, and c) the design and implementation of teaching approaches and processes that allow students with different characteristics to access scientific knowledge as it has been transformed for school content (Ravanis & Boilevin, 2022).

In recent decades, precursor models have been studied in the didactics of science in early childhood education (Delsérieys et al., 2018) – defined as “entities in young children’s thinking, which intervene between the naive mental representation and models” (Ravanis & Boilevin, 2022, p. 39). The concept of the precursor model was first proposed by Lemeigman & Weil-Barais (Lemeigman & Weil-Barais, 1993; Weil-Barais, 2022) in France and was based on the theoretical background created by the theoretical constructs of Piaget and Vygotsky (Ravanis, 2020). Its adaption and the highlighting of its importance for young children’s approach to the natural sciences within the framework of ECSE took place some years later (Ravanis, 2000, 2005).

Essentially, precursor models are cognitive entities established in children’s thinking, between personal constructions of reality and scientific knowledge. They also prepare children’s thinking by serving as the foundation upon which more complex models will be elaborated as they progress through higher school levels (Ravanis, 2024). At a functional level, precursor models do not incorporate all the functions of reference models — such as description, explanation, and prediction — but rather some of them, primarily description and prediction. These processes, at the preschool level, were considered sufficient and necessary for defining a precursor model (Ravanis, 2020). They were specifically constructed and devised to support children’s thinking, without contradicting the obstacles and experiential representations of children, and operate in such a way as to prepare and facilitate them. The characteristics of precursor models are compatible with the scientific models used in school education, while simultaneously reflecting a state of dynamic evolution (Ravanis, 2020, 2024).

STEAM education, on the other hand, represents a contemporary approach to learning that aims at the holistic development of students through the integration of various STEAM skills, with an emphasis on the natural sciences, through which students can develop critical thinking, problem-solving skills, and creativity (Martins & Baptista, 2024). Particularly through creativity, critical thinking, communication, and collaboration, a connection is sought between the individual STEAM domains and the real life and needs of students. This integrative STEAM approach constitutes a holistic approach to learning that is not limited solely to its individual domains but extends to all subjects and problematic situations (Chung Le et al., 2023; Martins & Baptista, 2024; Sanz-Camarero et al., 2023Ka).

The discipline of Engineering, which functions as a connecting link between theory and practical application, does not refer solely to the concept of construction. Comprising both the knowledge for design and creation and the problem-solving process, it constitutes an important challenge in early childhood education. The process it follows, the Engineering Design Process (EDP), operates under constraints (laws of nature, material constraints, etc.) as a cyclical process for solving everyday problems (Ioannou, 2023). STEAM education, therefore, through Engineering, introduces a design and problem-solving process — the Engineering Design Process — into education. Indeed, creative approaches and hands-on activities, through the techniques and methods of the creative arts, appear to attract the interest of both children and educators (Sousa & Pilecki, 2015). The Engineering Design Process consists of four (4) stages,

which children follow in a structured and visualized process (Ioannou, 2023): (a) Stage 1 – Problem, (b) Stage 2 – Inquiry, (c) Stage 3 – Designing and Testing, and (d) Stage 4 – Conclusions and Presentation.

In kindergarten, it appears that with STEAM education children can approach complex phenomena and concepts from the natural world, such as thermal phenomena, electricity, or optics (Ioannou et al., 2024; Ravanis et al., 2005; Timpili et al., 2023). A series of studies have also examined the extent to which preschool-aged children are able to understand water state changes through STEAM activities that followed the stages of the Engineering Design Process (Ioannou, 2023; Ioannou et al., 2024, 2025; Kalampos et al., 2024).

It therefore appears that the integration of STEAM education — and particularly science education — into Early Childhood Education and kindergarten helps children to understand the world around them and to acquire essential skills, by drawing on their pre-existing mental representations in order to construct their scientific knowledge. Thus, the construction of precursor models is strengthened through appropriately designed activities, and especially through STEAM activities.

PRECURSOR MODELS ABOUT THE WATER STATE CHANGES

In the context of water state changes, Kambouri-Danos et al. (2019) studied the structure of a precursor model that can support children's scientific thinking about water state changes. The study also notes that, although research has shown that children face difficulties in understanding individual phenomena such as evaporation or condensation, research has not yet been conducted to identify the full sequence of water state changes, which would allow for the meaningful introduction of the water cycle in early childhood education.

Although children face increased difficulties in understanding the thermal character of the concepts of evaporation and condensation (Bar, 1989; Kambouri-Danos et al., 2019), it appears that in early childhood education these concepts can be introduced through various teaching interventions, such as activities that utilize some form of dramatization (Åkerblom et al., 2019; Karlsson, 2017) or activities based on experimental situations, predictions, and processes of verification or rejection of those predictions (Kambouri-Danos et al., 2019). However, the aforementioned studies examine water state changes in isolation, with limited or incidental — or no — connection to the water cycle.

Concerning the water cycle in early childhood education, research focuses primarily on children's understanding of cloud formation and rain (Ahi, 2017; Bar, 1986; Christidou & Hatzinikita, 2006; Malleus et al., 2017; Saçkes, 2010; Savva, 2014). Although children often use experience-based explanations to describe clouds or rain (Malleus et al., 2017), it appears that they can recognize parts of the water cycle even without recognizing the water cycle as a whole (Ahi, 2017; Karlsson, 2017).

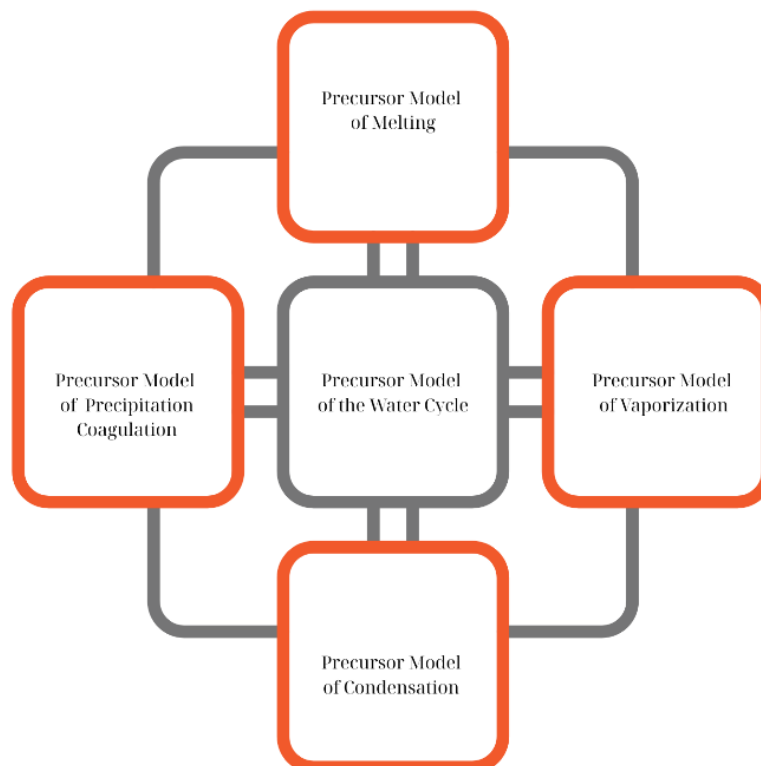
All of these matters were studied through specially oriented published or forthcoming studies, which focus on thermal phenomena and water state changes through a sequence leading to the water cycle in nature (Ioannou, 2023; Ioannou et al., 2024, 2025). Through these studies, it appears that children were able to shape and develop four distinct precursor models concerning melting, vaporization, condensation, and precipitation-coagulation. In these precursor models, children recognized the physical processes of the phenomena and also identified the thermal characteristics of these processes.

Furthermore, the research showed that many children were able to describe the water cycle — even without the use of scientific terminology — through thermal phenomena and water state changes. Drawing on the precursor models formed during the previous phases, which were able to support understanding of water state changes, a precursor model for the

water cycle as a whole was constructed (Figure 1). These findings are consistent with the research of Kambouri-Danos et al. (2019), which highlights children's ability to form a stable precursor model capable of supporting understanding of water state changes.

Young children, therefore, are capable of approaching the water cycle in nature through the study of thermal phenomena and water state changes. Indeed, it appears that they can construct corresponding stable precursor models capable of supporting the understanding of water state changes (melting, vaporization, condensation, precipitation, coagulation) and the water cycle as a whole, through the ability to formulate appropriate descriptions and predictions for the various phenomena.

FIGURE 1



The development of the precursor model for the water cycle through the individual development of 4 precursor models for water state changes.

CONCLUSION

The present work seeks to contribute to a constructive scientific dialogue that connects the educational and didactic use of precursor models in ECSE with research in the field of early STEAM education. In recent years, the integration of STEAM education in early childhood is increasingly being recognized as a necessity, as it allows children to approach complex phenomena through designed teaching practices as well as experiential and cross-curricular approaches. However, the content and methodology of STEAM implementation in Early Childhood Education often remain fragmented or superficial. The use of precursor models in STEAM education therefore presents considerable research interest.

It appears that young children can successfully approach water state changes — such as melting, vaporization, condensation, precipitation, and coagulation — through authentic problems, real or virtual experiments, dramatization, and other experiences (Ioannou, 2023;

Ioannou et al., 2024, 2025). It seems that the critical point of cognitive progress at the conceptual level, as well as the response at the pedagogical level of this particular STEAM research, was the sequence of phases, which followed a progressive path of conceptual evolution based on the existing literature and the initial research findings. This sequence led to the construction of a stable precursor model for the water cycle.

In agreement with previous relevant studies on water state changes, it was found that early scientific thinking in children can be enhanced and reorganized and can take the form of a precursor model through the utilization of children's pre-existing knowledge and real-world experiences (Ravanis et al., 2022; Kambouri-Danos et al., 2019). The use of precursor models as a tool for conceptual mapping and evolution thus proves to be extremely valuable. Precursor models allow the mapping of children's mental representations and cognitive capacities, functioning as solid bridges between experiential and scientific knowledge. Research shows that children, even at a very young age (4 to 6 years old), when provided with a supportive, well-designed, and rich learning environment, can construct stable frameworks for approaching physical reality that are compatible with school scientific knowledge.

Furthermore, in the studies that utilized the Engineering Design Process (Ioannou, 2023; Ioannou et al., 2024, 2025), it appears that its structure and flexibility offer the researcher or educator the opportunity to design and prepare the research process to be followed. The Engineering Design Process also appears to be in full alignment with the structure of an educational project, as it strengthens the orientation towards problem-solving, following and reinforcing scientific thinking while also providing the time and space for changes that may arise from opportunities encountered during implementation.

However, the most significant contribution of the Engineering Design Process for the present paper is the support it offers during the process of constructing precursor models. Initially, it provides the space for studying, identifying, and categorizing children's pre-existing mental representations prior to the introduction of a problematic situation connected to their everyday lives. Subsequently, it appears to facilitate the development of children's thinking and expression through inquiring, prediction, and the utilization of their experiences. It is also developed in a way that enhances children's engagement in experimental and other activities in order to construct new knowledge, and finally, it provides the opportunity for drawing conclusions. It therefore appears that the structure and operation of the Engineering Design Process can contribute to the development of scientific thinking and scientific skills in children through its support of the construction of precursor models.

Finally, the connection between precursor models and the STEAM educational approach opens new perspectives both for the theoretical treatment of precursor models in early childhood and more broadly for the practical integration and utilization of Science Didactics within STEAM education, through the exploitation of children's cognitive and developmental capacities.

REFERENCES

- Ahi, B. (2017). The effect of talking drawings on five-year-old Turkish children's mental models of the water cycle. *International Journal of Environmental and Science Education*, 12(3), 349-367. <https://doi.org/10.12973/ijese.2017.01232a>.
- Åkerblom, A., Součková, D., & Pramling, N. (2019). Preschool children's conceptions of water, molecule, and chemistry before and after participating in a playfully dramatized early childhood education activity. *Cultural Studies of Science Education*, 14, 879-895. <https://doi.org/10.1007/s11422-018-9894-9>.

- Bar, V. (1986). *The development of the conception of evaporation*. The Amos de-Shalit Science Teaching Centre, The Hebrew University of Jerusalem, Israel.
- Bar, V. (1989). Children's views about the water cycle. *Science Education*, 73, 481-500.
- Breiner, M. J., Johnson, C. C., Harkness, S. S., & Koelher M. C. (2012). What is STEM? A Discussion about Conceptions of STEM in Education and Partnerships. *School Science and Mathematics*, 112(1), 3-11.
- Bybee, R. (2010). Advancing STEM Education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30-35.
- Chachlioutaki, M. E., Pantidos, P., & Kampeza, M. (2016). Changing semiotic modes indicates the introduction of new elements in children's reasoning: The case of earthquakes. *Educational Journal of the University of Patras UNESCO Chair*, 3(2), 198-208. <https://doi.org/10.26220/une.2747>.
- Christidou, V., & Hatzinikita, V. (2006). Preschool children's explanations of plant growth and rain formation: A comparative analysis. *Research in Science Education*, 36, 187-210. <https://doi.org/10.1007/s11165-005-9006-1>.
- Chung Le, H., Nguyen, V. H., & Nguyen, T. L. (2023). Integrated STEM approaches and associated outcomes of K-12 student learning: A systematic review. *Education Sciences*, 13(3), 297. <https://doi.org/10.3390/educsci13030297>.
- Delserieys, A., Jégou, C., Boilevin, J. M., & Ravanis, K. (2018). Precursor model and preschool science learning about shadow formation. *Research in Science & Technological Education*, 36(2), 147-164. <https://doi.org/10.1080/02635143.2017.1353960>.
- Ergazaki, M. (2022). The idea of 'Precursor Models' in Biology learning environments for young children: The cases of genetic inheritance and natural selection. In J.-M. Boilevin, A. Delserieys & K. Ravanis (Eds), *Precursor Models for teaching and learning Science during early childhood* (pp. 169-191). Springer. https://doi.org/10.1007/978-3-031-08158-3_10.
- Ioannou, M. (2023). Ice melting in early childhood education: A case of designing and implementing a STEAM project about water state changes. *Mediterranean Journal of Education*, 3(1), 164-175. <https://doi.org/10.26220/mje.4478>.
- Ioannou, M., Kaliampos, G., & Ravanis, K. (2024). Condensation and precipitation of water vapor: The emergence of a Precursor Model through the Engineering Design Process. *Education Sciences*, 14(7), 757. <https://doi.org/10.3390/educsci14070757>.
- Ioannou, M., Kaliampos, G., Pantidos, P., & Ravanis, K. (2025). Fostering early understanding of vaporization in 5-6-year-olds via engineering design. *Journal of Physics: Conference Series*, 3105, 012009. <https://doi.org/10.1088/1742-6596/3105/1/012009>.
- Ioannou, M., Kaliampos, G., Fragkiadaki, G., Pantidos, P., & Ravanis, K. (2023). Thermal concepts and phenomena in Early Childhood Science Education: A literature review. *European Journal of Education Studies*, 10(5), 1-12. <http://dx.doi.org/10.46827/ejes.v10i5.4770>.
- Kaliampos, G., Ioannou, M., Pantidos, P., & Ravanis, K. (2024). The transformation of children's mental representations of 5-6 year olds for coagulation: Precursor Models through a storytelling approach. *Journal of Physics: Conference Series*, 2871, 012010. <https://doi.org/10.1088/1742-6596/2871/1/012010>.
- Kambouri-Danos, M., Ravanis, K., Jameau, A., & Boilevin, J.-M. (2019). Precursor Models and early years Science learning: A case study related to the water state changes. *Early Childhood Education Journal*, 47(4), 475-488. <https://doi.org/10.1007/s10643-019-00937-5>.

- Karlsson, A. B. (2017). "It vapors up like this": Children making sense of embodied illustrations of evaporation at a Swedish school. *International Journal of Early Childhood Environmental Education*, 5(1), 39-56.
- Kastriti, E., Kalogiannakis, M., Psycharis, S., & Vavougiou, D. (2022). The teaching of Natural Sciences in kindergarten based on the principles of STEM and STEAM approach. *Advances in Mobile Learning Educational Research*, 2(1), 268-277. <https://doi.org/10.25082/amlr.2022.01.011>.
- Lemeignan, G., & Weil-Barais, A. (1993). *Construire des concepts en physique : L'enseignement de la mécanique*. Hachette.
- Malleus, E., Kikas, E., & Marken, T. (2017). Kindergarten and primary school children's everyday, synthetic, and scientific concepts of clouds and rainfall. *Research in Science Education*, 47, 539558. <https://doi.org/10.1007/s11165-016-9516-z>.
- Martins, I., & Baptista, M. (2024). Teacher professional development in integrated STEAM Education: A study on its contribution to the development of the PCK of Physics teachers. *Education Sciences*, 14(2), 164. <https://doi.org/10.3390/educsci14020164>.
- Ravanis, K. (2000). La construction de la connaissance physique à l'âge préscolaire : Recherches sur les interventions et les interactions didactiques. *Aster*, 31, 71-94.
- Ravanis, K. (2005). Les Sciences Physiques à l'école maternelle : Éléments théoriques d'un cadre sociocognitif pour la construction des connaissances et/ou le développement des activités didactiques. *International Review of Education*, 51(2/3), 201-218.
- Ravanis, K. (2017). Early Childhood Science Education: State of the art and perspectives. *Journal of Baltic Science Education*, 16(3), 284-288. <https://doi.org/10.33225/jbse/17.16.284>.
- Ravanis, K. (2020). Precursor models of the Physical Sciences in Early Childhood Education students' thinking. *Science Education: Research & Practice*, 76, 24-31.
- Ravanis, K. (2024). The Precursor Models in Natural Sciences learning and teaching. In *Third Young Scholar Symposium on Science and Mathematics Education 2024 (YSSSEE 2024)*, August 30-31, 2024, Universitas Islam Negeri Raden Intan Lampung, Indonesia. <https://doi.org/10.5281/zenodo.18742360>.
- 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.
- Ravanis, K., Charalampopoulou, C., Boilevin, J.-M., & Bagakis, G. (2005). La construction de la formation des ombres chez la pensée des enfants de 5-6 ans : Procédures didactiques sociocognitives. *Revue de Recherches en Éducation: Spirale*, 36, 87-98. https://www.persee.fr/doc/spira_0994-3722_2005_num_36_1_1327.
- Ravanis, K., Kambouri, M., Jameau, A., & Boilevin, J.-M. (2022). Teaching interaction strategies with children 5–6 years in the mental construction of a Precursor Model: The case of water state changes. In J.-M. Boilevin, A. Delserieys & K. Ravanis (Eds.), *Precursor Models for teaching and learning Science during early childhood* (pp. 95-110). Springer. https://doi.org/10.1007/978-3-031-08158-3_6.
- Saçkes, M., Flevares, L. M., & Trundle, K. C. (2010). Four- to six-year-old children's conceptions of the mechanism of rainfall. *Early Childhood Research Quarterly*, 25(4), 536-546. <https://doi.org/10.1016/j.ecresq.2010.01.001>.

Sanz-Camarero, R., Ortiz-Revilla, J., & Greca, I. M. (2023). The impact of integrated STEAM Education on Arts Education: A systematic review. *Education Sciences*, 13(11), 1139. <https://doi.org/10.3390/educsci13111139>.

Savva, S. (2014). Year 3 to Year 5 children's conceptual understanding of the mechanism of rainfall: A comparative analysis. *Ikastorratza e-Revista de Didáctica*, 12, 1-13.

Sousa, D., & Pilecki, T. (2015). *From STEM to STEAM: Integrating the Arts*. California: Corwin.

Timpili, D., Kaliampos, G., & Ravanis, K. (2023). Representations of children 5-6 years old about electric current: a qualitative approach. *Journal of Educational Technology and Instruction*, 2(1), 1-14. <https://ijeti-edu.org/index.php/ijeti/article/view/34>.

Weil-Barais, 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. 11-32). Springer. https://doi.org/10.1007/978-3-031-08158-3_2.