Rethinking Precursor Models in Early Childhood Science Education: reflections, tensions, and future directions

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ABSTRACT
The concept of precursor models has gained increasing attention in early childhood science education as a means of bridging young children's initial mental representations with formal scientific knowledge. This paper offers a reflective and critical reading of the precursor model, drawing on empirical research across early childhood and beyond. Building on studies of children's understanding of physical phenomena, particularly water state changes, as well as recent work on adolescents' alternative ideas in inclusive contexts, the paper explores the epistemological status, pedagogical value, and limitations of precursor models. It is argued that precursor models can be understood as part of a broader constructivist framework concerned with the transformation of learners' alternative ideas across developmental stages and diverse learner populations. The paper concludes by proposing key directions for future research, including the extension of precursor model approaches to inclusive and interdisciplinary contexts.

KEYWORDS
Precursor Models, Early Childhood Science Education, natural sciences, reflective and critical approaches

RÉSUMÉ
Le concept de modèles précurseurs a attiré une attention croissante dans l'éducation scientifique de la petite enfance comme moyen de relier les représentations mentales initiales des jeunes enfants avec les connaissances scientifiques formelles. Cet article propose une analyse réflexive et critique du modèle précurseur, en s'appuyant sur des recherches empiriques menées dans le domaine de la petite enfance et au-delà. S'appuyant sur des études sur la compréhension des phénomènes physiques par les enfants, en particulier les changements de l'état de l'eau, ainsi que sur des travaux récents sur les idées alternatives des adolescents dans des contextes inclusifs, l'article explore le statut épistémologique, la valeur pédagogique et les limites des modèles précurseurs. On soutient que les modèles précurseurs peuvent être compris dans le cadre constructiviste plus large préoccupé par la transformation des idées alternatives des apprenants à travers les stades de développement et la diversité des populations d'apprenants. L'article conclut en proposant des orientations clés pour la recherche future, notamment l'extension des approches du modèle précurseur vers des contextes inclusifs et interdisciplinaires.

MOTS- CLÉS
Modèles précurseurs, éducation scientifique de la petite enfance, sciences naturelles, approches réflexives et critiques

INTRODUCTION

Over the past decades, research in early childhood science education has increasingly recognised that young children enter educational settings with pre-existing ideas about the natural world (Kambouri, 2015). These ideas, often described as mental representations or preconceptions, play a crucial role in shaping subsequent learning processes. Within this context, the concept of the precursor model has emerged as a promising theoretical and pedagogical construct (Lemeignan & Weil-Barais, 1993; Ravanis & Boilevin, 2022). Precursor models are commonly understood as intermediate cognitive structures that mediate between children's initial representations and scientifically accepted models (Ravanis & Boilevin, 2022). They aim to support children in developing more structured, coherent, and transferable understandings of scientific phenomena. As such, they occupy a central position within constructivist and socio-constructivist approaches to learning (Driver et al., 2001).

This paper offers a reflective reading of the precursor model, drawing on both theoretical literature and empirical research conducted in early childhood contexts. In particular, it builds on previous work examining children's understanding of water state changes, which demonstrated that young learners can construct stable precursor models through carefully designed teaching interventions (Kambouri-Danos et al., 2019). Rather than providing a comprehensive literature review, the aim here is to critically engage with the concept by examining its strengths, limitations, and future potential.

Importantly, while the precursor model has been primarily developed within early childhood research, there is increasing evidence that similar processes of conceptual development occur across age groups. Studies on adolescents' understanding of physical phenomena, such as gravity, show that learners, both typically developing and those with special educational needs, hold persistent alternative ideas that shape their reasoning (Kaliampos et al., 2026). This raises an important but underexplored question: to what extent is the precursor model a distinct theoretical construct, and to what extent does it reframe existing ideas within constructivist and conceptual change traditions? Addressing this question is essential if the concept is to move beyond descriptive usefulness and achieve stronger theoretical clarity.

In doing so, this paper seeks not only to review the concept of precursor models, but also to contribute to its further conceptual clarification by situating it within broader discussions on conceptual change, constructivist learning, and the relationship between cognitive development and the epistemological structure of scientific knowledge.

UNDERSTANDING PRECURSOR MODELS: A CONCEPTUAL READING

The concept of precursor models emerges from a long-standing concern in science education: how to support learners in moving from intuitive and often fragmented understandings toward more structured and scientifically aligned knowledge (Weil-Barais, 2001). This conceptualisation has been further developed in recent work, where precursor models are described as structured intermediate forms of knowledge that are intentionally constructed through teaching to support children's transition toward scientific understanding (Boilevin et al., 2022). From this perspective, the precursor model can also be interpreted as a point of articulation between cognitive and epistemological dimensions of learning. On the one hand, it responds to learners' developmental trajectories and the need to build on existing representations; on the other hand, it reflects the structure and constraints of scientific knowledge. In this sense, precursor models can be seen as occupying an intermediate position between learner-centred, psychodidactic approaches and perspectives that emphasise the

epistemological structure of scientific knowledge, highlighting their dual function as both cognitive supports and epistemological tools (Adúriz-Bravo, 2022; Boilevin et al., 2022; Ravanis & Boilevin, 2022).

Unlike misconceptions, which are often framed as obstacles to learning, precursor models represent productive forms of thinking. They are not simplified versions of scientific models, but rather transitional structures that allow learners to organise their understanding in ways that are compatible with scientific reasoning (Ravanis & Boilevin, 2022). In this sense, they enable children to identify relevant aspects of phenomena, establish causal relationships, and generate predictions. Empirical research provides strong support for this interpretation. For example, studies on children's understanding of water state changes have shown that young learners are able to construct a coherent precursor model linking changes of state with thermal variations (Kambouri-Danos et al., 2019). Similar findings have been reported in other domains, including shadow formation (Delserieys et al., 2018) and thermal expansion phenomena (Ravanis et al., 2013), suggesting that precursor models can support conceptual development across different areas of science.

Further evidence highlight the fragmented nature of young children's understanding of physical phenomena. For instance, research on preschool children's conceptions of sound shows that most learners associate sound primarily with its source or receiver, rather than recognising it as a propagating phenomenon in space (Ravanis et al., 2021). This type of reasoning illustrates the need for intermediate conceptual structures that can support the transition toward more scientific forms of understanding.

When considered within the broader field of science education, precursor models can also be linked to the concept of alternative ideas. Research on learners' understanding of scientific concepts demonstrates that children and adolescents construct systematic but non-scientific explanations rooted in everyday experience (Bar, 1989; Driver et al., 1994; Kaliampos et al., 2026; Tytler, 2000;). From this perspective, precursor models can be understood as structured transformations of these alternative ideas.

At the same time, the conceptual status of precursor models remains somewhat ambiguous. While they are presented as distinct from misconceptions, preconceptions or alternative conceptions, the boundaries between these constructs are not always clearly articulated. In practice, precursor models often appear to describe a stage within conceptual change, rather than a fundamentally separate category of knowledge. This raises the possibility that the concept, while pedagogically useful, may require further theoretical refinement to justify its distinctiveness.

THE PEDAGOGICAL VALUE OF PRECURSOR MODELS

The precursor model framework offers important pedagogical insights by emphasising the transformation of learners' existing ideas rather than their replacement. A key strength lies in its ability to bridge everyday and scientific knowledge. Rather than dismissing children's initial ideas, this approach builds on them, supporting their reorganisation into more coherent forms. This aligns closely with constructivist principles, where learning is seen as an active process grounded in prior knowledge (Driver et al., 2001).

Furthermore, precursor models support meaningful learning by focusing on relationships within phenomena. For example, understanding that heat causes changes of state enables children to apply their knowledge across different contexts, supporting explanation and prediction (Kambouri-Danos et al., 2019; Ravanis & Boilevin, 2022).

Therefore, the role of teaching interactions is also central as precursor models are constructed through guided interaction. Research has demonstrated that specific teaching

strategies, such as prediction–observation–interpretation sequences and structured dialogue, play a key role in facilitating conceptual change (Ravanis et al., 2013). For example, strategies such as highlighting contradictions between predictions and observations or guiding attention toward critical variables can significantly support conceptual development (Ravanis et al., 2013).

Importantly, recent research suggests that these constructivist principles extend to inclusive contexts. Studies on adolescents with autism indicate that they often share similar alternative ideas with their typically developing peers, although with differences in frequency (Kaliampos et al., 2026). This suggests that teaching approaches based on transforming alternative ideas can be applied across diverse learner populations, supporting inclusive educational practices.

Despite these advantages, research has shown that eliciting children's initial ideas is not straightforward in practice. Studies on pre-service early childhood teachers indicate that they often rely on closed, factual questions, rather than open-ended and productive ones that support deeper thinking and conceptual development (Christidou et al., 2025). This perspective also highlights the importance of considering learning as a socio-cognitive process. The construction of precursor models does not occur in isolation but is shaped through interaction, dialogue, and shared meaning-making processes within the classroom. Such an understanding reinforces the view that conceptual development is not solely an individual cognitive achievement, but also a socially mediated activity.

CONCEPTUAL TENSIONS AND CRITICAL REFLECTIONS

Despite their strengths, precursor models raise a number of important theoretical and methodological challenges that remain insufficiently addressed in the literature. While the concept has been widely used to describe learning processes in early childhood science education, its analytical precision and explanatory power remain open to question, indicating the need for further theoretical and empirical development. In addition, the distinction between precursor models, misconceptions, and alternative conceptions is not always clearly defined, leading to inconsistencies in their application (Lemeignan & Weil-Barais, 1993).

Another issue relates to their normative orientation. Precursor models are designed to guide learners toward scientific knowledge, which raises questions about how to balance this with respect for children's own ways of thinking, particularly in early childhood contexts where exploratory learning is emphasised. This issue also highlights an important practical limitation: even when the theoretical importance of children's ideas is acknowledged, teachers may lack the pedagogical tools to effectively access and work with them (Christidou et al., 2025).

Methodological challenges are also evident. Much of the research relies on qualitative analysis of children's discourse, which can raise issues of interpretation and generalisability (Patton, 2002). In addition, questions remain regarding the stability and transferability of precursor models. While children may demonstrate understanding in specific contexts, it is unclear whether these models persist over time or transfer across domains. A further concern relates to the potential re-labelling of existing constructs. The emphasis on intermediate cognitive structures closely aligns with long-standing work on alternative conceptions and conceptual change (Driver et al., 1994). As such, it is not always clear whether precursor models offer genuinely new theoretical insights, or whether they provide a pedagogically oriented reinterpretation of established ideas. This is not necessarily a limitation; however, it requires explicit acknowledgement and further investigation.

Finally, evidence from studies with older learners suggests that similar processes of conceptual transformation occur beyond early childhood. Adolescents' reasoning about gravity

reveals persistent alternative ideas requiring systematic reorganisation (Kaliampos et al., 2026). This raises the possibility that precursor models may reflect a broader mechanism of conceptual development. Such findings further underline the complexity of conceptual development, suggesting that the transition toward scientific understanding is not straightforward and requires carefully designed pedagogical mediation (Ravanis et al., 2021). These considerations suggest that the precursor model may be less a discrete category of knowledge and more a functional construct within broader theories of conceptual change.

FUTURE DIRECTIONS

Future research should prioritise the further conceptual clarification of precursor models by developing more precise definitions and criteria for their identification. This is particularly important in light of the conceptual ambiguities identified in this paper and would contribute to strengthening their theoretical coherence and consistency across studies.

A second important direction concerns the relationship between teaching interactions and conceptual development. While existing research highlights the role of dialogue and scaffolding, more fine-grained analyses of interactional processes are needed to better understand how precursor models are constructed, negotiated, and stabilised in classroom contexts. Such work would offer a deeper understanding of the mechanisms through which conceptual change is supported.

In addition, longitudinal research is needed to explore the stability and evolution of precursor models over time. In particular, it remains unclear whether these models persist, transform, or are reorganised as learners encounter more formal scientific knowledge in later stages of education.

Finally, expanding research across diverse contexts, including different scientific domains, age groups, and inclusive educational settings, would enhance the applicability and scope of the precursor model framework. Exploring how precursor models function across varied cognitive profiles may also provide valuable insights into their role as flexible tools for supporting learning in heterogeneous classrooms.

CONCLUSION

The concept of the precursor model offers a valuable framework for understanding how young children develop scientific thinking. By focusing on the transformation of learners' initial ideas, it provides a nuanced account of learning as a gradual and structured process (Kambouri-Danos et al., 2019; Ravanis & Boilevin, 2022).

This paper has argued that the relevance of precursor models may extend beyond early childhood. By linking this concept with broader research on alternative ideas and conceptual change (Driver et al., 1994; Tytler, 2000), including studies with adolescents and learners in inclusive contexts (Kaliampos et al., 2026), it becomes possible to reconceptualise precursor models as part of a wider theory of learning in science education.

From this perspective, precursor models should not be viewed solely as cognitive intermediaries, but as part of a broader conceptual framework that connects cognitive development, teaching practice, and the social dimensions of learning. Their value lies not only in supporting the transition toward scientific knowledge, but also in providing a lens through which the processes of learning and teaching can be better understood.

At the same time, this reconceptualisation highlights the need for further theoretical clarification and empirical investigation, particularly in relation to their stability, transferability,

and application across diverse educational contexts. In this sense, precursor models may be best understood not as fixed entities, but as dynamic and context-dependent tools within the broader process of conceptual development.

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