The use of precursor models in design-based research

ANA DE ECHAVE SANZ, FRANCISCO JAVIER SERÓN TORRECILLA

Department of Subject-Specific Pedagogy
Division of Experimental Science Education
University of Zaragoza
Spain
aechave@unizar.es
fjaseron@unizar.es

ABSTRACT

Design-based research (DBR) provides an appropriate framework for analyzing the application and utility of precursor models across diverse educational contexts and perspectives. Kolb's experiential learning theory further serves as a valuable lens for conducting a reflective, practice-oriented analysis of this conceptual approach. In this study, utilizing the Predict-Observe-Explain (POE) structured inquiry strategy, we evaluate numerous classroom interventions implemented over recent years to examine the affordances and potential limitations of these models. Specifically, we highlight several case studies involving pre-service teachers and primary school students engaged in developing explanatory precursor models for various physical and chemical phenomena. Furthermore, we argue that it is crucial to analyze how precursor models—developed as scaffolding tools by teacher educators—are adopted and utilized by both teachers and children in university and school settings. Within this framework, we examine how conceptual models relate to precursor models, emphasizing the significance of a comprehensive understanding of their constituent elements within science education.

KEYWORDS

Design-based research, Predict-Observe-Explain, experimental learning, didactic triangle, didactic transposition

RÉSUMÉ

La recherche orientée par la conception (ROC) offre un cadre méthodologique approprié pour analyser l'utilisation et l'utilité des modèles précurseurs dans différents contextes d'enseignement et selon diverses perspectives. Le cadre de l'apprentissage expérientiel de Kolb s'avère également précieux pour mener une analyse réflexive de ce concept d'un point de vue pratique. Dans le cadre de notre étude, en nous appuyant sur la stratégie d'enquête structurée POE (prédire, observer, expliquer), nous avons mis en œuvre de nombreuses interventions pédagogiques au cours des dernières années, ce qui nous a permis d'examiner le potentiel et les limites possibles de ces modèles. Plus précisément, nous mettons en lumière certains de ces cas impliquant des enseignants en formation initiale et leurs futurs élèves du primaire dans le développement de modèles précurseurs explicatifs relatifs à divers phénomènes physiques et chimiques. De plus, nous jugeons particulièrement pertinent d'analyser l'appropriation et l'utilisation des modèles précurseurs développés comme outils d'étayage par les formateurs d'enseignants, que ce soit dans le contexte universitaire ou scolaire. Dans ce cadre, nous analyserons comment les modèles conceptuels s'articulent par rapport aux modèles *précurseurs, tout en soulignant l'importance, du point de vue de la didactique des sciences, d'une compréhension approfondie des multiples éléments qui constituent ces derniers.*

MOTS- CLÉS
Recherche orientée par la conception, prédire-observer-expliquer, apprentissage expérientiel, triangle didactique, transposition didactique

INTRODUCTION

Design-based research (DBR) is an educational research methodology deeply rooted in the experiential analysis of instructional activities (Brown, 1992; Collins, 1992). This approach facilitates the design of teaching and learning sequences (TLS) within complex environments, such as science classrooms, enabling researchers and practitioners to analyze, evaluate, reflect upon, and modify interventions through an iterative process (Cobb et al., 2003; Galvin & Cochrane, 2023; Kelly, 2003). Further, experiential learning theory provides a robust framework for examining the mechanisms of knowledge construction and application (Kolb, 2014), thereby underscoring the value of precursor models across different instructional contexts.

Within this theoretical paradigm, the concept of a precursor model extends beyond the mere disciplinary knowledge of school science. It integrates both conceptual schemas and reasoning dynamics (i.e., school scientific thinking in action) while embedding an inherent evolutionary and transformative component directed toward canonical school science models (Acevedo-Díaz et al., 2017). This evolutionary nature allows researchers to differentiate between initial perceptual models, phenomenon-oriented models, and, ultimately, concept-oriented models (Guisasola, 2024; Gustina et al., 2023). Consequently, it enables the formulation of instructional strategies grounded in scientific inquiry, modeling, and argumentation practices tailored to the precursor models operating within the classroom (Setiyani et al., 2023).

To facilitate the transposition of school science models provided by teacher educators, we have designed several teaching scenarios over the past few years (de Echave et al., 2016; 2025; Rodríguez-Casals et al., 2022; Serón et al., 2023; Serón Torrecilla et al., 2024). In these scenarios, precursor models have been deployed through various roles and instructional approaches:

a) The appropriation of standardized school science precursor models by pre-service primary school teachers.
b) The implementation of these models in primary school classrooms by student teachers during their field placements; that is, utilizing a school science model explicitly designed with didactic elements for teaching.
c) The development of precursor models by primary school students themselves, driven by activity sequences linked to the classroom phenomena under investigation.

The findings derived from this variety of scenarios—spanning phenomena such as buoyancy, combustion, electricity, sound, and light/color—are extensive (Rodriguez-Casals et al., 2022; Serón et al., 2024). This diverse experiential base has driven a deep reflection on the relevance and instructional utility of precursor models. It has allowed us to map the classroom relationships between different conceptual domains and, through reflective analysis, address dimensions that require further theoretical development (Boilevin et al., 2022). Aligning our practice with instructional techniques consistent with the precursor framework, we implemented the POE strategy. This strategy has proven essential for comparing the precursor models operationalized across different scenarios designed to introduce scientific practices into the classroom.

While academic research on the POE model and its multi-level educational application (including teacher training) warrants further empirical investigation, current literature substantiates its efficacy (Sakyi-Hagan, 2024). Specifically, it promotes dialogic activities that are particularly relevant within Inquiry-Based Learning (IBL) frameworks where precursor models manifest (Kambouri-Danos et al., 2019). In turn, this paper reflects on these outcomes to evaluate our instructional interventions and highlight both the conceptual strengths and the underlying limitations of the precursor model approach—whether to be resolved through expanded empirical contexts or epistemological refinement.

APPROPRIATION OF PRECURSOR MODELS BY PRESERVICE PRIMARY TEACHERS

In the field of science education, the application of scientific conceptual models is widespread and constitutes a major area of didactic research. However, its extensive use has occasionally led to the misinterpretation or conflation of the specific concept of the precursor model. While scientific models represent abstract, simplified interpretations of phenomena, precursor models function strictly as didactic scaffolding tools (Ravanis & Boilevin, 2022). Therefore, it is essential to establish the relationships, boundaries, and conceptual difficulties that pre-service primary teachers encounter when understanding and appropriating precursor models.

In comparing the two, conceptual models and modeling practices represent fundamental scientific activities that allow students to approach complex phenomena. That is, they align school science closer to normative, canonical science to explain and predict natural phenomena. In contrast, precursor models serve as pedagogical and didactic scaffolding designed to bridge the gap between the learner's initial mental representations and new, highly abstract scientific concepts. A critical aspect of this process is the appropriation of precursor models that have not been autonomously generated by the pre-service teachers themselves. We examine how these external models can become highly effective tools when aligned with the POE strategy to activate students' prior ideas during classroom experiments.

The POE strategy is particularly effective in activating both scientific reasoning and pedagogical content knowledge during practical work, bridging "Minds-On" and "Hands-On" dimensions (Millar, 2004). These activities foster experiential learning, allowing researchers to distinguish the didactic dimensions of precursor models when utilized by teachers versus how they are manifested by children.

As a practical example, we analyze the phenomenon of static electricity through the appropriation of a precursor model we term the "balls and holes" model, designed by us as teacher educators. This model aligns with the kinetic molecular theory of charged matter, integrating the macroscopic, sub-microscopic, and symbolic representations characteristic of the physical sciences (Taber, 2015). It enables students to reason through macro-level phenomena using POE strategies without creating conceptual obstacles for the future evolution of the model of matter.

As a didactic tool, it allows us to track how teachers' representations of static electricity evolve through practical experience. Guided by the POE strategy, pre-service teachers progress toward a transformative adoption of this precursor model. This appropriation becomes highly evident in more complex experimental setups, such as those involving a Van de Graaff electrostatic generator. When the phenomenon no longer depends on manual manipulation and the machine operates autonomously to accumulate charge, it becomes easier to analyze the teachers' internalized models. Our analysis shows that, grounded in prior experience and the scaffolding of the precursor model, teachers successfully explain the generator's mechanism in a scientifically rigorous manner, representing a measurable improvement in conceptual understanding

PRECURSOR MODELS AND THEIR APPLICATION IN DESIGN TEACHING AND LEARNING ACTIVITIES: THE ROLE OF STUDENTS AND TEACHERS IN THE STUDY OF LIGHT AND SHADOWS

In the preceding section, we emphasized how the empirical components identified within the DBR framework and our training model are linked to practical work. These components are better understood when considering the didactic dimensions that teachers mobilize. Furthermore, we noted through the POE strategy that the observation stage is precisely when teachers confront and negotiate the tension between their own mental models and the pre-designed instructional model. At this stage, their initial representations are tested, facilitating the evolution of their precursor models. Crucially, this evolution directly influences how they design subsequent classroom activities, as it forces them to account for the interactions and precursor models that children bring to the classroom.

Precursor models are of fundamental importance in exploring how conceptually compatible representations are positioned within scientific teaching models. This positioning falls squarely within the domain of didactic transposition (Chevallard, 1991) and underscores the role assigned to precursor models in optimizing the didactic triangle (Houssaye, 1988). In identifying the elements of children's models linked to a given phenomenon (such as electricity), researchers can effectively guide instructional design (Pantidos & Kaliampos, 2023). Our data supports the premise that children's initial models must inform the teacher's instructional design. The core value of our analysis lies in exploring this space of confrontation between teacher and student models; it is within this intersection that a robust framework for experiential learning emerges, allowing for the continuous refinement of both the teachers' and the students' precursor models.

To illustrate this intersection within the didactic triangle, we examine teacher-student interactions during lessons on light and shadows. In one case, a pre-service teacher entered the classroom with an assumed model regarding shadows and the rectilinear propagation of light. The teacher designed a series of activities based on this initial understanding but had to dynamically restructure their pedagogical approach upon interacting with the children's own precursor models. The primary students were able to grasp specific characteristics of light, such as its rectilinear path, by experimenting with opaque/transparent materials and perceiving reflected light. The designed activity sequences allowed the children's models to evolve from purely perceptual frameworks to initial conceptual models, where light is treated as an independent entity beyond immediate visual perception, achieved by controlling the light source and working with projected light. These learning situations highlight the complex shift from the master pedagogical model to concrete activity design, emphasizing the primary students' capacity to construct precursor models through structured sequences—a dimension addressed in detail below.

CHILDREN'S PRECURSOR MODELS: THE CASE OF BUOYANCY

The implications of children's precursor models for instructional design are multifaceted. Research indicates that the constituent elements of children's precursor models exhibit a marked phenomenological character heavily tied to material and physical elements. From this phenomenological perspective, analyzing the conceptual leap that occurs when children identify a contradiction in their prior ideas reveals that precursor models serve as vital facilitating scaffolds (Tytler & Peterson, 2004). This transition occurs when instructional designs explicitly incorporate children's precursor models, acknowledging their pedagogical importance in supporting the restructuring of new ideas.

Our experience with various physical phenomena has allowed us to evaluate these dynamics deeply, and here we focus specifically on our contributions to the study of buoyancy. We highlight how multiple variables must be managed within activity design to foster the evolution of the students' precursor models. Within this phenomenological approach, many core elements of the target scientific model do not serve as the starting point of the learning process, but rather as its ultimate objective.

Consequently, for precursor models to evolve effectively, emphasis must be placed on the material context and the materiality of learning. This requires designing manipulative activities that allow children to link learning objectives directly to physical objects, materials, and empirical outcomes (e.g., exploring buoyancy by varying object shape, size, and material composition), prompting them to formulate questions and explanations.

Throughout these interventions, the observation of the phenomenon is guided by a focal question: "Does it float or sink?" (Rodríguez-Casals et al., 2022; de Echave et al., 2025). From an experiential learning perspective within practical schoolwork, children formulate predictions based on experiential models derived from prior everyday encounters. Because these initial models eventually require the integration of new, formal concepts, it is critical that children actively adopt a new perspective on the phenomenon.

When diving deeper into their precursor model, the teaching and learning process must focus precisely on these structural elements. This is achieved by introducing varied experiences with physical objects (e.g., testing a lemon with and without its peel). Such didactic transformations are adopted by students through structured teaching and learning sequences (TLS). In these transitions, the friction between students' intuitive ideas and formal physical concepts serves as the primary driver for transforming scientific knowledge—a context where the student's precursor model becomes uniquely relevant to explaining buoyancy events.

FUTURE DIRECTIONS

The precursor model represents a powerful epistemological framework, and may even take on ontological significance as its functionality and conceptual boundaries expand beyond the strictly experiential definitions that have characterized it so far. From our perspective, we outline several research lines that require further academic inquiry:

- The systematic role of precursor models for teachers, designed from the perspective of university teacher educators.
- The evaluation of the didactic component of precursor models within formal teacher training curricula.
- The operational potential of precursor models to strengthen and stabilize the vertices of the didactic triangle.
- The interactive dynamics during the design of teaching sequences between teachers' frameworks and primary school students' precursor models.
- The empirical analysis of children's precursor models as foundational baseline data for adapting science curricula to school contexts.

While noted by various scholars, these lines of thought have frequently been overlooked in favor of focusing purely on the functional, immediate performance of the models. Ultimately, there is a pressing need to adopt a holistic perspective that integrates the didactic and pedagogical components of the model within its broader study context, maximizing its influence on all stakeholders involved.

CONCLUSIONS

As argued throughout this study, we emphasize the concrete experience of conceptual transformation, which facilitates abstraction and allows for a clearer identification of a model's structural elements. In this regard, the DBR framework—operationalized through practical activities and Kolb's experiential learning theory—provides a rigorous basis for decoding the mechanisms underlying the precursor models of various physicochemical phenomena. Concurrently, we emphasize its potential for didactic transposition and its utility in refining our understanding of the didactic triangle. Based on our reflective analysis, the context of these interactions presents distinct operational differences depending on the agent involved: teacher educators, pre-service teachers, or primary students.

First, it is highly relevant to analyze the operation of these models from the perspective of teacher educators. From this viewpoint, emphasis must be placed on the didactic elements mobilized during interactions with pre-service teachers. It is here that the POE strategy demonstrates its value within university training, particularly when embedded in experiential learning through practical laboratory work. This approach allows us to analyze the critical appropriation of models that occurs immediately following the observation phase. This phase represents a turning point, as student teachers explicitly recognize the tensions between their intuitive conceptions and the target precursor model—a process that merits longer longitudinal exploration and analysis.

Second, and directly connected to the teacher-training scenario, are the implications these processes hold for classroom activity design. In the interactions between practicing student teachers and primary school students, the model plays a central role. The design of the instructional sequence is decisively influenced by both the scientific content and the didactic strategies acquired during university training, especially when teachers explicitly account for the children's initial models.

Third, the internalized model that children hold regarding a phenomenon stands out as a primary element for structuring learning around empirical observation. This cognitive model serves as the baseline that allows students to evolve toward more sophisticated precursor models of scientific learning throughout their school careers.

As a final reflection, while literature indicates that precursor models are dynamic and evolve as they impact educators, teachers, and students, further empirical exploration is required. Future research should focus on demonstrating how the cognitive scaffolding provided by these models is inherently adaptive, evolving systematically at each educational stage in relation to the same natural phenomenon under study. Our experience confirms that this adaptability makes the precursor framework uniquely relevant to the field of experimental science education within the context of practical work.

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