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THEORETICAL PAPER

Design of Teaching and Learning Sequences and Complex Educational Games: a strategic proposal for mobilizing the Model of Educational Reconstruction

Design de sequências didáticas e jogos educacionais complexos: proposição de estratégia para mobilização do Modelo de Reconstrução Educacional

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Abstract. The Model of Educational Reconstruction (MER) has been employed in research within the field of Science Education to support educational design, particularly through development research. Based on its theoretical and methodological premises, we aim to address the following question: *How can the theoretical and methodological aspects of the MER be mobilized for the design of Teaching and Learning Sequences (TLS) and Complex Educational Games (CEG)?* To this end, we propose a Mobilize Strategy that recursively articulates three elements: the characteristics of teaching and learning environments; the design trajectory; and the pedagogical potentialities framework. This represents an ongoing effort to operationalize the design process based on the MER, offering promising pathways for its application across different types of interventions. We argue that the MER can be adjusted according to the specificities of the educational intervention. In the case of CEG, for instance, a phase dedicated to preliminary ludic research is required. However, we maintain that, regardless of the type of intervention, the first phase of educational design grounded in the MER culminates in the identification of pedagogical potentialities. The next steps toward advancing what has been proposed here involve deepening the understanding of how the MER can support the validation processes of educational interventions.

Keywords: Science Education, social research, Instructional Design, Design-Based Research, Pedagogical Potentialities.

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Resumo. O Modelo de Reconstrução Educacional (MRE) tem sido empregado em pesquisas no campo da Educação em Ciências como suporte ao design educacional, especialmente por meio da pesquisa de desenvolvimento. Considerando suas premissas teóricas e metodológicas, buscamos responder à seguinte questão: *Como mobilizar os aspectos teóricos e metodológicos do MRE para o design de Sequências Didáticas (SD) e Jogos Educacionais Complexos (JEC)?* Para isso, propomos uma Estratégia de Mobilização que articula recursivamente três elementos: características dos ambientes de ensino e aprendizagem; percurso de design; e quadro de potencialidades pedagógicas. Trata-se de um esforço contínuo de instrumentalização do processo de design com base no MRE, oferecendo caminhos promissores para sua aplicação em diferentes tipos de intervenção. Compreendemos, assim, que o MRE pode ser ajustado de acordo com as especificidades da intervenção educacional. No caso dos JEC, por exemplo, é necessária uma fase voltada à pesquisa preliminar lúdica. No entanto, defendemos que, independentemente do tipo de intervenção, a primeira fase do design educacional fundamentado no MRE culmina na identificação das potencialidades pedagógicas. Os próximos passos para o avanço do que aqui foi proposto consistem em aprofundar a compreensão sobre como o MRE pode contribuir para os processos de validação das intervenções educacionais.

Palavras-chave: Educação em Ciências, Pesquisa Social, Design Instrucional, Pesquisa Baseada em Design, Potencialidades Pedagógicas.

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Introduction

Design-Based Research (DBR) has proven to be an important theoretical and methodological approach for promoting and implementing educational interventions, thereby enhancing teaching and learning processes (Bruno & Carolei, 2018; Chusinkunawut et al., 2021; Johann et al., 2025; Lie et al., 2021). One of the main characteristics of these studies is the design of instruments and methodological strategies for both research and teaching, facilitating the relationship of theoretical aspects (whether of specific or pedagogical concepts) with educational practice.

In this context, in 1996, a group of German researchers proposed the Model of Educational Reconstruction (MER), which has since been used in science education research, predominantly as a methodological framework (Duit, 2006; Duit et al., 2012; Kersting et al., 2018; Komorek & Kattmann, 2008; Niebert & Gropengiesser, 2013; Reinfried et al., 2015). MER's structures the instructional design process from three components: i) Content structure analysis; ii) Investigations into student perspectives; iii) Design and assessment of teaching and learning environments (Duit et al., 2012). However, it is noteworthy that conceiving the MER just as a methodological framework disregards the theoretical aspects that justify the choice of its components and the relationship established between them (Duit et al., 2012; Kattmann et al., 1996; Silva, 2019).

Therefore, it is essential to highlight that the understanding of MER is not shared here from a predominantly methodological perspective. It is argued that the MER is characterized by the integration of the grand theories (partial theories) that support it, with the intermediary theoretical framework (meta-theory) that defines it, and with the design tool (theories made usable)[1,2] associated with it. This defense comes from the understanding presented by Kattmann (2007, p. 97, our translation), who states that the model is "a meta-theory, in which several partial theories are used to frame professional teaching and learning". The author also highlights that these partial theories are gathered, modified, and made usable in the MER.

Aiming to contribute to the advancement of theoretical discussions surrounding the model, we previously proposed the Constructivist Intermediate Framework of Educational Reconstruction (CIFER) was previously proposed highlighting which aspects of grand theories are considered in the MER, as well as how these aspects make up its intermediate framework to theoretically support the design process of teaching and learning environments (Silva & Ferreira, 2020; Silva et al., 2022). Then, as an intermediary framework, the MER structures the design process by providing theoretical orientations that can be epistemological, cognitive, pedagogical, and methodological (Silva, 2019). As a design tool, the MER instrumentalizes the design process through its three components and the interactions established between them (Duit et al., 2012), which lead to understanding the model's characteristic design path.

1 For a better understanding of the major theories, intermediate frameworks and design tools, see Ruthven et al. (2009).
2 For an in-depth understanding of MER as an intermediate theoretical framework and as a design tool see Silva and Ferreira (2020).

Given the above, it is corroborated with the idea that the MER is a valuable and promising model for development research (Labude, 2008) that emphasizes the practical nature of educational interventions (Sarmento *et al.*, 2013) and, having them as a research object, have the purpose of developing them to solve real problems identified in educational practice (Plomp, 2013). In this context, there is research into the development of Teaching and Learning Sequences (TLS) and Complex Educational Games (CEG).

When we talk about the development of TLS, it is important to understand that, in Brazil, the definition of *Didactic Sequence* proposed by Zabala (1998) is traditionally used. Elsewhere in the world, a commonly accepted definition is the Teaching and Learning Sequence (TLS) developed by Méheut and Psillos (2004). These ideas are not contradictory, but they differ significantly in their structuring elements (Mesquita et al., 2021). However, we consider that none of these alone is sufficient to place the TLS in the context of the MER. Therefore, we propose an expansion of the concept of TLS, understanding it as a set of ordered, articulated and structured activities based on a gradual process of investigation, which intertwines the scientific and student perspectives, with the aim of achieving specific educational objectives and offering solutions to educational problems present in contexts of Science Education practice (Silva et al., 2022).

Regarding CEG, it is important to highlight that, more than being mere tools, these games can be characterized as interventions that provide complete learning experiences, as CEG functions as mediators between the individual and knowledge. In this sense, we differentiate CEGs from traditional Educational Games, which are developed, applied, and evaluated without any theoretical or methodological rigor (Lira & Smania-Marques, 2021).

The CEG are defined as games developed to provide active learning, which balances playful and educational aspects to promote a favorable learning environment, structured with support in design processes guided by consistent theoretical and methodological references (Lira & Smania-Marques, 2021; Smania-Marques et al., 2024). To start a new CEG it must be engaged with a real educational problem (the same applies to TLS). The main characteristic of these games is the definition of objectives that aim to contemplate both a ludic dimension, which involves aspects such as socialization, affectivity, fun, pleasure and displeasure (Kishimoto, 2005); with an educational, as an educational dimension, which involves the development of competencies and/or skills and the learning of content (Zabala, 1998) with a multidimensional approach (Conrado & Nunes-Neto, 2018).

Mobilizing the theoretical and methodological aspects of the MER in the design process of TLS and CEGs is no simple task. This model presents an extensive set of theoretical aspects and complex methodological interactions, which, in addition to being clearly understood, must be considered throughout the proposed design path based on it. Considering what has been presented, this work seeks to answer the following research question: How can the theoretical and methodological aspects of MER be mobilized for the design of Teaching-Learning Sequences and Complex Educational Games in Science Education?

To answer this question, the objectives are: (1) to consolidate the idea that the MER is a promising intermediate framework and design tool to support the design process of teaching and learning environments; (2) to present a viable mobilization strategy for implementing this model in TLS and CEG design processes.

The following text initially presents the structuring aspects of the MER, highlighting its intermediate theoretical framework — that is, how certain elements of major theories, such as constructivist foundations, are modified and reconstructed to compose the theoretical structure of the model. Next, we present the strategy for mobilizing the theoretical and methodological foundations of the ERM, as proposed in this article, emphasizing how this strategy can be applied to the design of Teaching-Learning Sequences and Complex Educational Games. Finally, we will offer some concluding remarks, aiming to highlight the implications of the proposal for science research and teaching, as well as suggestions possible.

Structuring aspects of the model of educational reconstruction

The structuring aspects of the MER deal with the theoretical and methodological elements that underline its intermediate theoretical framework and structure its design tool. As we have said, the methodological discussion of MER is very widespread in the literature in the Science Education literature. Thus, at this moment, the emphasis will be on expanding the theoretical discussion of the model, considering as a starting point the contributions of Silva (2019).

Theoretically characterizing the MER means pointing out which aspects of major reference theories are considered in structuring this model, showing how these aspects are modified, improved and/or restructured to make up its intermediate framework and how they can be mobilized through the design tool associated with it.

For example, in terms of Design-Based Research (DBR), the aim of preliminary research is the exhaustive analysis of the educational context and problem, together with the development of a conceptual frame of reference, based on the literature review (Plomp, 2013). In the Constructivist Intermediate Framework for Educational Reconstruction (CIFER), the aspect of preliminary research is reconstructed through the interaction of theoretical aspects from DR and Constructivist Foundations. Thus, we propose the idea of extended preliminary research, which broadens its nature with the aim of reaching students' pre-instructional conceptions, establishing relationships between this knowledge and scientific knowledge, and maintaining the assumption that, in the process of designing the learning environment, scientific concepts have the same weight as students' conceptions, which are considered teaching tools.

The aspects listed from the major theories that were modified to propose CIFER are systematized in Table 1.

Table 1. Aspects of the grand theories imported and/or reconstructed in the Constructivist Intermediate Framework of Educational Reconstruction.

Grand theories of reference	Theoretical aspects listed from the grand theories of reference	Theoretical aspects transposed and/or reconstructed in the intermediate framework
Constructivist Bases	**Constructivist Epistemology** 1. Defends the mixture of empirical and conceptual, deriving from reason, as a source of knowledge. 2. Conceives knowledge of science as intersubjective.	**Educational Reconstruction Model Ideas** 1. The knowledge needed to develop science teaching and learning environments comes from the conceptual knowledge of science and the students' pre-instructional knowledge[3], more than that, from the relationships that can be established between this knowledge. 2. The structure of scientific knowledge is fundamentally different from the structure of knowledge to be taught, as the goals for which each structure is created are distinct.
	Constructivist Pedagogy: Classic Approach to Conceptual Change 3. Learning is seen as the replacement of pre-instructional conceptions with scientific ideas. 4. Students' ideas are seen as obstacles to learning. 5. Learning is based on purely rational aspects. 6. The knowledge acquisition process is seen as an individual construction process.	**Conceptual Reconstruction** 3. Learning is seen as the reconstruction of pre-instructional conceptions by scientific ideas. 4. The students' conceptions are understood as starting points, being necessary tools for the teaching and learning processes. 5. Learning is based on rational, affective, and situational aspects. 6. The process of knowledge acquisition is seen as an individual construction process activated within a given social and material environment.
German tradition of *Bildung* and *Didaktik*	**Didactic Analysis** 7. Principle of the primacy of teaching objectives and intentions in the instruction planning process.	**Educational Importance Analysis** 7. The first step in planning teaching and learning environments is the definition of learning objectives, based on the students' perspectives and the structure of the scientific content to be taught.
	Fundamental interaction of instructional variables 8. The importance of considering the fundamental interaction of all the variables that determine instructional planning. 9. The interaction between instructional variables is significantly influenced by the intellectual and behavioral preconditions and the students' sociocultural relations.	**Fundamental interaction between the components of the Model of Educational Reconstruction** 8. The necessary interaction between the three components of the MER: content structure analysis, investigations into student perspectives, and design and assessment of teaching and learning environments. 9. Understanding that the student is a socially situated subject. This is an essential aspect of planning teaching and learning environments.
	Elementaryization Process 10. The elementary ideas of scientific content need to be identified, considering the learning objectives and perspectives of the students.	**Content clarification process** 10. The content clarification allows rescuing scientific content what its abstraction and reduction disregarded, thus trying to define the structuring ideas of a given scientific content from an educational perspective.
Design-Based Research	**Research characteristics** 11. Interventional, collaborative, fundamentally responsive, theoretically grounded, and iterative.	**Research characteristics** 11. Interventional, collaborative, fundamentally responsive, theoretically grounded, and iterative.
	Research Phases 12. Preliminary research, prototyping phase, evaluation phase.	**Research Phases** 12. Extended preliminary research (aspects of scientific content and student perspective), prototyping phase, and evaluation phase.
	Processo de *design* 13. Cyclical and iterative	**Processo de *design*** 13. Recursive process

Source: Adapted from Silva et al. (2022)

3 Pre-instructional knowledge is those that characterize learners' understanding of certain content before instruction or educational intervention.

The first structuring aspect of the MER to be considered is the major theories that influence it. According to Silva (2019), this model has constructivist foundations, the German tradition of *Building* and *Didaktik* and Design-Based Research as grand theories. The elements captured from these theoretical references bring to the CIFER contributions of an: i) epistemological nature - they indicate the general theory of knowledge that underpins the ideas of the MER; ii) cognitive nature - they suggest explanations for how scientific knowledge is learned; iii) pedagogical nature - they indicate how teaching and learning processes are inferred in the MER; and iv) methodological nature - they elucidate the design path described in the MER for planning the teaching process, whether it is the result of research or not.

The clarification of CIFER allowed the structuring of a definition, which is considered crucial to help understand the MER and its implementation in research and teaching processes. This definition, based on several aspects of those listed in Table 1, is the one that situates what must be understood by Pedagogical Potentials (PP). In this context, the PP is understood as the educational demands arising from the approximations (which generate learning needs) and distances (which generate learning difficulties) between the students' pre-instructional conceptions and the scientific reference conceptions, which need to be reconstructed using methodological strategies. A scheme for structuring PP can be seen in Figure 1.

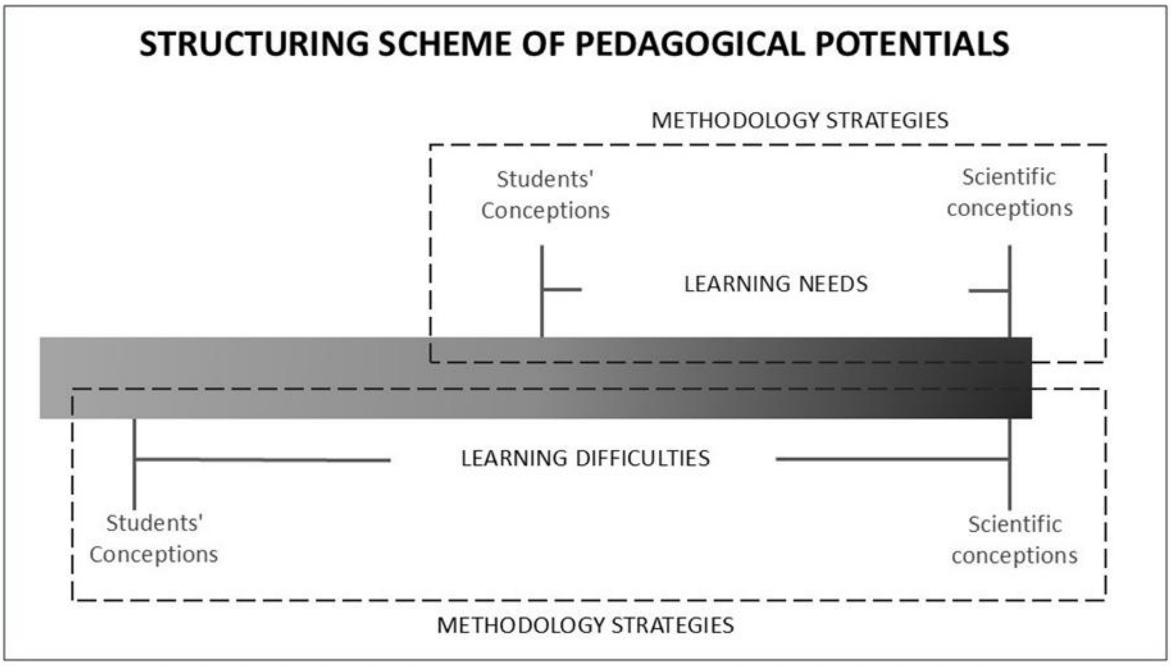

Figure 1. Structuring Scheme of Pedagogical Potentials. Source: Authors

Therefore, it is the set of learning needs, learning difficulties and methodological strategies that emerge from the analysis of the clarification of the content and the analysis of the students' perspectives on a given piece of scientific content – in other words, the dialog between scientific conceptions and student perspectives. These PP include aspects relating to the structure of the content to be taught and the cognitive and affective characteristics of the students, considering aspects such as motivation, interest and engagement. In short, through the PP, it is possible to define, in a non-arbitrary way, the design principles, the educational objectives and the structure of the teaching and learning environment to be developed.

Based on the MER's perspective on the science learning process, which is based on constructivist foundations[4] , it is considered that learning needs are generated from pre-instructional conceptions that are close to scientific conceptions. These close conceptions need (re)constructions that involve enrichment, complementation, expansion and improvement, so that they are even more aligned with the scientific content. Learning difficulties, on the other hand, are generated by pre-instructional conceptions that are far removed from what is currently accepted in the scientific community about a given piece of content. These distant conceptions need (re)constructions that involve new elaborations, organizations and structures, to become closer to what is presented in science.

The intention in these cases is not to replace pre-instructional knowledge with scientific knowledge, or to propose a scientism-based education. It is also about presenting explanations based on scientific knowledge as a viable possibility for understanding the world, the universe and oneself, as well as for cultural and social education, problem-solving and decision-making. In other words, it's about expanding students' repertoire of knowledge by (re)constructing scientific explanations.

The aim of Educational Reconstruction is to promote a dialogical education between different forms of knowledge, as opposed to an absolutist education based on a single way of understanding reality. It is important to explain that this purpose incorporates the argument that to agree or even disagree with something, it is necessary to have previously understood it, considering the different metaphysical, epistemological and cultural assumptions regarding the nature of knowledge. Therefore, teaching and learning environments must provide a favorable context for the processes of knowledge reconstruction, which are not simple, to take place in the students' cognitive structure.

Finally, we would like to emphasize the importance of understanding methodological strategies as tools for addressing learning needs and difficulties, as well as for guiding the development of educational interventions. These strategies serve as a foundation for identifying and structuring the starting points of the teaching process, based on the students' pre-instructional knowledge, learning needs and learning interests.

In short, through the PP, it is possible to define, in a non-arbitrary way, the design principles, the educational objectives, and the structure of the teaching and learning environment that one intends to design. We believe that the proposal to understand PP and their structuring scheme in the context of Educational Reconstruction is a unique effort by our research group, which expresses the intention of instrumentalizing educational design based on the MER. This initiative seeks to fill a gap in the texts on the model, in which the pedagogical potential of students' conceptions is recognized - with these conceptions being treated as starting points and intellectual tools for deepening learning (Duit & Treagust, 2003; Duit et al., 2012)

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4 To learn more about the process of learning science in the light of the Model of Educational Reconstruction, see Silva and Ferreira (2020) and Duit et al. (2012).

- but still lacking a systematic structuring that points out how such potentialities can materialize throughout the design process.

In methodological terms, the design tool associated with the MER is structured from three components, which interact with each other and make the theoretical aspects listed in CIFER usable, defining a step-by-step for the design process of teaching and learning environments. The first component of MER – Content Structure Analysis – aims to clarify the structure of scientific content from an educational point of view (Duit et al., 2012; Kattmann, 2007). The second component seeks to understand students' cognitive and affective perspectives on a given science content, which is why it is called Investigations into Student Perspectives. The purpose of the third component of MER – Design and Assessment of Teaching and Learning Environments – is to plan and assess teaching and learning environments. These three components establish an intimate relationship with each other so that the results of one influence the development of the others. This interaction is guaranteed through a procedure that the authors of MER call recursive (Duit et al., 2012; Komorek & Kattmann, 2008).

These theoretical and methodological aspects must comprise all the design processes developed based on the MER. Ensuring it implies building methodological design strategies that effectively mobilize and implement those aspects in the development of teaching and learning environments.

The mobilize strategy of theoretical and methodological aspects of the model of educational reconstruction

If, on the one hand, the literature in the field of Science Education provides general indications on how to develop the process of designing teaching and learning environments based on the MER - such as the definition of the three components that make up this process and the need to articulate them through a recursive process - on the other hand, there are still some open questions: What steps, and in what order, should be followed to develop a teaching and learning environment in the context of the MER? What characteristics should this environment have to ensure the implementation of the theoretical and methodological aspects of the MER? How can the three components of the MER be mobilized in a recursive way throughout the design process? And, at the end of building an environment, how can we check that it does, in fact, incorporate the essential aspects of the MER?

If we consider, for example, that one of the principles of MER is that scientific concepts should have the same weight and value as students' conceptions in the process of designing teaching and learning environments, a new question arises: what methods can be used to ensure this balance?

Duit et al. (2012) proposed that during a design process, after going from the first component to the second, we should return to the first. Thus, the method would be to carry out a preliminary survey of scientific concepts, a survey of pre-instructional concepts and then promote interaction between these different types of knowledge to identify the PP arising from this dialog. Nevertheless, the question remains: how can these aspects be mobilized throughout the design of the teaching and learning environment?

It was from reflections such as these that we developed methods to help make the design process based on the MER a reality. These methods emerged from the systematic analysis and reflection on the construction of TLS and CEG carried out in our research group (Lira & Smania-Marques, 2021; Vasconcelos & Smania-Marques, 2021; Lira et al., 2021; Silva et al., 2022; Silva & Smania-Marques, 2023; Smania-Marques et al., 2024).

The deepening of the theoretical and methodological understanding of the MER allowed, then, to propose a methodological design strategy that has the potential to promote the mobilization and implementation of the theoretical and methodological aspects of the MER in the design process of educational interventions, which is called mobilize strategy (see Figure 2).

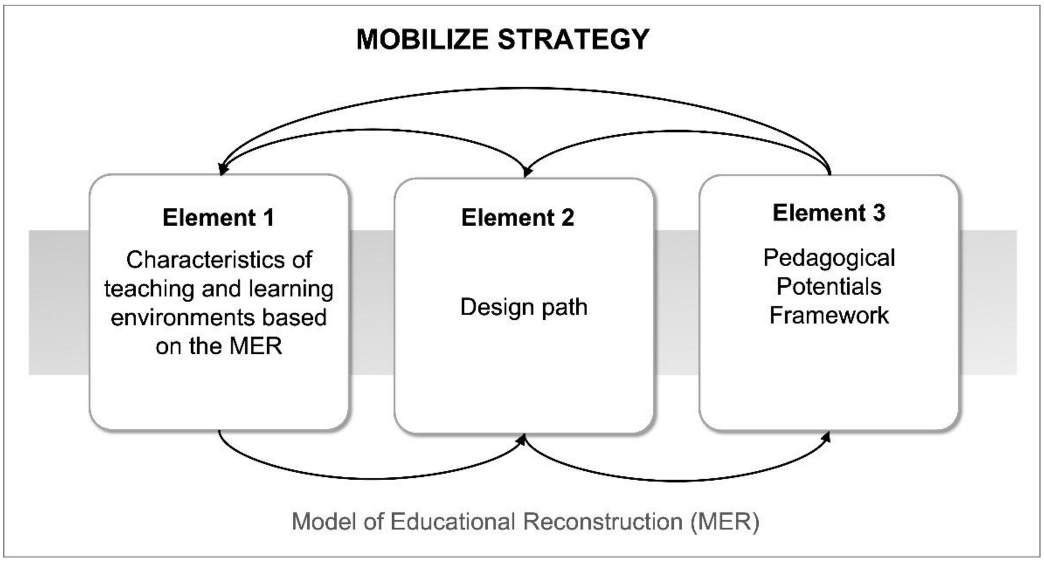

Figure 2. Mobilize Strategy. Source: Authors

It is a set of concrete and interdependent elements that make it possible to implement the theoretical and methodological aspects of MER in the process of designing educational interventions. The Mobilize Strategy proposed here is made up of three main elements:

1. Characteristics of teaching and learning environments based on MER - clarify the fundamental characteristics of these environments, which must be considered throughout the design path;
2. Design Path - guides the construction of teaching and learning environments that incorporate the characteristics presented in the previous element, ensuring the implementation of the theoretical and methodological aspects of the MER throughout the process;
3. Pedagogical Potentialities Framework (PPF) - promotes dialog between pre-instructional conceptions and scientific conceptions in the design process, allowing for the identification of learning needs and difficulties, as well as possible starting points for instruction. In addition, the PPF enables the development of specific stages of the design path and ensures the implementation of cognitive and affective aspects of

learning, which are fundamental in teaching and learning environments based on the MER.

The description of these elements offers possible answers to the questions raised earlier, as we will see below.

Element 1: Characteristics of teaching and learning environments based on the Model of Educational Reconstruction

The first element is the set of characteristics of teaching and learning environments based on the MER: (1) The scientific concepts and students' conceptions are equally crucial for the teaching and learning process; (2) The student participates actively in the activities proposed in the teaching and learning environment; (3) Scientific content should be understood as a possibility, among others, of interpreting the world; (4) The educational objectives consider multiple dimensions of the content (5) The teacher is the mediator of teaching and learning processes; (6) The teaching and learning environment must provide opportunities for multiple forms of interaction between students and the phenomenon studied (7) The learning of the concepts involves cognitive and affective aspects; (8) The evaluation should involve cognitive and affective criteria related to student learning (Silva et al., 2022).

These characteristics emerged from the process of clarifying the CIFER and seek to elucidate the roles that students, teachers, scientific knowledge, the material world and assessment have in the teaching and learning processes planned based on the MER[5].

In overall terms, this set of basic characteristics should constitute all teaching and learning environments designed according to the terms of the MER. However, for environments that do not presuppose the presence of a mediator, characteristic 5 should be relativized. This happens, for example, in the constructive process of CEG. Although they can be used with the help of mediation, CEG don't necessarily presuppose a context of teaching formal content, to be taught before or after the game activity. It is during the game that learning takes place, and it is possible even when there is no mediator.

In our experience with the use of MER's theoretical and methodological assumptions for the design of TLS and CEG, it was possible to observe that these characteristics are implemented in the design process through different types of actions, which vary depending on the type of intervention. For example, developing didactic actions that enable the expression of students' conceptions about content and others in which scientific conceptions are the focus of the study mobilizes characteristic 1 in the TLS design. Another example would be designing game mechanics that provide for the active participation of students in the playtesting of CEG design, mobilizing characteristic 2.

With this set of characteristics, it is possible to propose an infinite number of combinations of actions to build a teaching and learning environment. The design process of an

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5 A detailed discussion of these views can be found in Silva (2019).

environment is made from a methodological path that is organized according to the nature of the educational intervention that is intended to be planned.

Design paths for two types of teaching and learning environments are presented below, TLS and CEG, which include these characteristics and mobilize the other theoretical and methodological aspects of the MER.

Element 2: Design path

Design path is the element that guarantees, from a set of stages, the development of a methodological path that prevents the results from the three components of the MER from becoming a cluster of knowledge coming from three distinct lines of research that do not communicate with each other. In practice, it means that the design path is structured to guarantee that the necessary interactions between the MER components are respected.

In this way, the design path cannot be conceived as a set of stages organized in a linear and sequential manner - from the first, through the second, to the third component - the latter being understood as the end point of the process. Furthermore, the stages that make up the design path must be organized so that the result of one stage is both the starting point for the next stage and a reason for reflection on a previous stage. This is what allows the fundamental interaction between the components of the MER to be implemented through a recursive process (Duit et al., 2012).

Depending on the educational intervention that is intended to design, the design path supported by the MER can assume different structures, which, without fail, must guarantee the mobilization of all theoretical and methodological aspects of the MER. Based on this assumption, two design path proposals are presented below, one for the development of TLS and the other for the development of CEG.

Both proposals are the result of reflections and syntheses built on the various attempts to implement MER in our research processes aimed at developing TLS and CEG (Lira & Smania-Marques, 2021; Lira et al., 2021; Silva & Smania-Marques, 2023; Silva et al., 2022, 2025; Vasconcelos & Smania-Marques, 2021). Thus, what we are presenting here are proposals that have been shown to facilitate the implementation of MER in the design processes of teaching and/or learning environments within the scope of Development Research (Plomp, 2013).

Figure 3 presents a design path that has been shown to facilitate the development of TLS. This route also guarantees the mobilization of the TLS concept, which is taken as a reference as it includes a set of stages that promote the intertwining of the scientific and student perspective to achieve specific educational goals, offering solutions to problems identified in educational practice.

It consists of nine stages, which must be developed after identifying the educational problem to be solved by the implementation of the TLS in the design process. This problem can be identified from empirical data from scientific research in Science Education - such as evidence of difficulties in learning certain scientific content, even after structured instruction processes - or from observations made by the school community and from teachers' experiential knowledge[6] built up in educational practice.

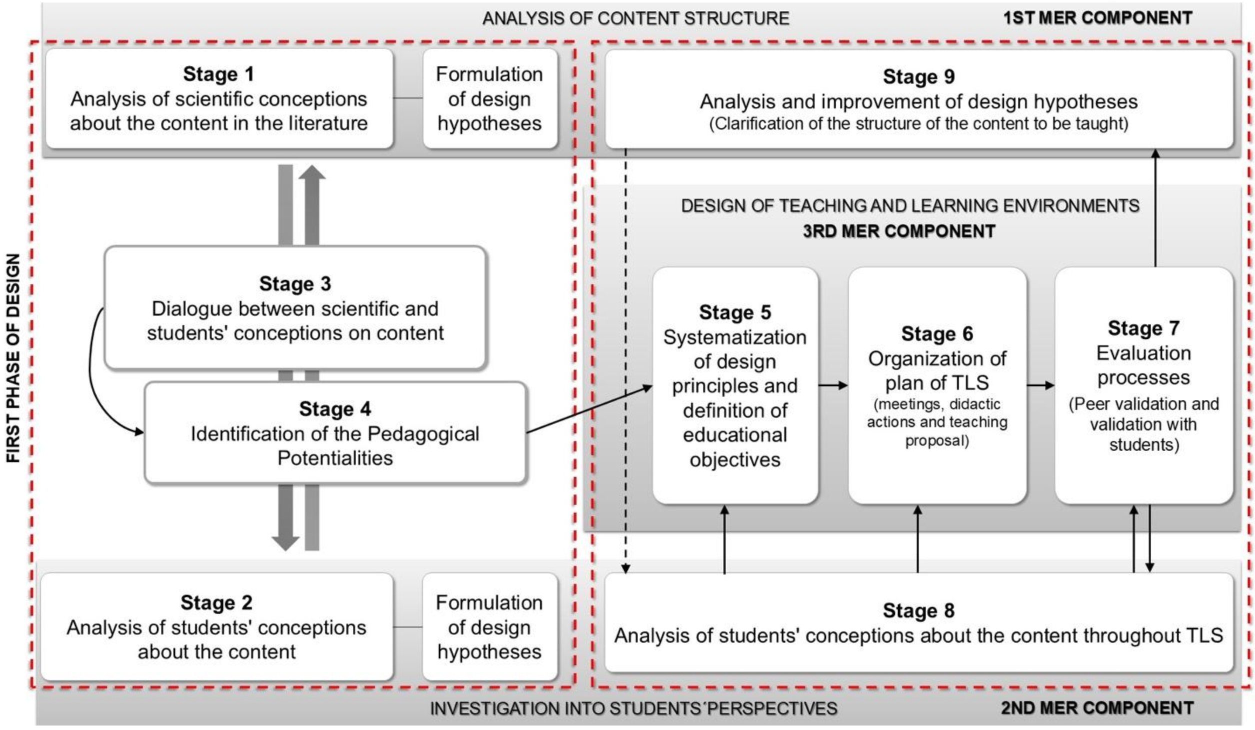

Figure 3. Design Path for the design of the Teaching and Learning Sequence based on the Model of Educational Reconstruction. Source: Adaptado de Silva et al. (2022)

As the MER was proposed for the design of TLS, it is perfectly suited to this purpose (Méheut & Psillos, 2004). However, using the MER to build CEG required some adaptations that proved to be innovative from both a theoretical and methodological point of view. For this reason, the description of the design path for TLS will be more objective than that for the CEG design path.

The first phase of design involves the results of four stages that allow for a sophisticated understanding of the educational problem to be solved with the intervention. Thus, this phase constitutes extended preliminary research, which should happen similarly for any learning environment planned by the MER (TLS, CEG, or any other type of environment).

The analysis of scientific conceptions about the content in the literature (stage 1, first component of the MER; see Figure 3) enables the construction of knowledge about the structure of the content from an educational point of view. In this stage, aspects of the content structure are analyzed, such as the elementary ideas surrounding the theme/concept, historical and epistemological aspects of scientific knowledge, and main scientific terms associated with learning the theme/concept. The results of this stage enable the formulation of design hypotheses, which are also formulated from the results of the Analysis of students' conceptions about the content (stage 2, second component of the MER; see Figure 3). The

6 To understand more about teaching knowledge, see Tardif (2012).

design hypotheses guide how scientific content should be presented in the instructional process.

Let's look at an example. In the work by Silva and Smania-Marques (2023), whose objective was to develop a TLS on the food chain for elementary school, the set of steps shown in Figure 3 was used. From the first stage, it was understood that the scientific conception of the food chain is that it is formed by a sequence of interactions between different organisms that serve as food for each other in an ecosystem. The results of the second stage indicated that, for the students, the food chain is mainly made up of living beings represented by animals, with human beings commonly disregarded as members of this chain.

Based on these results, the following project hypothesis was formulated: "It is essential to understand that the food chain represents a sequence of interactions between different organisms - such as bacteria, fungi, plants, animals, including humans - that act as a source of energy for each other in an ecosystem." (Silva & Smania-Marques, 2023, p. 8).

In this case, the design hypotheses emerge from the knowledge acquired about the cognitive and affective perspectives of the students, including their learning needs and difficulties, motivation, interest and engagement in relation to the scientific content. It is these hypotheses that guide the dialog between the scientific conceptions and the students' conceptions of the content (stage 3, see Figure 3), in which the approximations and distances between these conceptions are identified, as well as the identification of pedagogical potential (stage 4, see Figure 3). The latter involves recognizing learning needs and difficulties, as well as the design strategies associated with each design hypothesis formulated. Stages 3 and 4 are therefore responsible for promoting interaction between the first and second components of the MER.

The results obtained in the first phase of design enable decision-making to carry out the construction of the TLS plan to be made consciously and based on the knowledge built on the design hypotheses and PPs. As the main characteristic of the design tool associated with the MER is to provide a breadth of knowledge from the content clarification process, its use implies deciding which PP will be listed to structure the TLS plan or any other educational intervention.

This decision-making characterizes the end of the First Phase of design and is the starting point of the Second Phase of design, whose objective is to develop a proposal to solve the educational problem analyzed in the previous phase through the design of the TLS plan and its evaluation.

The systematization of design principles[7] and definition of educational objectives (stage 5, third component of the MER; see Figure 3) is the first step in developing the TLS plan. The first function as the overall goal of TLS, the second function as specific goals, encompassing the three dimensions of content that emphasize cognitive and affective aspects of learning. According to Zabala (1998), these dimensions of content are: conceptual (what should one

7 For more on how the design principles read Plomp (2013) and Van den Akker (1999).

know?), procedural (what should one know how to do?), and attitudinal (what should one know how to be?).

It is important to emphasize that any other decision regarding the constitution of the TLS plan should only be made later, specifically during the stage of structuring the TLS plan into meetings, didactic actions and teaching proposals (stage 6, third component of the MER; see Figure 3). It is therefore recommended that the number of meetings that will make up the TLS be aligned with the time frame envisaged for approaching the scientific content in the school context, in line with the practical conditions for its implementation.

This allows the construction of educational interventions aligned with the real possibilities of implementation in educational practice, ensuring that the research process carried out for the design of the TLS results not only in the production of theoretical knowledge for the area of Science Education, but also in practical knowledge, in line with the objectives expected by the DBR.

Of the aspects present in the concept of TLS taken as a reference in this study — order, structure, and articulation — the didactic actions represent the structure of the plan, showing aspects that cannot be changed from one context of TLS implementation to another. Methodology Strategies indicate how didactic actions can be implemented in educational practice. On the other hand, they represent the flexible part of the TLS plan, which can be adapted depending on the implementation context.

In the construction of a TLS on the food chain, one of the didactic actions planned for the first meeting was to "propose questions to guide initial reflections on the problem presented" (Silva & Smania-Marques, 2023). The methodological proposal detailing how this action could be implemented is described as follows:

> Once the challenge has been launched, the teacher explains that, to begin the reflections that will help the students find answers to the proposed question, they should answer the following set of questions in their notebooks: (a) Do all living beings feed on the same things? (b) Are there living beings that produce their own food? (c) Are there living beings that only feed on other living beings? (d) Are there living beings that feed on the dead parts or waste products of other living beings? (Silva & Smania-Marques, 2023, p. 10).

Considering the four fundamental questions that guide the second step of planning educational interventions in terms of the MER - Why, What, How and Why (Duit et al., 2012) - it can be seen in the example presented above that the structuring of didactic actions aims to answer the questions "What? and Why?"; the methodological strategies refer to the question "How?"; and the educational objectives, defined as the first step of planning, correspond to the question "Why?".

After organizing the first version of the TLS plan, which involves many adjustments and readjustments, the next step in the design process is to submit this first version to *Evaluation processes* (stage 7, third component of the MER; see Figure 3). This stage involves analyzing whether the proposed objectives have the potential to be achieved with the implementation of TLS. This can be done by first considering the experiential knowledge of researchers and teachers in the field of Science Education, which is what we call peer validation; or by implementing the DS in a real educational context, which is what we call validation with the target audience, which should happen by analyzing the students' conceptions about the content to be taught throughout the TLS (stage 8, second component of the MER, see Figure 3).

So that validation processes are not conducted based on arbitrary criteria, it is essential to consider criteria based on the MER itself, which we call here learning indicators. These indicators can be of a general nature – defined based on the MER's own assumptions, based on the concept of learning that the model defends – or specifically, related to the construction of knowledge about the scientific content promoted throughout the instructional process. In the latter case, the degree of elaboration of the students' conceptions can be considered, classifying them as poorly informed, partially informed or well-informed, according to their proximity to scientific conceptions.

In the context of TLS validation, indicators have so far been defined to help assess the TLS plan in the context of peer validation, helping to analyze whether the characteristics of the proposed TLS can be effectively observed in its plan. This set of indicators can be found in Silva and Smania-Marques (2023). In addition, as part of the validation with the target audience, general learning indicators were defined, which are available in Silva et al. (2025).

These validation processes help in the analysis of the intervention itself, allowing an assessment of criteria such as time and number of meetings; order, structure, and articulation of didactic actions and meetings; adequacy of educational goals; adequacy of the methodology strategy with the didactic actions; and adequacy of the proposal to the level of education for which it was designed, among others (Silva, 2019). In addition, through the validation processes, the analysis and improvement of design hypotheses (stage 9, first component of the MER, see Figure 3) are performed, thus allowing the clarification of the structure of the content to be taught. A new design cycle would be initiated if the results of this clarification were to support a new analysis of the students' conceptions about content. It is represented in Figure 3 by the black dotted line that indicates a possible but not mandatory movement in the design path.

Figure 4 presents a design path that has been shown to facilitate the development of CEGs. The support of the MER in the design process of CEG provides theoretical and methodological foundations, so their construction is not the result of an arbitrary process and without criteria, and so there is a balance between educational and playful aspects. Based on it, the CEG's target audience can be students, when conceived as an educational innovation for formal teaching environments, or the public, when conceived as a science dissemination innovation for non-formal or informal learning processes.

The dashed lines between the stages indicate optional movements, while the solid lines indicate mandatory movements of the MER. The First Phase of design involves both preliminary research from an educational point of view (stage 1, first and second components of the MER) and a ludic point of (stage 2, first, second, and third components of the MER). The objective is both to reach a deeper understanding of the educational problem to be solved with the CEG (with the same considerations raised for the entire Phase 1 of Figure 3), as well as to investigate the potential for achieving the playful dimension of the CEG, which is related to its ability to provide socialization, affectivity, fun, pleasure and even displeasure.

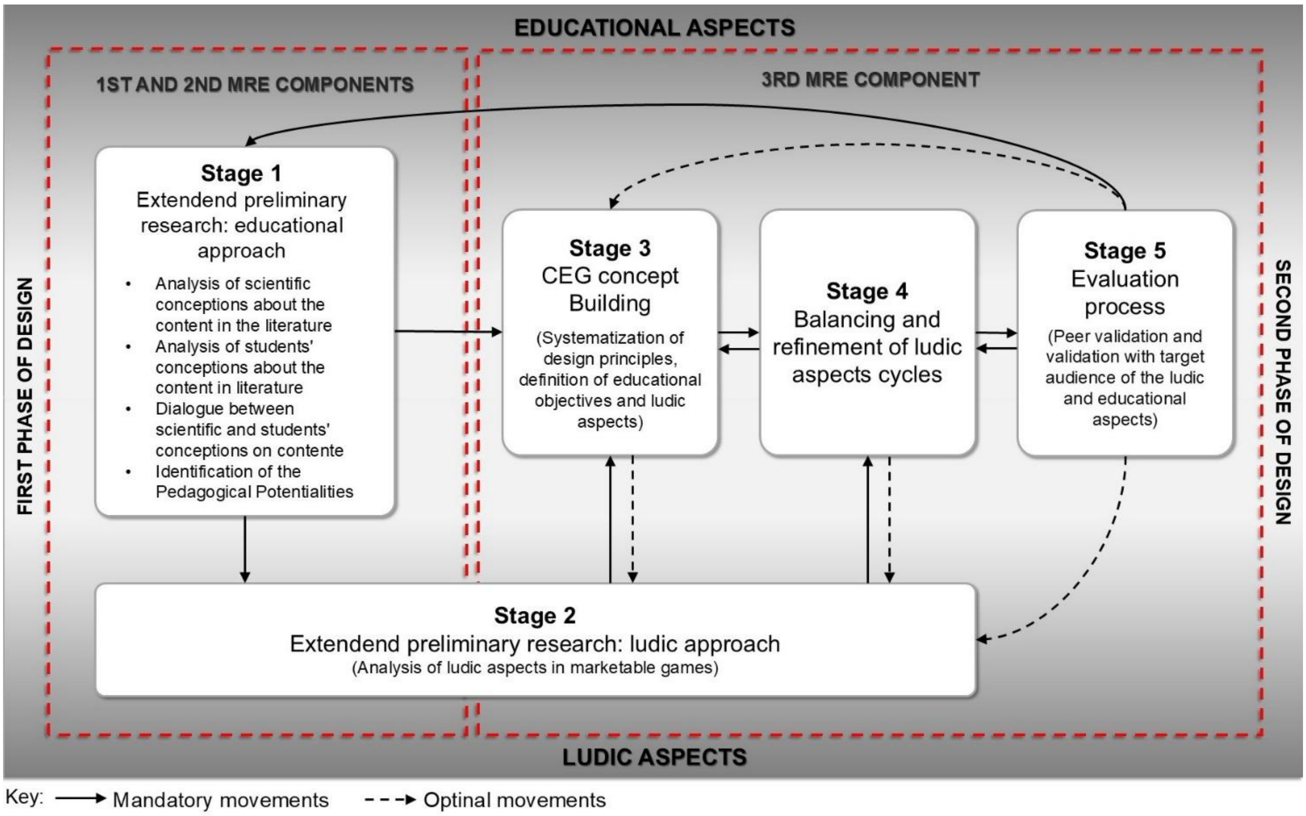

Figure 4. Proposed methodological path for the design of the Complexes Educational Games based on the MER. Source: Adapted from Smania-Marques et al. (2024)

The results of the first design phase are the starting point for the second phase (prototyping phase), which mobilizes the 3rd component of the MER, consisting of the following stages: (3) CEG concept building; (4) Balancing and refinement of ludic aspectos cycles; and (5) Evaluation processes. The objective of the second phase is to develop an educational innovation and carry out improvement tests to identify potential pathways to achieving the desired results following the ludic and educational objectives in a cyclical process of concept construction and revision, balancing, refinement, and evaluation of the CEG. This is an "iterative design phase consisting of iterations, each being a micro-cycle of research with formative evaluation as the most important research activity aimed at improving and refining the intervention" (Plomp, 2013, p. 15).

The results of the second phase of design lead to new decisions regarding the conception, objectives, and planning of innovation, and thus to new test cycles, indicated by the arrow that goes from stage 5 to stage 1 (when the objective is to start a new development study cycle) or optionally to stage 3 (when the goal is to improve the CEG).

The extended preliminary investigation of the educational approach for CEG (stage 1, see Figure 4) takes place as described in the interactions between stages 1 to 4 of the first design phase for TLS.

The preliminary research of the ludic approach (stage 2, see Figure 4) is a proposal for a theoretical-methodological advance in the terms proposed in the first component of the MER. It is essential to clarify that, although when the MER was proposed, its authors indicated that it could become a support for the design of any type of learning environment (Duit et al., 2012), initially, its objectives aimed at the construction of TLSs (Mehéut & Psillos, 2004). Therefore, there is no indication/forecast/reference in the MER for the need for a preliminary survey of recreational aspects.

However, in the design of CEG, in addition to clarifying the structure of scientific content from an educational point of view, it is also necessary to clarify possible play structures from an educational point of view. The preliminary research of the ludic approach occurs from an intense and prolonged game activity with marketable games. It contemplates different types (card games, board games, dice games, tile games, Role Playing Game) and game mechanics (player-generated rules or fixed rules, turns, action points, auction or bidding, cards, capture/eliminate, catch-up, dice, movement playing tokens or miniatures, resource management, risk and reward, role-playing, tile-laying, worker placement, game modes).

The game mechanics can promote new ways to help people understand the content, develop skills, abilities, and self-confidence, in addition to having the potential to help increase group collaboration, develop creative thinking, and create opportunities for engagement motivations (Lerner, 2014). From investigative play with marketable games throughout stage 2 (see Figure 4), inspiration arises for the main playful aspects that, when combined with the contents, provide opportunities for the achievement of educational goals. This stage is not completed in the first phase of design, as during stage 3 (see Figure 4), it is possible to resort to game activities (investigative play) again to improve the CEG concept proposal and adjust the principles of playful aspects to the educational goals. When it happens, stage 2 is no longer limited to the first component of the MER and permeates the second and third components, which enables the influence of the target audience's pre-instructional conceptions in the game design. Furthermore, the effectiveness of this micro-cycle research is directly related to the weight given to these conceptions.

Stage 3 (see Figure 4) is the moment to plan the conception of the CEG: the systematization of design principles; educational objectives; ludic objectives; measurable outcomes; degree of complexity; limits; the amount of chaos (chance/luck), and strategy elements; the repetition of a sequence of events (turns and rounds); and game mode (single-player or multiplayer; cooperative or competitive). The first product of this stage is an outline of the CEG rules.

Rules are the formal structures within games that limit or dictate what a player can do. From the rules, the first version of the CEG is built and submitted to an investigative play cycle in stage 4 (see Figure 4). The development team conducts the tests, supported by reflection instruments to balance and refine the playful aspects, with educational objectives as a reference.

The educational objectives should be defined as described above for the TLS design process.

The ludic objectives must be related to educational objectives. The educational objectives directly interfere, for example, in the decision of the game mode (single-player or multiplayer; cooperative or competitive). In a CEG, whoever wins is the person or group that comes closest to developing educational goals (Smania-Marques et al., 2024).

The target audience is generally characterized by four main types of gamers: the conquerors who play to win; explorers seeking information and secrets; social ones whose objective is to converse and interact with other people; and the highly competitive ones who play to compete and eliminate other players. However, there are many other possibilities for characterizing the players' personalities and intentions, which prevents the exact prediction of how a game will be played (Lerner, 2014).

For the game to become fun, it is imperative to think of different ways to negotiate conflicts and establish rules that make participation meaningful, engaging, and rewarding. Clear ludic objectives are essential for players to know what they must do to successfully reach the end of the game. When they are not, players can feel lost or discouraged and end up leaving the game. For the target audience to remain motivated, the ludic objectives must be challenging and achievable, as when they seem impossible, there is a tendency to give up.

Thus, the definition of measurable outcomes must consider that all games end in measurable outcomes; that is, whoever plays must win, lose, draw or receive some score. Therefore, the play objectives have to do with the end of the game. The winner of the game is whoever does the following achieves the stipulated score; captures a certain number of components of a specific type; scores the highest score; scores the lowest score; among other possibilities.

The level of difficulty is essential for the success of the CEG. Balancing the amount of chaos and strategy can help to define the difficulty. Chaotic elements are events that happen randomly, for example, dice rolling and drawing of shuffled cards. Using many actions that rely on these strategies limits the player's decision-making, which in most cases reduces the level of difficulty of the game. In contrast, the strategy elements depend exclusively on the player's cognitive orchestration capacity.

The greater the dependence on strategy development, the greater its difficulty level tends to be. In a process called balancing feedback cycles, it is possible to measure the game system's response to the players' actions in which their knowledge, skills, and abilities must match the challenges of the activity (Lerner, 2014). It is important in this balancing to consider the fact that, in some cases, the rules may favor more experienced players.

The game becomes easier in response to the player's success, or harder in response to their difficulties. When the game becomes too difficult too quickly, it can generate anxiety; on the other hand, if it stays easy for too long, it can lead to boredom.

The game needs to be as much fun as it is educational. Consequently, the balance of playful and educational aspects is essential. This balance is the result of the cyclical playtesting movement between stages 3 and 4, which favors, for example, the definition: of the rules limit (while a large set of rules can both restrict the game and overload players with complexity, few rules can leave players confused about what to do); of the repetition of a sequence of events (turns and rounds, which are the possibilities of actions of each player, shaped by the conflict type[8]); the game limits (board size, number of cards, game time, number of pieces, tokens, tiles, playing cards, and other elements); and visual elements (color palette evaluation, font size and type, component size, and the integration of images, graphics, and other effects to make games inherently pleasing and attractive).

In particular, the visuals are crucial since they engage players in the narrative, world, and aesthetics of the game to transport them away from their real-world surroundings and make them emotionally invest in the game (Lerner, 2014; Smania-Marques, 2024). It is therefore important that, during the test matches in stage 4 (see Figure 4), the testing team includes members who are representative of the target audience. As these refinement tweaks occur, it turns to building the game design (stage 4).

The evaluation process (stage 5, see Figure 4) occurs when the development team feels minimally secure and satisfied with the educational innovation, that is when there are indications of the potential achievements of educational and playful objectives from the mobilization of a set of rules and components that allow for the fluidity of a match.

The construction of the CEG constantly alternates between development, playtesting, evaluation and redesign, gradually improving the final product. Since designers cannot fully anticipate player actions, this cyclical movement is essential to building CEG that people enjoy. People outside the development group are invited to play and report their experiences in instruments suitable for reflection for a more robust assessment (Smania-Marques et al., 2024). The more diverse the peers and target audience composition, the better the validation process.

In this context, peers are both people who master scientific content and frequent players. The evaluation of CEG by this team will help make the problems and potentialities of the proposed intervention explicit. Among the results expected at this stage are feedback on the suitability of the proposal to the educational and recreational objectives of the game.

Thus, stages 3, 4, and 5 (see Figure 4) are repeated in a spiral cycle, progressively increasing the number of participants over time, providing opportunities for formative evaluations (Plomp, 2013). At the end of this development study cycle, it is crucial to understand if the assessment confirms the *design hypotheses* (arrow from stage 5 to 1, see Figure 4) or if it indicates a review of the design of playful or educational aspects, such as the target audience indicated for the CEG resulting from this design process (arrow from stage 5 to 3, see Figure 4).

These results are therefore the starting point for a new development study, either from stage 1 or 3, since:

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8 The type of conflict shapes the basic relationship that players have with each other and with the game, since conflict can occur between individual players, groups or teams, and game systems. Conflict creates dramatic tensions and challenges, which fuel the player's emotional investment in a game (Lerner, 2014). Although often framed as competition, conflict also includes some collaboration. People play games for various reasons, but usually at least one of the motivations is to win. When it is known *a priori* that the game will end in a concrete result, the conflict becomes more exciting and the rules more acceptable (Lerner, 2014). Therefore, each CEG will have some kind of conflict.

> "it is possible that the design/development component in such a research project will not begin from scratch but with the evaluation of an existing intervention with the aim of identifying the need for improvement, which then is followed by re-design and a number of design cycles" (Plomp, 2013, p. 15).

Returning from stage 5 to stage 1 (see Figure 4) may involve, for example, reviewing pedagogical potential that has not been covered or including new potential that has been identified. This implies a complete new design cycle. The next steps could include the start of a validation study – a possible stage 6, not yet represented in Figure 4 – in which the game will be subjected to a semi-somative evaluation with the target audience, focusing on its functional character and its effectiveness[9].

Therefore, two examples elucidate how to design TLS and CEG based on the MER. They do not intend to propose a fixed design path based on the MER, but a possibility with clear stages permeating the three components of the model, articulated with each other. The design path is an element that guarantees the assumption, defended by Duit *et al.* (2012), that the three components of the MER must be developed concurrently, from iterative cycles, so that the results of one influence the development of others.

Element 3: Pedagogical Potentials Framework

One aspect common to the two design paths presented in the previous section is the identification of pedagogical potential at the end of the first phase of the design process (stage 4, see Figure 3). This identification process can be carried out using the third element of the Mobilization Strategy we proposed, which will be described below.

Identifying the pedagogical potential of pre-instructional conceptions, in relation to scientific conceptions about a particular scientific content to be taught, guides both the choice of learning needs and difficulties to be addressed in proposing the educational intervention and the definition of the methodological strategies that can be employed in it.

Pedagogical potential is therefore configured as educational demands that emerge from the dialog between scientific conceptions and student conceptions, acting as guidelines for the design process of teaching and learning environments. These demands derive from the similarities and differences identified between the two types of conceptions, and can take the form of learning needs, learning difficulties or methodological strategies. The latter are especially marked by the identification of starting points for teaching, anchored in what the student already understands about the content.

In this sense, it is important to emphasize that the identification of Pedagogical Potential (PP) is based on testable educational guidelines, which emerge from the analysis of scientific conceptions in dialogue with students' pre-instructional conceptions. The latter indicates ways in which the scientific content should be highlighted throughout the instructional

9 To find out more about the components and principles of Design Research theory, read Plomp (2013).

process. We call this set of design guidelines design hypotheses. They therefore constitute the reference knowledge for structuring the Pedagogical Potential Framework (PPF) (Table 2).

Table 2. Structure of the Pedagogical Potential Framework.

PEDAGOGICAL POTENTIALS FRAMEWORK
Design hypotheses about the content to be taught: These are testable educational guidelines that emerge from the analysis of scientific conceptions in dialog with students' pre-instructional conceptions, so that the latter indicates ways in which scientific content should be made evident throughout the instructional process.
Approximations: Pre-instructional conceptions aligned with the scientific knowledge of reference. **Distancing:** Pre-instructional conceptions contradictory to the scientific knowledge of reference.
Potencialidades Pedagógicas These are the educational demands arising from the approximations (which generate learning needs) and the distances (which generate learning difficulties) between the pre-instructional conceptions and the scientific reference conceptions, which need to be (re)constructed based on methodology strategies. Learning needs: Pre-instructional conceptions close to the scientific content of reference that need (re)constructions that involve enrichments, complements, extensions, and enhancements, to become even more aligned with it). Learning difficulties: Pre-instructional conceptions that are distant from the scientific content of reference and that need to be (re)constructed, involving new elaborations, organizations and structures, to come closer to what is presented in science. Methodology strategies: Methodological possibilities for addressing learning needs and difficulties, which help in the design of the educational intervention

Source: Authors

After drawing up the design hypotheses, the students' conceptions, identified in the second component of the MER, should be organized according to their intrinsic relationship with these hypotheses. Next, for each design hypothesis, the pre-instructional conceptions are classified, distinguishing between those that are closer to the reference knowledge and those that are more distant.

Each close conception represents a learning need, while each distance represents a learning difficulty. We adopted this perspective because we believe that pre-instructional conceptions that are closer to reference knowledge have greater potential to be expanded throughout the teaching process, through continuous mental processes in which concepts are modified or reconnected in a way that is not antagonistic to previous ways of thinking (Duit et al., 2012; Silva et al., 2025).

On the other hand, pre-instructional conceptions that distance themselves from the reference knowledge have greater potential to be expanded through discontinuous and revolutionary mental processes, in which concepts are fundamentally reorganized (Duit et al., 2012; Silva et al., 2025).

The methodological strategies, in turn, can be translated into identifying the starting points for learning, which emerge from analyzing what the student (or target audience, in the case of CEG) already knows about the scientific content. The assumption underlying this approach is that, by starting with knowledge of science that is familiar to the student, the instructional process increases the chances that they will be interested and motivated to participate effectively.

In summary, the third element of the mobilization strategy we propose in this study, the QPP, is made up of six devices: (1) design hypotheses (reference knowledge); (2) approximations (pre-instructional conceptions aligned with the reference knowledge); (3) distancing (pre-instructional conceptions contradictory to the reference knowledge); (4) learning needs (framed by the approximations); (5) learning difficulties (framed by the distancing); and (6) methodological strategies (definition of learning starting points) (Table 2).

In retrospect, we understand that the version of the QPP presented here results from the refinement of our analysis of the development of TLS and CEG, previously mentioned in relation to the first two elements. As the results of the preliminary research emerged, we felt the need for a strategy that would allow us to more clearly identify PPs that would serve as a tool for designing the intervention. Throughout the different research processes, we proposed different versions of the QPP, until we arrived at the one presented in Table 2. A completed version of the QPP, referring to biodiversity content, can be found in Silva et al. (2022).

The PPF can contain more than one design hypothesis with its associated PPs. It promotes the systematization of the results from extended preliminary research. From the data of the PPF, it is possible, therefore, to visualize a vast repertoire of learning needs, learning difficulties, and methodology strategies on the scientific content that is the focus of the educational intervention. It is the materialization of stage 4 in Figure 3.

Without exhausting the possibilities, FFP allows outline the needs, learning difficulties, and methodology strategies associated with a design hypothesis. This favors the conscious choice of which PPs will be addressed in the educational intervention, focus of the design process, as well as enabling them to see in advance what will not be covered in this intervention.

When this in-depth reflection does not occur, the teacher can be more easily surprised by unforeseen and unwanted situations, such as the lack of achievement of objectives related to specific contents that would not be desired to be outside the proposed intervention.

It is only when the PPs are very explicit that the design principles and educational objectives that act as a starting point for the prototyping of learning environments are defined (second phase of design, ver Figures 3 and 4). At this point in the design process, it is essential that the designers implement the characteristics of the teaching and learning environments based on the MER (element 1 of the mobilize strategy, see Figure 2).

Final Considerations

A large part of the advances presented in this work come from discussions that emerged in our Biology Education Research Group, whose main theoretical and methodological contribution is MER. Thus, our observations and practices - research, teaching, and extension - have been analyzed to clarify the mobilize strategy presented here, which has the potential to facilitate the incorporation of MER assumptions into the design processes of educational interventions. We defend the MER as an intermediate framework and present in this paper how aspects of the main theories are reconstructed or reformulated, thus structuring the design tool (the three components of the MER).

To answer the question “How to mobilize the theoretical and methodological aspects of MER for the design of Teaching and Learning Sequences (TLS) and Complex Educational Games (CEG) in Science Teaching?” it was proposed the mobilize strategy for the design of teaching and learning environments, which promotes the interaction of elements in a recursive way, mobilizing the theoretical and methodological aspects of the MER. The MER has been used principally for the design of TLS, CEG, and Comic books (which were not considered in this study as the structuring of its design path involves aspects and stages that are still in the clarification phase). It is important to note that the proposed mobilization strategy has been tested in the construction of TLS and CEG submitted for peer validation, whose descriptive articles are currently being developed and published.

The subsequent steps to advance what was proposed here should be in the sense of answering one concern that has not yet been resolved: When finalizing the construction of an environment, how to know if it presents the essential aspects of the MER? Another possible research perspective is to carry out development and effectiveness research using the instruments proposed here, especially those that intend to validate interventions. Progress in this direction has been made with a study that presents a set of general learning indicators based on the MER (Silva et al., 2025).

Studies on the formative potential of using MER to develop TLS in the context of initial teacher training have also been carried out, as we argue that the use of MER for this purpose contributes to the construction of teachers' professional knowledge (Epaminondas et al., in press). The potential of the QPP to contribute to the construction of learning indicators directly related to the content to be taught is still in the development and testing phase.

Finally, understanding and considering the affective aspects of learning in terms of the MER has been a challenge that every research has tried to overcome. It is already understood how these aspects are expressed through the pedagogical potential in the design process. However, it is necessary to advance to integrate the students’ concerns in these processes in a more sophisticated way.

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