

The Model of Educational Reconstruction: an Instructional Design in Science Education

O Modelo de Reconstrução Educacional: um Design Instrucional no Ensino de Ciências

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Abstract

From the perspective of research on models which contribute to and foster the relationship between theory and practice, in turn enabling students to better understand scientific knowledge, we present the Model of Educational Reconstruction (MER) – a theoretical-methodological resource for science teaching. The Model of Educational Reconstruction is presented from the perspective of investigation by design, specifying links between student conceptions, scientific knowledge and the development of learning environments. In this sense, this study aimed to present the MER in its theoretical and methodological premises and consequently its contributions to Science Education. The study involved a quali-quantitative approach, and is characterized as a descriptive study. Data collection occurred by retrieving scientific articles available on the Internet through access to the Google platform using the following descriptors: Model of Educational Reconstruction, Instructional Design and Design Tools. The use of the MER as a methodological contribution was verified in 11 countries with 48 studies, concentrating studies in Germany, with increasing expansion in Brazil, Indonesia and Italy. The studies contemplate more representative proposals for High School, with an emphasis on teaching Physics and Biology. Studies have pointed out the model as an important theoretical-methodological lines, constituting an effective framework for planning and instructional design, as well as support for the teachers' professional development.

Keywords: Science Education. Educational Reconstruction Model. Instructional Design.

Resumo

Na perspectiva da investigação de modelos que contribuem e fomentam a relação entre teoria e prática, possibilitando aos alunos uma melhor compreensão do conhecimento científico, apresentamos o Modelo de Reconstrução Educacional (MER) – um recurso teórico-metodológico para o ensino de ciências. O Modelo de Reconstrução Educacional é apresentado na perspectiva da investigação por design, especificando ligações entre as concepções dos alunos, o conhecimento científico e o desenvolvimento de ambientes de aprendizagem. Nesse sentido, este estudo teve como objetivo apresentar o MER em seus pressupostos teóricos e metodológicos e consequentemente suas contribuições para o Ensino de Ciências. O estudo envolveu abordagem quali-quantitativa e caracteriza-se como um estudo descritivo. A coleta de dados ocorreu por meio da recuperação de artigos científicos disponíveis na internet por meio do acesso à plataforma Google utilizando os seguintes descritores: Modelo de Reconstrução Educacional, Design Instrucional e Ferramentas de Design. A utilização do MER como contribuição metodológica foi verificada em 11 países com 48 estudos, concentrando estudos na Alemanha, com expansão crescente no Brasil, Indonésia e Itália. Os estudos contemplam propostas mais representativas para o Ensino Médio, com ênfase no ensino de Física e Biologia. Estudos têm apontado o modelo como uma importante linha teórico-metodológica, constituindo um referencial eficaz para o planejamento e design instrucional, bem como suporte para o desenvolvimento profissional dos professores.

Palavras-chave: Ensino de Ciências. Modelo de Reconstrução Educacional. Design Instrucional.

1 Introduction

Research in Science Education in the 1970s and 80s only focused on alternative conceptions and spontaneous argumentation by the student, involving long-term and unrepresentative proposals for teaching at the time (Méheut, 2005; Méheut; Psillos, 2004). Therefore, perspectives emerged aiming at teaching which promotes changes in educational practice, to the detriment of traditional models which hardly provide useful and favorable prescriptions for a conceptual redefinition (Van Den Akker, 1999; Van Den Akker et al., 2010).

In this line, the “Physical Science Study Committee” project emerged in the United States, proposing students’

active participation through different teaching resources, problem situations, experimental practice and theoretical development, bringing them closer to scientific activity. The Nuffield Foundation in England instituted the “Science for All” project in schools, focusing on free thinking about science, scientists and experimental investigation, in addition to practices seeking to awaken the subject’s critical thinking. The “Physics Curriculum Development Project” in the Netherlands aimed to bring students closer to Teaching Physics, encouraging them to understand everyday physical phenomena (Viennot, 2009).

In this context, even though these institutions sought to collaborate with new approaches to Science Teaching in

their specificities, the implementation of these projects was not well received by the scientific community at the time and generated dissatisfaction, especially with regard to the methods used, the assessment form and the application time, and they did not realize the relevance to the instructional process. These “failures” culminated in discussions about new models for Science Teaching on research more suited to improving teaching practice with feedback occurring in a shorter time (Kaestle, 1993; Wright, 1993).

Therefore, interest in innovations in curricular content began to emerge in the early 2000s, proposing to deal with them on a small and medium scale, contrasting large-scale proposals and traditional research (Méheut; Psillos, 2004). These innovations constituted a specific field of science education, Research in Educational Design, seeking to teach and learn specific content in the Science Education field (Pietrocola, 2017). Thus, from the perspective of research on models which contribute to and foster the relationship between theory and practice, in turn enabling students to better understand scientific knowledge, we aim to present the Model of Educational Reconstruction (MER) instructional design framework in its theoretical and methodological premise, as well as its contributions to Science Education.

2 Development

2.1 Methodology

The methodological proposal involved a qualitative approach in seeking to understand the meaning attributed to the study object, its individuality and significance to the social context (Triviños, 2011; Gil, 2010); as well as quantitative, through an analysis and collection of statistical data in numbers which are expressed graphically (Ludke; André, 2013). The research involved a descriptive study through describing values and characteristics that affect the object, as well as bibliographical research, whose data source is available on websites (Severino, 2007).

Data collection occurred through retrieving scientific articles available on the Internet via access to the Google platform using the following descriptors: Model of Educational Reconstruction, Instructional Design and Design Tools. Data were collected on sites whose articles were subject to analysis, open in the public domain, indexed in scientific journals or in annals of scientific events in the national and international scope.

2.2 History of the Model of Educational Reconstruction (MER)

Design research emerged in the 1980s, representing an emerging paradigm for the study of Science learning in an implementation line of short-term curricula, teaching-learning sequences, teaching strategies and design tools (Brown, 1992; Collins, 1992; Méheut; Psillos, 2004). Design can be understood as a noun (project, design/drawing or model) and as a verb (to project, model or design/draw).

In this sense, it can present different proposals with

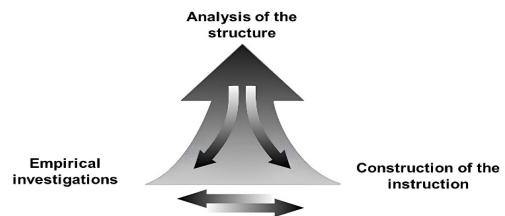
its own elements in its methodological configuration; the “Teaching Learning Sequence” can also be used, in which designs instituted in their stages can collaborate to compose didactic scenarios and significantly contribute to research in Science Education.

According to Dolz and Schneuwly (2004) and Dolz, Noverraz and Schneuwly (2004), the sequences represent a set of activities which are planned systematically about a certain theme, aiming to help students clarify their concepts and seek to expand and approximate knowledge prior to scientific concepts. In this case, one of the several designs which present this characteristic is included in the Model of Educational Reconstruction (MER).

MER emerged in Germany in the 1990s (Duit, 2006, 2007; Kattmann et al., 1997) with an epistemological, constructivist and investigation by design position (Wittmann, 1995), representing a theoretical framework for planning, implementing and evaluating teaching-learning research and developing learning environments (Méheut; Psillos, 2004).

The MER proposal is perceived in dissertations, theses and scientific articles. Its relevance involves research insertions at a theoretical, methodological or theoretical-methodological level, depending on the study object and the established research axes in different knowledge areas (Silva; Ferreira, 2020). The model integrates three educational research lines: Content Structure Analysis, Empirical Investigations and Instruction Construction (Figure 1).

Figure 1 - Outline of the Model of Educational Reconstruction (MER) stages



Source: Kattmann et al. (1997); Duit; Komorek; Wilbers (1997); Duit et al. (2012).

In order to configure this MER triad, researchers sought contributions from the references of German education and from other nationalities, providing opportunities for teaching with more effective practices that would promote conceptual change. This proposition consists of three fundamental axes which guide theoretical training and promote methodological structuring.

2.3 Model assumptions

Axis 1 - Teaching Content: Corresponds to the contents related to the formal teaching curriculum and its potential for the learning process, with an emphasis on the importance of common sense concepts, the relationship with the school curriculum and the student’s reality; key elements in this

process (Westbury; Hopmann; Riquarts, 2000).

Axis 2 - The Didactic Analysis or Didactic Analysis Model: Provides opportunities for the contributions of Wolfgang Klafki's Didactic Analysis. This analysis sets up a group of questions which teachers discuss about the approach of some content to be proposed to students before presenting it in the classroom (Klafki, 1964). The analysis constitutes a teaching model in content observation; an action guide for lesson planning before the method (Heidemann, 2000).

Thus, five interdependent questions are established for its execution, provided that together they provide an overall understanding of the study object, enabling the teacher to prepare for teaching certain content in the classroom (Vilmar, 2004), as shown in Table 1 below.

Table 1 – Klafki's Didactic Analysis in Class Planning

Questions	Considerations
A - What is the general idea represented by the content? What are the basic phenomena or principles? What are the general laws?	The way content is presented in manuals, books, documents or teaching references.
B - What is needed to work with this content? What are the experiences, knowledge, skills, and competencies which must be developed when students deal with this content? What is the significance of this content from a pedagogical point of view?	The familiarity of the content for the subjects. Students' pre-understanding constitutes the starting point for the planning process, and their teacher must consider it for class planning.
C - What is the significance of this content for the future of students?	The perspective, the meaning, the interests in applying the content to the students' lives.
D - What is the structure of this content when considering the pedagogical perspective?	The particular, specific, significant and important elements relating to the content.
E - What are the situations that can help to make this content interesting, questionable, accessible and understandable for students?	The presentation of content through methods to be used to promote the teaching-learning process.

Source: Klafki (1964).

In view of this, the role of Didactic Analysis would be to promote the teacher's reflection in approaching the content from key questions before its presentation in the classroom. As a result, the analysis establishes a guide for applying content in the classroom, providing teachers with a critical look in structuring classes which are more consistent with the students' perspectives.

Axis 3 – Constructivism and Conceptual Change: the model emphasizes an epistemological and constructivist framework for the teaching-learning process from the constructivism perspective in education and about conceptual change (Duit, 2006, 2007; Duit; Treagust; Widodo, 2008).

Constructivism emphasizes that knowledge is not passively received, however it is constructed by the subject. When constituted by non-school bases, this knowledge is often not in accordance with the vision of science, considered as misunderstandings or alternative conceptions, and it can present an extremely resistant character to change, representing challenges for teachers and researchers in Science Education

(DUIT, 2009), since some ideas are rooted in common sense and in disagreement with the scientific vision, being quite naive and limited (Duit; Treagust, 2003).

2.4 The Model of Educational Reconstruction stages

These assumptions discussed above constitute the theoretical basis of the model, formulating the methodological structure that is composed of three stages: Content Structure Analysis, Empirical Investigations and Instruction Construction (Duit, 2006, 2007; Silva; Ferreira, 2020).

Stage 1 - Content Structure Analysis: Understanding the Content Structure through the clarification processes of the subject (analysis of textbooks, publications and their historical development) and by the Educational Meaning Analysis, represented by Klafki's Didactic Analysis.

The Content Structure Analysis considering the Content Structure, refers to the Fundamentalization process under the construction of the set of elementary ideas of the content structure for instruction. On the other hand, Content Structure Analysis, considering the Educational Meaning Analysis, refers to the premises of Klafki's Didactic Analysis under the set of five questions assigned before addressing the content in the classroom, as mentioned above.

Stage 2 - Empirical Investigations: constitute empirical studies on the various characteristics of the learning environment and research on the students' perspective, including their pre-instructional conceptions and affective variables, such as interests, self-concepts and attitudes (Van Dijk; Kattmann, 2007).

At this stage, empirical research can be evidenced through articles and references in the area under study; and therefore, points of difficulties presented by the students and/or teachers to study and learn certain content can be observed (for example) (Silva; Ferreira, 2020).

Stage 3 - Instruction Construction: This involves teaching materials, learning activities and Teaching and Learning Sequences (Niebert; Gropengiebert, 2013). The didactic research scenario is established at this stage, and its design is above all structured by the specific needs and learning abilities of students to achieve the established goals, and various empirical methods are used to evaluate materials and activities.

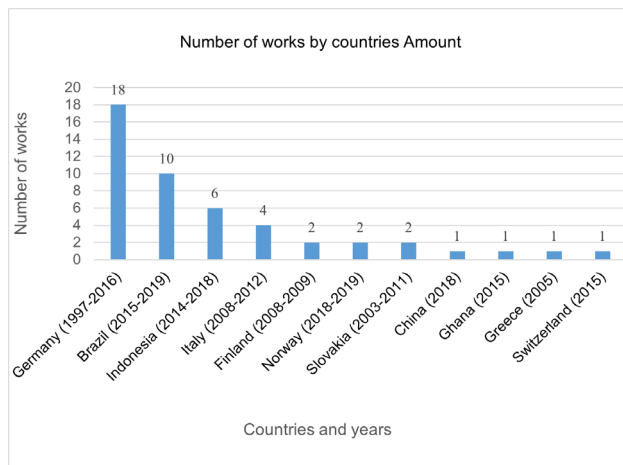
These methods consist of interviews with students and teachers, applying questionnaires and using video documentaries on educational practice (Silva; Ferreira, 2020). There is no proposal at this stage to follow to compose the didactic scenario, as the creators of the model leave how the sequence can be structured "open", only following a constructivist character.

2.5 The MER approach in studies around the world

Several articles have been published since the 1990s which convey information about the use of MER in school and academic contexts. It has been highlighted in academic works at international and national levels, and its perspectives

have received notoriety in conferences such as the “European Science Education Research Association”, in which growing proposals are recognized from the model’s perspective with a significant number of contributions in this regard to instructional design. The use of MER has been developed as a theoretical-methodological support since 1997. A total of 48 studies have been currently counted, ranging from basic education to higher education, distributed over 11 countries in different regions of the world (Figure 2).

Figure 2 - Number of works published in each country



The cradle of MER was Europe through Germany (a pioneering country in this methodology), which stands out as being the most prevalent in the numbers of studies, presenting a quantity of 18 works conducted over the period from 1997 to 2016, and consequently with the oldest productions. However, there are two other subsequent countries in the representation scale which belong to distinct continental regions; South America - Brazil, and Asia - Indonesia.

Brazil had 10 studies carried out in the period from 2015 to 2019, which although is a short period of time (four years), constitutes considerable production compared to the other verified countries. Indonesia had six works published over four years (2014-2018), and Italy had four studies, also over four years (2008-2012). To this end, the other countries presented a small amount of productions, varying between one and two studies.

Thus, it is observed that the model has already become a reference for studies in the Asian continent with Indonesia and China. It has also spread to the African continent through research carried out in the country of Ghana. In this perspective, it is worth noting that Brazil is the only country in the Americas that has contemplated the model so far. In addition, it is important to emphasize that Brazil presents a relatively recent introduction of the model, however it already occupies second place in the world in research with MER in quantitative terms.

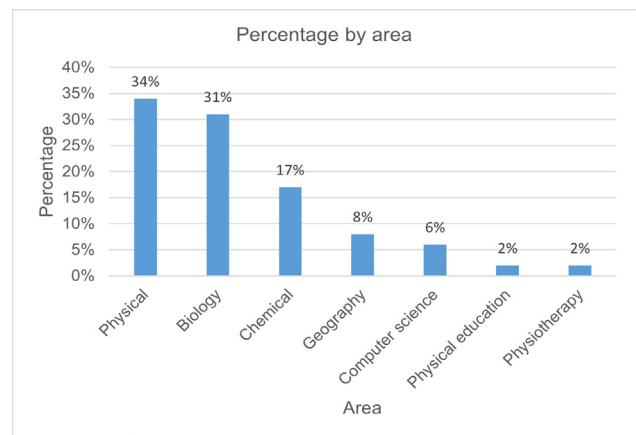
Considering the education levels, Elementary Education was the least explored, although it surpassed the number of studies in Higher Education in Germany and Italy. The most

representative in Brazil were the intermediate and higher levels, while the largest number of studies in Germany is aimed at the intermediate education level, covered in nine of the 18 studies. Higher education was the most representative in Indonesian studies and the only one covered in Norway, Finland, Greece and China.

Thus, MER consists of a method which flows in approaches regardless of the education level to be researched, so there are variations according to the plurality of purposes contemplated in the studies, meaning it involves the researchers’ intentions and therefore derives from the objectives established in research developed with the model (Silva; Ferreira, 2020).

Considering the different knowledge areas, the studies involving the model included the Natural Sciences, Human Sciences, Health and Computer Science (Figure 3).

Figure 3 - Percentage of works by area

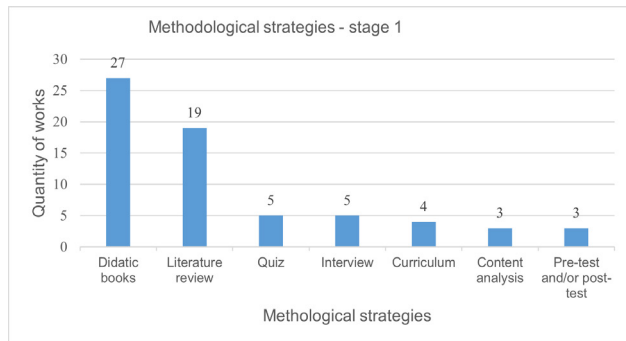


In turn, the Physics area stands out, which presented the highest percentage, being considered in 34% of the studies on the model, followed by Biology with 31%, and then Chemistry with 17%, characterizing the three knowledge areas with greater representation. However, in an antagonistic way, the areas with the lowest occurrence correspond to sciences related to Health, with Physiotherapy and Physical Education, both represented in only 2% of the studies.

Considering the strategies used in developing the studies in the light of MER, the analyzes resulted from verifying the development of the model’s methodological stages: 1 - Content Structure Analysis; 2 - Empirical Investigations; and 3 - Instruction Construction.

From this same perspective, it was possible to identify and raise a wide range of referrals adopted by researchers in the studies verified. When analyzing the procedures for carrying out the first stage (corresponding to the Content Structure Analysis), in this case it is observed that most of the works pointed to the analysis of textbooks, together with other procedures that include interviews with professors or researchers, questionnaires, curriculum analysis, analysis of historical documents, among others (Figure 4).

Figure 4 - Methodological strategies used in stage 1 of MER

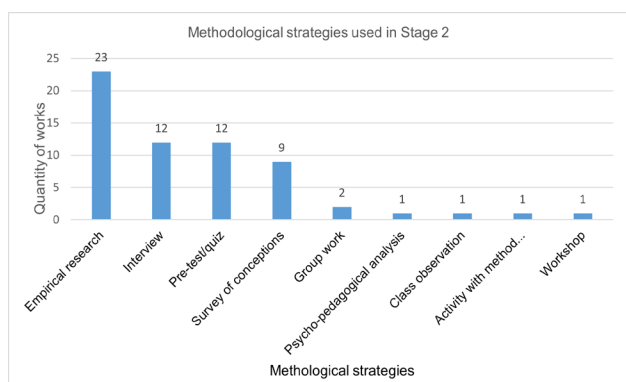


From this same point of view, we highlight the analysis of Textbooks which occurred more frequently in related studies. This may be directly related to the relevance of this manual in the educational scenario, being historically used as an important resource by teachers and students, thus it has broad importance in teaching and learning processes (Santana Filho, 2016), especially due to its potential to contribute to scientific and citizen training (Vasconcelos; Souto, 2003).

Therefore, this stage is characterized by a broad analysis of the structural aspect of a content through published works, such as textbooks, and also verifying and clarifying scientific concepts through educational perspectives (Duit, 2006, 2007). The teacher assumes an important role in the educational basis of the stage, as seen from their inferences about the arguments present in the model, and it is possible to develop and conduct approaches related to the students' perspectives (Silva; Ferreira, 2020).

Considering the systematized procedures for stage 2 (corresponding to Empirical Investigations), there is a predominance of empirical studies which are also associated with other methodological strategies such as interviews, questionnaires and pre-tests (Figure 5).

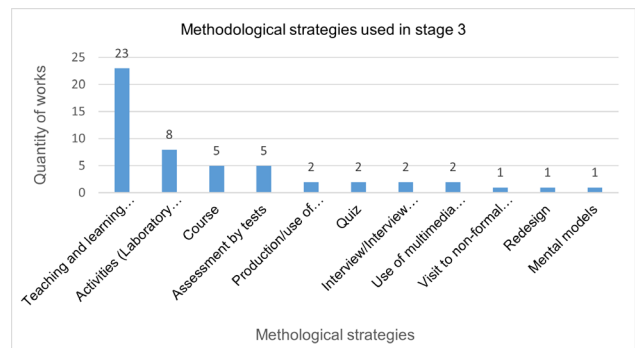
Figure 5 - Methodological strategies used in Stage 2 of MER



The use of such resources, which intend to capture information from the subjects, can be justified by the fact that the model values considering the students' conceptions as a fundamental aspect in the learning process, whose knowledge construction takes place through their previous experiences (Van Dijk; Kattmann, 2007).

The systematization of the procedures adopted for stage 3 (corresponding to the Instruction Construction) enabled highlighting that there were several productions related to the step, highlighting the Teaching-Learning Sequences as the most used methodological basis, in addition to the use of tests, courses, experimental activities, construction of models, simulations, among others (Figure 6).

Figure 6 - Methodological strategies used in stage 3 of the MER.



Thus, it is possible to demonstrate that it is at this stage of the model that the greatest diversity of methodological referrals occurs. This fact can occur because this phase subsidizes and uses elements from the previous stages in its structuring. In turn, pedagogical materials, teaching and learning activities, as well as didactic sequences can be developed (Niebert; Gropengieber, 2013; Silva; Ferreira, 2020), and above all because the authors of the model do not pre-determine exactly how this last stage of the model should occur until the conclusion in terms of the methodological resource to be used.

Furthermore, the methodological assumptions in the investigated research methodologies guiding the structuring of activities that the authors chose for stage 3 are not found, except for the guidelines arising from stages 1 and 2 of MER. Thus, the absence of guidelines or methodology for the design of the instructional process observed in the literature, and also in the model itself, constitutes an opening for the use of one or more proposals at this stage, since the model itself does not propose well-defined actions for its structuring, as it does for stages 1 and 2.

From this perspective, it is important to mention that unlike international studies with MER, the Brazilian studies did not use all stages of the model, because although the stages are closely linked, it is possible to contemplate stages 1 and 2 individually in different studies. Thus, national research focuses more on studies which use stage 1 and/or 2, and studies which include stage 3 have less occurrence.

Therefore, Brazilian studies on the model showed greater interest in the aspects inherent to the Content Structure Analysis in order to clarify the aspects that are related to the treated content (Niebert; Gropengieber, 2013; Silva; Ferreira, 2020), and interest in investigating their objects of study through Empirical Investigations, while few contemplated

the Instruction Construction, which lacks studies that perform integral immersion in the methodological aspects of MER.

3 Conclusion

MER represents an instructional design which aims to improve the school teaching and learning process configured in three stages, which can be presented individually or together (except the third), without compromising the teaching and learning process. The model showed a higher prevalence of use in the international context, with prevalence in Germany, while studies at the national level are still in a recent context; however, it is highlighted quantitatively when compared to other regions in the world.

In noting great interest from outside groups in the perspective of the model, there are researchers who have begun to direct it towards new approaches, and it has been a specific focus in several projects at the “Leibniz Institute for Science and Mathematics Education” in Kiel, Germany. In addition, it is the theoretical reference of the Graduate Program in Science Education at the University of Oldenburg.

MER is presented as an important theoretical-methodological design, and represents an effective framework for planning and instructional design, in addition to supporting the teachers’ professional development. Therefore, we hope that this design will gain even greater visibility in the educational scenario in Brazil, the Americas and other western regions, as well as in other knowledge fields from this study.

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