RBECT
Revista Brasileira de Ensino de Ciência e Tecnologia

Revista Brasileira de Ensino de Ciência e Tecnologia
ISSN: 1982-873X

https://periodicos.utfpr.edu.br/rbect

Instruments used to identify subsumer concepts in physics teaching: what the area's journals say

Ingridy Loreian
166795@upf.br
0000-0003-1319-1048
Instituto de Educação Tapejara LTDA, Tapejara, Rio Grande do Sul, Brasil.

Luiz Marcelo Darroz
ldarroz@upf.br
0000-0003-0884-9554
Universidade de Passo Fundo, Passo Fundo, Rio Grande do Sul, Brasil.

Cleci Teresinha Werner da Rosa
cwerner@upf.br
0000-0001-9933-8834
Universidade de Passo Fundo, Passo Fundo, Rio Grande do Sul, Brasil.

ABSTRACT

Subsuming concepts are specific knowledge, existing in the individual's cognitive structure, which allows giving meaning to new knowledge. Based on this conception, this article presents the results of an investigation that aimed to recognize, in Brazilian scientific production, the instruments used by researchers in the field of Physics teaching to identify subsuming concepts in their didactic-methodological approaches. To this end, state-of-the-art research was developed in articles contained in journals in the Teaching Area, and available online in the CAPES evaluation system. The study corpus consisted of twelve articles that contain the word “subsumer” in their title, abstract, and/or keywords. These materials were analyzed and classified considering their similarities, to show which instruments are used to identify the subsuming concepts. As a result, there was a predominance of the use of questionnaires for this purpose.

KEYWORDS: Meaningful Learning. Physics Teaching. Subsumers. Meaningful Learning Theory

1 INTRODUCTION

Physics is the science that studies nature and its phenomena. It is the part of the human construction that seeks to understandably describe all the reality experienced, building significant knowledge on which the development of science, technology, and society is anchored.

In this context, it is hoped that the teaching of Physics prepares the student for different situations of everyday life and the exercise of citizenship, providing the development of knowledge that corresponds to general culture and a vision of the world (BRASIL, 2002). This objective is reinforced by the National Curricular Common Base (BNCC), promulgated in 2018, which recommends the teaching of Physics able to provide an understanding of the world from the experiential context of students (BRASIL, 2018).

However, even in the face of the recommendations of official documents, what is evident, in most Brazilian schools today, is the development of the teaching of Physics focused on the sole transmission of contents. In this model, through expository methodologies, emphasis is placed on solving problems that are far from the daily context of students (BARBOSA *et al*., 2017).

According to Moreira (2017), such methodologies lead students to assume a position of mere receptors of knowledge, in a passive way in which they are only responsible for learning through repetition and memorization of outdated content. For Borges (2016), this fact may favor the student's misinterpretation that Physics is limited to applying formulas in artificial situations.

In an attempt to change this teaching model and develop actions that spark curiosity and interest in students to learn, Santos (2008) proposes that didactic-methodological actions are structured based on the assumptions of the Meaningful Learning Theory (MLT) advocated by David Paul Ausubel. According to the author, the premise of teaching from what students already know can favor the development of meaningful learning that responds to the needs of the contemporary world (SANTOS, 2008).

According to Ausubel (1973), meaningful learning, aimed at by MLT, is the process by which new knowledge is related in a non-arbitrary and non-literal way to existing knowledge in the cognitive structure of the learner, making it possible to expand, relate and structure their knowledge. That which is present in the minds of the learners and serves as an anchor for new learning is called “subsumers” by Ausubel and can be a proposition, an image, a symbol that is formed from the personal experiences of individuals (MOREIRA, 2019).

Considering the didactic-methodological situations structured in the assumptions of the MLT as potential promoters of learning capable of helping students to understand the world in which they are inserted, and taking into account the existence, in the specialized national literature, of several teaching proposals, elaborated based on this conception, the following question arises, which refers to the research question of this investigation: “How do national researchers in the area of Physics Teaching, who base their proposals on the MLT, identify the subsumer knowledge of the apprentices?”.

Seeking to answer this question, the objective of the present research is to identify, in the works published in national journals, how the subsumer concepts

are evidenced in the didactic-methodological proposals that are based on the MLT. Therefore, this work is organized as follows: initially, the assumptions of the MLT are discussed; next, the research methodology used is described; later, the results found are presented and commented on; and, as a closing, final considerations are made about the study carried out.

2 MEANINGFUL LEARNING THEORY

Proposed by David Paul Ausubel in the 1960s, the MLT starts from the premise that the promotion of meaningful learning "begins with the integration of information previously established in the student's cognitive structure with new knowledge" (CARMO FILHO; RIBEIRO; GONÇALVES, 2004, p. 1591). That is, in the Ausubelian view, learning is a process by which information is related in a non-arbitrary and non-literal way with relevant knowledge and presence in the student's cognitive structure, called by Ausubel a "subsumer concept" (MOREIRA, 2019).

In this direction, Ausubel (1973) understands that when a newly learned concept has little or no relationship with the subsumers present in the cognitive structure of the learner, mechanical learning occurs. Although this type of learning is considered opposed to meaningful learning, the theorist emphasizes that it is sometimes necessary to form the first concepts in an unknown area. From this perspective, mechanical learning and meaningful learning resulting from the process of interaction between new knowledge and subsuming concepts form a continuum, so that one can lead to the other, insofar as the learner, when they do not have in their cognitive structure knowledge, first learns mechanically, to then creates subsuming concepts and finally establishes meaning for the new knowledge (MOREIRA; MASINI, 2001).

To facilitate the occurrence of meaningful learning, Ausubel indicates the use of advance organizers after identifying the subsuming concepts present in the student's cognitive structure. Thus, the learner sets relationships between previous knowledge and the concepts that will be studied. These advance organizers correspond to materials presented before potentially significant material so that they serve as an anchor and facilitate learning, building a bridge between what the student already knows and what they will learn. According to Moreira and Masini (2001), these previous organizers need to be familiar with the students, be pedagogically willing, and present objectives.

It is also noteworthy that, being a didactic strategy that creates links between previous knowledge and new information; a previous organizer has the function of providing conditions for learners to organize these references in their cognitive structure. Thus, they are classified by Ausubel (1973) in two classes: expository and comparative. According to Loreian, Darroz, and Rosa (2020), materials that aim to provide basic notions of the knowledge to be learned are called "expository organizers", that is, materials that seek to establish subsuming concepts of a new unfamiliar knowledge student. For the same authors, "materials that address concepts with which the student has already had contact, but succinctly and not enough to become a subsumer, are classified as comparative organizers" (LOREIAN; DARROZ; ROSA, 2020, p. 213).

Throughout the process of establishing meaningful learning, in which new information is related to concepts that already exist in the learner's cognitive structure, it operates, according to Ausubel (1973, apud MOREIRA, 1999), a process called “knowledge assimilation”. In this process, the meanings of the concepts are expanded in an organized and differentiated way, and the learner can assimilate the relationship between the anchor ideas. For the author, assimilation in the learning phase encompasses:

> (1) selective anchoring of learning material to relevant ideas existing in the cognitive structure; (2) interaction between newly introduced ideas and existing (anchored) relevant ideas, with the former's meaning emerging as a product of this interaction; and (3) the connection of new emerging meanings with the corresponding anchored ideas in the memory interval (retention) (AUSUBEL, 1973, p. 24).

During this assimilation process, a potentially significant new knowledge or proposition a' “is assimilated with a more inclusive idea or concept already existing in the cognitive structure A', resulting in A'a', which represents the modified subsume” (MOREIRA; MASINI, 2001, p. 25). In this sense, Ausubel (1973, apud MOREIRA, 1999) suggests that assimilation has a facilitating effect on knowledge retention. For him, newly assimilated information becomes available during a period of fixation and, for a while, remains dissociable as individual entities.

In this context, Moreira and Masini (2001) emphasize that assimilation is an internal process of the student that results in the production of meanings leading to forgetting. In learning, forgetting is a continuation of this assimilation environment, facilitating the acquisition and retention of new concepts.

According to Ausubel (1973), learning needs to be accompanied by retention-forgetting, so that information is retained for a certain period. These, assimilated and organized, interact with previously established concepts. The perception of assimilation occurs with the interaction and modification between new and existing concepts in the student's cognitive structure. Forgetting depends on the link between potentially meaningful material and preexisting knowledge in the learner's cognitive structure. In the absence of this connection between concepts, there is a partial and spontaneous loss of these new meanings, which can no longer be anchored, in which case it is said that obliterating assimilation or significant forgetting has occurred.

Still, concerning the occurrence of the relationship between the new information and the existing one in the cognitive structure of the learner, Ausubel (1981 apud MOREIRA; MASINI, 2001) considers that it can occur in three different ways: (i) subordination, when new information acquires meaning through the interaction between more general knowledge; (ii) superordination, when the new information is more comprehensive than the subsumers and the students start to assimilate them; and (iii) combination, when the new information is not assimilated by existing concepts, that is when there are no specific subsumers, but the assimilation process of the new idea is similar to another one already carried out in some previous learning experience.

As meaningful learning takes place, concepts are developed, elaborated, and differentiated as a result of successive interactions. These interactions are called by Ausubel (1973) “progressive differentiation” and “integrative reconciliation”. Progressive differentiation happens when a new concept is learned through the

subordination process, but also modifies its subsumer. This process is important for programming teaching, as it allows more general ideas and concepts to be introduced at the beginning and gradually deepened. The subject first has a more general view of the subject, and then gets to know it more specifically. Integrative reconciliation, in turn, takes place during superordinate or combination learning. It is when the ideas of the cognitive structure are relatable, "allowing this framework to be reorganized, promoting new meanings for the contents" (MAZARO; DARROZ, 2020, p. 7).

In meaningful learning, new knowledge becomes progressively and differently meaningful to the subject. Therefore, the assessment of meaningful learning must seek evidence of learning involving assimilation and understanding. Therefore, understanding should not be explained mechanically, as this can often be the result of reflective and conversing learning, in which the progressive differentiation of these concepts significantly acquired by the student is perceived.

Starting from the conception that learning becomes meaningful for the subject when it develops from the anchoring of new knowledge in concepts present in its cognitive structure, the next section describes the methodology used to identify the instruments adopted by researchers in the area of Teaching Physics for the recognition of the subsumers of its apprentices.

3 METHODOLOGY

In an attempt to deepen the understanding of the investigated object, a qualitative approach was chosen for this research. This choice was based on the conception of Triviños (1987), who considers that qualitative research aims to describe the complexity of a given problem, analyze the interaction of certain variables, understand and classify dynamic processes experienced by social groups, collaborate in the process of change in a given group, and enable, in greater depth, the understanding of the particularities of the behavior of individuals.

In this direction, the present research was not based on the quantification of works that identify the subsuming concepts, but on the perception of how researchers in the area identify, in the cognitive structure of students, a knowledge that can serve as an anchor for other learning. In this way, a bibliographic nature is used in the treatment of data to, through a critical and in-depth reading of scientific articles that support their actions in the MLT interpret and understand how the subsuming concepts are evidenced in the context of Physics teaching.

To this end, initially, a set of Brazilian journals available online was selected, which are part of the WebQualis System of the Coordination for the Improvement of Higher Education Personnel (Capes), strata A1, A2, B1, and B2. WebQualis was chosen as a data source because it is a research database that investigates the Brazilian production in the area of Physics teaching and also because the system brings together the journals with the greatest academic circulation and notoriety in the country. The option to limit it to journals stems from the identification that this research dissemination vehicle represents the space for publishing works that have passed through events or even that result from theses and dissertations. Therefore, selecting journals means bringing together the production of events and Brazilian graduate studies, at least part of them. The option to select the four mentioned strata stems from the identification that in them we have the highest

concentration of research in Physics teaching associated with research works already concluded.

To identify the articles that made up the research corpus, a search was carried out in these journals for works that presented the expression “subsumer” and/or “subsumers” in the title, in the keywords, and/or in the abstract. The material found from this arrangement is shown in Board 1, totaling 12 articles for investigation.

Board 1 – List of articles that constituted the research corpus

Strata	Year	Journal	Title	Author(s)
A1	2006	Revista Brasileira de Ensino de Física	Construction of concepts of modern physics and on the nature of science with the support of hypermedia	Daniel Iria Machado; Roberto Nardi.
A1	2012	Revista Ensaio	Advance organizers for meaningful learning in Physics: the animated short film format	Rafael João Ribeiro; Sani de Carvalho Rutz da Silva; André Koscianski.
A2	2011	Revista Brasileira de Ensino de Ciências e Tecnologia	The influence of prior knowledge in the teaching of Modern and Contemporary Physics: an account of conceptual change as a process of meaningful learning	Alex Lino; Pôlonia Altoé Fusinato.
A2	2012	Ensino, Saúde e Ambiente	Subsumers for Physics Applied to Medicine in the Context of Physics Teaching	Maria Fernanda Parisoto; Marco Antonio Moreira; José Tullio Moro.
A2	2015	Investigação em Ensino de Ciências	Learning the syntax of Physics language	Henrique Cesa; Estevan Ballestero; Sergio de Mello Arruda; Marinez Meneghello Passos; Marcos Rodrigues da Silva.
A2	2016	Caderno Brasileiro de Ensino de Física	Experimental activities and computer simulations: integration for the construction of thermal energy transfer concepts in high school	Fernanda Teresa Moro; Italo Gabriel Neide.
A2	2017	Investigações em Ensino de Ciências	Identifying the conceptual evolution in the electromagnetism teaching, through a UEPS based on an	Carla Beatriz Spohr; Isabel Krey Garcia; Maria

			automotive sound system generator of energy	Cecília Pereira Santarosa.
A2	2019	Revista Brasileira de Ensino de Ciências e Tecnologia	The use of mental maps for understanding the relationship between Mathematics and Physics	Leticia Oberoffer Stefenon; Marco Antonio Moreira; Concesa Cabellero Sahelices
B1	2015	Ensino & Pesquisa	Approaching fluid statics through practice of David Ausubel's cognitivist learning theory	Camila Fernandes Cardozo.
B1	2018	Revista Multidisciplinar de Licenciatura e Formação Docente Ensino e Pesquisa	Subsumers investigation of middle level students about radioactivity and its relationship with science, technology and society (STS) using MAXqda10 software	Thaiz Regina Antiszko; Elenise Sauer.
B1	2018	Revista de Estudos e Pesquisas sobre Ensino Tecnológico	The formation of operative groups and their influence on the learning process in the electricity laboratory	Andrea Cantarelli Morales; Francisco Catelli.
B2	2018	Com a palavra o professor	Use the Word and Excel for students to create EJA subsumers for software use Modellus	Daniel de Jesus Melo Santos; Sergio Luiz Bragatto Boss.

Source: Research data (2011).

After composing the research corpus, the reading of the selected material began, grouping the articles in a converging process between similarities and the establishment of emerging categories of analysis. According to Moraes and Galiazzi (2007, p. 23-24), emerging categories are produced to compare and contrast in the units of analysis the set of data obtained, which the researcher organizes as "[...] an inductive process, of walk from the particular to the general, resulting in what is called emergent categories".

Following the described methodology, the investigation provides the interpretations and conclusions recorded below.

4 RESULTS

In this item, the results of this investigation are presented and discussed, which sought to examine which are the most used instruments for the identification of subsuming concepts in Physics teaching. To this end, the works were grouped into two categories: "Questionnaires" and "Diverse Strategies". The works contained in each of them and the interpretation resulting from the reading of these materials are exposed in continuity.

4.1 Questionnaire

In the understanding of Gil (2008, p. 128), questionnaires are defined "as the investigation technique composed "of a more or less high number of questions presented in writing to people, with the objective of knowing opinions, beliefs, feelings, interests, expectations, situations experienced". Based on this conception, this category gathers the works that present the use of questionnaires as an instrument to identify the subsumer concepts of the students. Board 2 presents the list of the 7 articles that work with open, closed, and mixed questionnaires.

Board 2 – Works that use questionnaires with instruments to identify subsuming concepts

Articles	Questionnaire
MORO, Fernanda Teresa; NEIDE, Italo Gabriel. Experimental activities and computer simulations: integration for the construction of thermal energy transfer concepts in high school. **Caderno Brasileiro de Ensino de Física**, v. 33, n. 3, p. 987-1008, 2016.	Open
LINO, Alex; FUSINATO, Pôlonia Altoé. The influence of prior knowledge in the teaching of Modern and Contemporary Physics: an account of conceptual change as a process of meaningful learning. **Revista Brasileira de Ensino de Ciências e Tecnologia**, v. 4, n. 3, p. 73-100, 2011.	Open
SPOHR, Carla Beatriz; GARCIA, Isabel Krey; SANTAROSA, Maria Cecília Pereira. Identifying the conceptual evolution in the teaching of electromagnetism, through a UEPS based on an automotive sound system generator of energy. **Investigações em Ensino de Ciências**, v. 22, n. 3, p. 162-175, 2017.	Open
MORALES, Andrea Cantarelli; CATELLI Francisco. The formation of operative groups and their influence on the learning process in the electricity laboratory. **Revista de Estudos e Pesquisas sobre Ensino Tecnológico (Educitec)**, v.4, n. 8, p. 404-420, 2018.	Open
PARISOTO, Maria Fernanda; MOREIRA, Marco Antonio; MORO, José Tullio. Subsumers for Physics Applied to Medicine in the Context of Physics Teaching. **Ensino, Saúde e Ambiente**, v. 5, n. 1, p. 46-63, 2012.	Closed
SANTOS, Daniel de Jesus Melo; BOSS, Sergio Luiz Bragatto.Use Word and Excel for students to create EJA subsumers for software use Modellus. **Com a palavra o Professor**, v. 3, n. 7, p. 15-30, 2018.	Closed
ANTISZKO, Thaiz Regina; SAUER Elenise. Subsumers investigation of middle level students about radioactivity and its relationship with science, technology and society (STS) using MAXqda10 software. **Revista Multidisciplinar de Licenciatura e Formação Docente Ensino e Pesquisa**, v. 16, n. 1, p. 173-189, 2018.	Mixed

Source: Research data (2011).

The analysis of these studies also allowed us to divide this set of articles into three subcategories: open questionnaires, closed questionnaires and mixed questionnaires.

Open.

With a high degree of freedom of response,

> the open questionnaire is one of the means used by researchers to collect research data from the group of participants, as well as their opinions and impressions about the research proposal (CHAR; DINIZ; RIBEIRO, 2011, p. 262).

Next, four works that adopt this feature to recognize subsumer concepts are described.

The first work that composes this subcategory, entitled "Experimental activities and computer simulations: integration for the construction of thermal energy transfer concepts in high school", aimed to qualitatively analyze the implications of using computer simulations linked to experimental activities for students. thermal energy concepts. The investigation involved a group of students from the 2nd year of high school, to which the researchers applied an open questionnaire, consisting of six questions, to highlight the subsumer concepts of these subjects about the concepts of temperature and heat, in addition to their perception of applicability. these concepts in everyday situations. The results indicate that the use of this type of questionnaire made it possible to identify that the participants had wrong or incomplete scientific knowledge of subsumers on thermal energy, but that could serve as an anchorage for the desired learning (MORO; NEIDE, 2016).

The research entitled "The influence of prior knowledge in the teaching of Modern and Contemporary Physics: an account of conceptual change as a process of meaningful learning" was the second article selected for this subcategory. The investigation sought to validate a proposal for a significant teaching of Modern and Contemporary Physics focused on the study of Classical Physics concepts in high school. The implementation of the proposal was carried out in a public school in the countryside of São Paulo, with the discussion of the radiation content of a black body together with the study of the theme of heat transfer mechanisms. In the investigation, the researchers used a questionnaire composed of four open questions to recognize the subsuming concepts of the participating students. The results were analyzed by grouping the responses into two categories called "classical subsumers" and "quantum subsumers". The conclusions of the work corroborate that it was possible to perceive the presence of subsuming concepts for the two themes approached through the instrument used (LINO; FUSINATO, 2011).

In the study entitled "Identifying the conceptual evolution in the electromagnetism teaching, through a UEPS based on an automotive sound system generator of energy", the third work of this subcategory, a Potentially Meaningful Teaching Unit (UEPS) was developed and implemented for the study of electromagnetism in high school. To identify the subsuming concepts present in the cognitive structure of the participants, a set of seven open and descriptive questions was used. The answers were grouped into two categories that sought to verify whether the answers given were based on common sense conceptions or were supported by knowledge accepted by the scientific community. The results indicate the presence of many understandings based on common sense

conceptions, also revealing that the UEPS was able to provide satisfactory conditions for the development of meaningful learning (SPOHR; GARCIA; SANTAROSA, 2017).

The last work included in this subcategory is entitled "The formation of operative groups and their influence on the learning process in the electricity laboratory". Seeking to identify the subsumers evidenced in the study groups for potentially significant teaching of electricity concepts, an open and descriptive questionnaire composed of four questions about general electricity was used. According to the heterogeneity and homogeneity of the subsumers manifested, the classes of the Electroelectronics Laboratory discipline of a Mechanical Engineering course were organized so that the proposed activities could promote the integration or differentiation of basic electricity concepts. The results indicate that the identification of subsuming concepts was very important for the success of the methodology adopted at work and helped to promote the desired meaningful learning (MORALES; CATELLI, 2018).

The analysis of these works indicates that, as they are able to demonstrate the opinions, impressions, and conceptions contained in the minds of the respondents, open questionnaires have been used by researchers in the area to identify the subsuming concepts present in the structure of the research.

Closed.

For Chaer, Diniz and Ribeiro (2011, p. 262), a questionnaire with closed questions is characterized by multiple-choice questions that present "specific alternatives for the informant to choose one of them". In this direction, the two works that used this medium to recognize subsuming concepts are described below.

The first work, entitled "Subsumers for Physics Applied to Medicine in the Context of Physics Teaching", presents a study that investigated the prior knowledge of a group of undergraduate Physics students about the applicability of Physics concepts in the area of Medicine. According to the authors, bibliographic research was carried out on articles from forty journals of the Capes WebQualis System, which indicated that such prior knowledge is little investigated by the world scientific community. From this stage, the prior knowledge of the area of a group of undergraduates from a public university in Rio Grande do Sul was investigated, through a questionnaire composed of 29 closed questions. The answers obtained showed that some participants had well-formed subsumers about the investigated concepts, while others had knowledge that needed to be emphasized or reinforced. This indicator was used to prepare instructional material for a teacher training course (PARISTO; MOREIRA; MORO, 2012).

The second work selected for this subcategory is entitled "Use the Word and Excel for students to create EJA subsumers for software use Modellus". Developed together with a high school group of Teaching Young People and Adults (EJA), the study sought to build subsumers through activities carried out with the softwares Word and Excel, aiming to facilitate the use of the Modellus software in the teaching-learning process. of kinematics concepts. To identify the students' previous concepts regarding the use of a computer, a closed questionnaire with four questions was applied. The result showed that most students had little

knowledge about computer use. Based on this finding, the authors organized an instructional material, using Word and Excel programs, to establish subsumers to use the Modellus software, which would serve as a previous organizer for the understanding of kinematics concepts. After the implementation of the proposal, the results showed that "by raising the students' prior knowledge on the subject addressed, possibilities were created to facilitate the understanding of the situation that would be proposed later" (SANTOS; BOSS, 2018, p. 28).

A closed questionnaire presents a lower degree of freedom for the responders to answer (CHAR; DINIZ; RIBEIRO, 2011). Even so, according to the analysis of the works in this subcategory, this instrument has been used by researchers to recognize subsuming concepts present in the cognitive structure of the participants, since they make it possible to perceive different aspects of reality, such as attitudes, behaviors, feelings, and patterns.

Mixed.

The combination of open and closed questions generates mixed questionnaires, which, in general, ask the respondents for a justification, an opinion, or contribution to the investigated element (AMARO; PÓVOA; MACEDO, 2004). In the analysis of the articles gathered in the "Questionnaires" category, a study was found that used this type of instrument to identify the subsumer concepts of the students: "Subsumers investigation of middle level students about radioactivity and its relationship with science, technology and society (CTS) using MAXqda10 software". The article aimed to investigate the assumptions that high school students present regarding the radioactivity content and its relationship with the STS through the MAXqda10 program. To this end, data collection took place through a mixed questionnaire composed of seven questions, and the analysis of the content of the responses was performed using the MAXqda10 software, which contributed to the stratification and recording of the analysis steps, providing transparency and agility to the process (ANTISZKO; SAUER, 2018). According to the results, the investigated group presented relevant subsumer concepts for the introduction of the subject, but it lacked some more specific and scientific connections about radioactivity.

Also, according to the authors, the mixed questionnaires provided important information on the elements contained in the students' cognitive structure, contributing to teachers in the search for adequate strategies for planning their teaching actions (ANTISZKO; SAUER, 2018).

4.2 Diversified methodologies

In this category, the works that present diversified methodologies for the identification of subsuming concepts of the research participants were grouped. Board 3 presents, in alphabetical order of references, the list of articles selected for this category.

Board 3 – Works that present diversified methodologies for the identification of subsuming concepts

Article	Methodology
MACHADO, Daniel I.; NARDI, Roberto. Construction of concepts of modern physics and on the nature of science with the support of hypermedia. **Revista Brasileira de Ensino de Física**, v. 28, n. 4, p. 473-485, 2006.	Hypermedia
RIBEIRO, Rafael João; SILVA, Sani de Carvalho Rutz da; KOSCIANSKI, André. Advance organizers for meaningful learning in Physics: the animated short film format. **Revista Ensaio**, v. 14, n.3, p. 167-183, 2012.	Short movie
CARDOZO, Camila F. Approaching fluid statics through practice of David Ausubel's cognitivist learning theory. **Revista Ensino & Pesquisa**, v. 13, n. 1, p. 96-108, 2015.	Simple low-budget experiments
STEFENON, Leticia Oberoffer; MOREIRA, Marco Antonio; SAHELICES, Concesa Cabellero. The use of mental maps for understanding the relationship of Mathematics and Physics. **Revista Brasileira de Ensino de Ciências e Tecnologia**, v. 12, n. 3, p. 223-240, 2019.	Concept maps
BALLESTERO, Henrique C. E. *et al*. Learning the syntax of Physics language **Investigações em Ensino de Ciências**, v. 20, n. 3, p. 1-20, 2015.	Problem solving

Source: Research data (2011).

The research entitled "Construction of concepts of modern physics and on the nature of science with the support of hypermedia", the first work included in this category, presents a didactic proposal based on MLT for the construction of concepts of Modern Physics and on the nature of Science with the support of hypermedia. According to the authors, the structure of the proposal, which constitutes a hypertext, was established in order to allow the exploration of concepts according to the principle of progressive differentiation through sequences of screens in which the most general aspects are started to later reach the with a higher degree of specificity (MACHADO; NARDI, 2006). At the beginning of the didactic proposal, which was implemented with a group of students from the third year of high school, through the interaction of the subjects with the hypertext, "we sought to identify and develop necessary subsumers for the deepening of the concepts of the theory of relativity and their correlations" (MACHADO; NARDI, 2006, p. 477). The results demonstrate that the methodology used favored the evolution of the students' conceptions regarding the concepts addressed.

The second work selected for the category, "Advance organizers for meaningful learning in Physics: the animated short film format", presents the creation of a previous organizer, in the form of a short film, to assist in the preparation of subsumers. The material was tested in a preview with a few students, who gave their opinions in written form. Thus, the researchers evaluated the opinion of these students in order to know, in advance, the ability of the material to reveal necessary subsumers for a later process of meaningful learning of the concept of moment of a force. According to the authors, predicting subsumers with a small part of the students, or even with the teacher's own

experience, prevents the advancement of technical terms in the zero phase of learning (RIBEIRO; SILVA; KOSCIANSKI, 2012). The results show that the short film built and implemented proved to be effective in the role of the previous organizer of the process of significant learning of the proposed theme.

With the objective of identifying the students' previous knowledge to deepen or correct, in theoretical classes, their conceptions in the direction of significant learning of fluid statics, the third work in this category, entitled “Approaching fluid statics through a practice of David Ausubel’s cognitivist learning theory”, presents a methodological proposal based on the cognitivist theory of David Ausubel. Elaborated by a scholarship holder from the Institutional Scholarship Program for Teaching Initiation (PIBID), the proposal was implemented with a second-year high school class and consisted of the construction of five simple and low-cost experiments to approach the initial concepts of fluid statics. In this, the perception of the concepts contained in the cognitive structure of the participants took place from the writing of a report that presented the procedures performed in each proposed experiment (CARDOZO, 2015). The analysis of the reports showed the existence of a disparity between the existing subsumer concepts. According to the author, while some participants demonstrated an understanding of certain theoretical aspects of the subject, “others presented theoretical inadequacies about the concepts of volume, mass, volumetric density, pressure, and force” (CARDOZO, 2015, p. 107).

The article entitled “The use of mental maps for understanding the relationship between Mathematics and Physics” is the fourth work grouped in this category. The authors sought to verify, through mental maps and conceptual schemes, the assumptions of Environmental and Sanitary Engineering students about the association between Mathematics and Physics, in an attempt to understand how these associations can contribute to these subjects giving meaning to the concepts of calculus. To this end, the students, during the course of Differential and Integral Calculus I, were organized to work on building their initial concepts in two types of mental maps: free and directed. In the first, “academics could freely associate their understanding of the concepts, and in the second, they should observe an organization with pre-established and pre-ordered words” (STEFENON; MOREIRA; SAHELICES, 2019). The results demonstrate “that both types of mental maps are suitable for organizing ideas and allow understanding of how Mathematics and Physics are perceived by students” (STEFENON; MOREIRA; SAHELICES, 2019, p. 236).

The last work selected for this category, entitled “Learning the syntax of physical language”, presents a case study that investigated the process of learning the physical language of one of the students enrolled in the discipline Introduction to Classical Mechanics of a postgraduate course at a university in the state of Paraná, Brazil. In the course, contents related to Newtonian, Lagrangian, and Hamiltonian formalisms are covered. In order to achieve the proposed objective, the records produced by the academics in the classroom during the resolution of problems, their evaluations, and their testimonies made during classes and during interviews were analyzed. The results indicate that the student was not able to build meaningful learning of physical language, although he was successful in learning the syntax of the physical language involved in the course. Also, according to the researchers, the difficulties presented by the student “were due to the lack of referents and their low knowledge of vocabulary related to the content in

question, which added to the absence of subsumers for this learning" (BALLESTERO *et al*., 2015, p. 1).

The analysis of the data gathered in this category indicates that researchers in the field of Physics teaching have also made use of hypermedia, dialogues, mental maps and written records as instruments for the identification of concepts capable of anchoring new knowledge and promoting meaningful learning of physical content.

5 FINAL CONSIDERATIONS

Identifying subsumers means perceiving a highly organized knowledge structure, which has a conceptual hierarchy and stores previous experiences of the learner, being able to anchor new knowledge (MOREIRA, 2019). Based on this conception, the present work focused on recognizing which instruments have been used by researchers in the field of Physics Teaching in the process of identifying subsuming concepts of didactic-methodological actions based on the MLT.

The analysis of the selected works showed that the main instrument used to recognize the subsuming concepts present in the cognitive structures of the participants in the questionnaires. Of the twelve works included in the corpus, seven made use of this instrument; of these, four used open questionnaires, two closed, and one mixed. However, the data also identified other instruments used, such as hypermedia – hypertext and short videos–, dialogues between students and teachers, elaboration of mental maps, and written records during problem-solving and evaluation. Although with different structures and resorting to the use of different instruments – questionnaires and different strategies –, all the resources proved to be effective in what they were proposed.

Finally, it is worth mentioning that, although it was not the objective of this investigation, the results reaffirm that the structuring of didactic-methodological proposals based on the MLT helps to promote non-arbitrary, generalizing, and value-integrating learning regarding the meaning of physical concepts. In this sense, identifying the instruments adopted for the recognition of subsuming concepts can favor the design and organization of methodologies that favor the learners' development of learning that help them to relate school contents to their daily lives.

INSTRUMENTOS UTILIZADOS PARA A IDENTIFICAÇÃO DOS CONCEITOS SUBSUNÇORES NO ENSINO DE FÍSICA: O QUE DIZEM OS PERIÓDICOS DA ÁREA

RESUMO

Conceitos subsunçores são conhecimentos específicos, existentes na estrutura cognitiva do indivíduo, que permitem dar significado a novos conhecimentos. A partir dessa concepção, apresentam-se, neste artigo, os resultados de uma investigação que teve como objetivo reconhecer, na produção científica brasileira, os instrumentos usados por pesquisadores da área de ensino de Física para a identificação dos conceitos subsunçores em suas propostas didático-metodológicas. Para tal, desenvolveu-se uma pesquisa do tipo estado da arte em artigos contidos em periódicos nacionais, da Área de Ensino, disponíveis on-line no sistema de avaliação da CAPES. O corpus do estudo se constituiu de doze artigos que contêm o vocábulo "subsunçor" em seu título, resumo e/ou palavras-chave. Esses materiais foram analisados e classificados considerando suas semelhanças, a fim de evidenciar quais instrumentos são utilizados para identificação dos conceitos subsunçores. Como resultado, verificou-se a predominância do uso de questionários para esse fim.

PALAVRAS-CHAVE: Aprendizagem Significativa. Ensino de Física. Subsunçores. Teoria da Aprendizagem Significativa.

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Received: Jul. 21st, 2021.
Approved: Jul. 06th, 2022.
DOI: 10.3895/rbect.v15n2.14543
How to cite: LOREIAN, I.; DARROZ, L. M.; ROSA, C. T. W. Instruments used to identify subsumer concepts in physics teaching: what the area's journals say. **Brazilian Journal of Science Teaching and Technology**, Ponta Grossa, v.15, p. 1-20, 2022. Available at: <https://periodicos.utfpr.edu.br/rbect/article/view/14543>. Access on: XXX.
Mailing address: Ingridy Loreian - 166795@upf.br