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Use of Different External Mediating Mechanisms of the Bohr Atom Model: Evidence of Meaningful Learning through Verbal-Gestural Analysis in Elementary School Students

Savana dos Anjos Freitas[a]
Agostinho Serrano de Andrade Neto[a]

[a] Universidade Luterana do Brasil, Programa de Pós-Graduação em Ensino de Ciências e Matemática, Canoas, RS, Brasil.

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ABSTRACT

The present article sought to investigate if the use of different external mediation mechanisms to teach the Bohr Atom model in elementary education with the didactic methodology of the Potentially Significant Teaching Units (PSTU) can result in Meaningful learning. Therefore, we naturally use the theoretical contribution of the Ausubelian Meaningful Learning Theory, in particular by discussing elements that indicate evidence of meaningful learning. This theory was adopted with the purpose of understanding and analyzing whether or not there is evidence of meaningful learning with elementary level students after about a year of using the didactic methodology. The didactic methodology used was the application of didactic sequences inspired by the PSTU model, modified to be applied in Elementary School. We also use different external mediation mechanisms that independently reproduce the Bohr atom model, such as model building (psychophysical mediation), teacher explanation on a blackboard (social mediation), use of textbooks (cultural mediation) and computer simulations (hypercultural mediation). Data analysis was carried out through two semi-structured interviews according to the Report Aloud protocol followed by the depictive gestural analysis, performed with an interval of almost one year, both interviews were carried out after the application of the didactic methodology, in order to assess the retention of the learning residue. We argue that the students' verbal-gestural production indicates that there was meaningful learning of the Bohr Atom model, especially related to social and hypercultural mediations.

Keywords: Meaningful learning; Bohr atom; Elementary School; PSTU; Verbal-gestural analysis.

Corresponding author: Savana dos Anjos Freitas. E-mail: savanafreitas@rede.ulbra.br

Uso de Diferentes Mecanismos Externos de Mediação do Modelo do Átomo de Bohr: Evidências de Aprendizagem Significativa por meio de Análise Verbo-Gestual em Estudantes de Ensino Fundamental

RESUMO

O presente artigo buscou investigar se a utilização de diferentes mecanismos externos de mediação para ensinar o modelo de Átomo de Bohr no ensino fundamental, com a metodologia didática das Unidades de Ensino Potencialmente Significativas (UEPS), pode resultar em aprendizagem significativa. Assim, utilizamos naturalmente o aporte teórico da Teoria da Aprendizagem Significativa Ausubeliana, em especial, discutindo elementos que indiquem evidências de aprendizagem significativa. Essa teoria foi adotada com o intuito de compreender e analisar se existe, ou não, evidências de aprendizagem significativa com alunos do último ano do nível fundamental após cerca de um ano da utilização da metodologia didática. A metodologia didática empregada foi a aplicação de sequências didáticas inspiradas no modelo de UEPS, modificadas para serem aplicadas no Ensino Fundamental. Também utilizamos diferentes mecanismos externos de mediação que, independentemente, reproduzem o modelo do Átomo de Bohr, como a construção de maquetes (mediação psicofísica), explanação do professor em um quadro-negro (mediação social), utilização de livros didáticos e vídeos (mediação cultural) e simulações computacionais (mediação hipercultural). A análise dos dados ocorreu mediante duas entrevistas semiestruturadas conforme o protocolo Report Aloud, seguidas da análise gestual descritiva, realizadas com um intervalo de quase um ano, sendo ambas as entrevistas realizadas após a aplicação da metodologia didática, a fim de se verificar a retenção do resíduo da aprendizagem significativa. Argumentamos que a produção verbo-gestual dos alunos indica que houve aprendizagem significativa do modelo do Átomo de Bohr, em especial, vinculada às mediações social e hipercultural.

Palavras-chave: aprendizagem significativa; átomo de Bohr; ensino fundamental; UEPS; análise verbo-gestual.

INTRODUCTION

The meaningful learning of concepts related to the area of science with elementary students, and especially the final years, is a difficulty currently encountered. Science education is often overlooked by several obstacles found in Brazilian classrooms: either by the lack of qualified teachers, by the use (or even the existence) of science labs, or by the natural complexity in teaching concepts relevant to the areas of Chemistry and Physics, mainly.

Anderson (2002) points out that the teaching of science, for many people, is considered complex, since understanding concepts require a great deal of abstraction. Chavan (2013) confirms and says that even the science teachers teach can be complex, given this level of abstraction necessary. Teachers need to understand the subject in a deep and flexible way so they can help students relate one idea to another, attack an alternative conception, and even create cognitive maps useful for learning.

The classrooms are focused on a model of teaching in which teachers use the blackboard (or projector) in their explanations and then the students copy in their notebooks or take pictures in their smartphones (Moreira, 2011a). In other contexts some

teachers are considered excellent for explaining in detail the content with oral expositions that enchant students, but can such meaningful learning be achieved? Is it that when the students meet, after a few months, with this same content, will there be any learning left or is it only in that short period of time directed to the test? (Moreira, 2011a). Moreover, the learning of theoretical models – these so important in the learning of concepts of physics and sciences in general, like the Atom of Bohr – is the object of investigations that go back even the famous article of Helen Doerr (1997).

If many authors agree that meaningful learning of concepts and models is particularly difficult (nonetheless desired), many hindrances may manifest themselves when one returns to science teaching in Elementary School. According to Melo, Campos, and Almeida (2015), many teachers have no training in this area of knowledge, that is, they do not graduate in Physics or Chemistry, which technically does not qualify them to work with these disciplines, thus generating difficulties in teaching. The lack of laboratories is also a factor mentioned by the authors since it can negatively affect the motivation of teachers and students to teach science and become a barrier to meaningful learning.

Some research shows that the number of students interested in subjects such as Chemistry and Physics declines significantly at the time of transition between elementary and middle school. Thus, it is necessary to seek to understand why this is so, as well as to find solutions so that it is possible that students do not lose interest. According to Dare and Roehrig (2016), the PISA results showed in their last edition that the interest in scientific careers is similar for girls (27%) and boys (24%) for 15 years in different countries. However, by the end of high school, only 12% of girls are interested in continuing in the STEM (Science, Technology, Engineering, and Mathematics) areas, while 40% of boys are still interested in continuing in this area.

In view of this, some specific problems are presented in the context of the present research, namely: a) School located in a neighborhood considered of social vulnerability; b) Teachers not graduated in Physics or Chemistry to teach classes of the 9th grade of Elementary School; c) Laboratory of Sciences without access to students. In addition, this research, in particular, has the objective of testing a didactic model that is capable of promoting meaningful learning of the Bohr Atom Model. Likewise, the challenge of obtaining, in an auxiliary way, evidence of the link between mental simulations and meaningful learning and, of course, meaningful learning in Elementary school through Potentially Significant Teaching Units (PSTU) combined with didactic resources.

From these problems, it was sought to understand if the use of PSTU with distinct resources could contribute to the teaching of Sciences and enable meaningful learning with Elementary School students, in order to better know the Physics and acquire an interest in this area, in order to which do not decline when entering high school.

It is believed that the use of different didactic resources (computer simulation, modeling using mock-ups, use of different textbooks, low-cost experiments, among others) that illustrate the operation of the Bohr atom model with the combination of a PSTU didactic sequence for Elementary School can provide elementary school students with meaningful learning of the Bohr atom model.

Thus, this article presents data that were obtained through the application of PSTU in Elementary School for the meaningful learning of the Bohr atom model with students of the last year of the elementary level of Basic Education. Therefore, the article presents the results obtained after this application in the classroom having as theoretical support the meaningful learning of David Ausubel discussing the possible evidence of finding in the search for meaningful learning.

THEORETICAL REFERENCE

Meaningful learning and forgetting depend on two integrated factors: the relationship of potentially significant new materials with relevant ideas in cognitive structure of the learner, and a second step, the subsequent spontaneous and gradual loss of dissociation of new meanings, which are acquired through this interaction, that is, of the anchored ideas (obliterating subsumption) (Ausubel, 2000).

Thus, whether in memorizing or meaningful learning, the actual reproduction of the retained material is also affected by factors such as cultural and attitude tendencies and situational requirements specific to the scope of reproduction. These differences between memorization and meaningful learning processes explain, for the most part, the superiority of meaningful learning and retention relative to the memorized ones, but whether meaningful learning is or is not required is evidence.

Moreira (2012) states that the search for evidence of meaningful learning is important and not just the establishment of meaningful learning. It is important recursion, in which the learner can express the meanings they understand, justifying their answers. Still, on the signs of meaningful learning, Moreira (2012) states that:

> Undoubtedly, quite difficult to assess meaningful learning. Mainly because it implies a new attitude towards the evaluation. It is much simpler to assess the right or wrong type, but the result is largely mechanical learning. (Moreira, 2012, 24)

It is surprising that it is not always easy to show that there has been meaningful learning. Genuine understanding presupposes the possession of clear, concise, distinct, and transferable meanings. However, if this knowledge is tested by asking learners to expose the characteristic attributes or the essential elements of a concept or principle, one can simply get verbalizations that have been acquired and memorized. Therefore, at a minimum, comprehension checks should be formulated using a different language and presented in a slightly different context than the initial presentation of the material (Ausubel, 2000).

As Moreira (2011b), unlike mechanical learning, in which forgetting is rapid and complete in meaningful learning forgetting is residual. Meaningful learning is not one in which the student will never forget because forgetting is a natural

consequence of learning. Ausubel referred to as obliterated assimilation, that is, a progressive loss of the dissociability of the new knowledge, which served, at first, as a cognitive anchorage.

There is a good reason to believe that there has been meaningful learning if you score some aspects. If the subject that was developed with the learners was organized and programmed appropriately and if the ideas were available in the cognitive structure, if the material is presented in a lucid and incisive manner, if misunderstandings are corrected quickly and if the students were properly motivated to learn meaningfully and pay attention to the considerations as a great review and pace it is possible to trust that meaningful learning has occurred (Ausubel, 2000).

Ausubel (2000) still reiterates that human cognitive equipment, unlike that of a computer, cannot effectively deal with information related to itself on an arbitrary and literal basis, one can only internalize relatively simple learning tasks and these are retained by a short period of time unless they are well apprehended. Thus, the evidence is meaningful learning the relation with time. Mechanical learning is retained for a very short time in the student's cognitive structure since meaningful learning has the possibility of relearning (which does not exist in mechanical learning) in a shorter period than the original learning.

Therefore, meaningful learning can happen through two main factors, with the material used and the knowledge that is present in the student's cognitive structure. Therefore, it is possible to seek evidence of meaningful learning to understand whether or not there was meaningful and non-mechanical learning, and one of the evidence of meaningful learning is retention of the concept (or model) after a significant period of time.

In order to investigate meaningful learning and its relation with the use of Bohr atom models in elementary school, principles of the theoretical framework of Cognitive Mediation Theory (CMT) are used here (Campello de Souza, da Silva, Roazzi, & Carrilho, 2012). One of the principles of CMT is that, since the human brain is naturally limited, elements present in the environment are used to complement cognitive ability, including in the learning of sciences, and in particular, the Bohr Atom model. These elements are hereafter termed external mediation mechanisms.

The referential also defines four major types of mediation that human beings use to complement their cognitive ability: psychophysical mediation (which uses physical elements of the environment, such as the abacus for calculation), social mediation (which uses the cognitive ability of others, similar to Vygotsky Proximal Development Zone (ZPD), cultural mediation (by elements brought about by culture, such as pencils, paper and more currently videos), and finally, hypercultural mediation (where the external mediation mechanism is ultimately capable of independent decision-making through an ``if-then-else loop`` or similar). The theoretical reference in question is not the focus of this study, which uses the Ausubelian reference, as already discussed; only these principles and concepts are presented here.

One point that has not been discussed within the theoretical framework of meaningful learning and which this article seeks to explore is the link between meaningful learning – especially the learning residue, namely the modified subsumption – and the mental images produced by students after a long time. It is argued that such a meaningful learning is evidenced by the richness that a particular concept is articulated by the student – when expressed verbally – a model that makes use of the same mental images (these come directly from external mediating mechanisms introduced during the teaching process) after a long time, being this model able to make predictions and resolutions of problems correctly, also constitutes evidence of meaningful learning.

Thus, the key question in this article is whether it is possible to learn meaningful learning of the Bohr atom model following a didactic strategy of combined use of PSTU and the use of four different external mediation mechanisms representing the Bohr atom. To answer this key question, it is also necessary to answer the auxiliary question of whether it is possible to identify meaningful learning after a verbal-gestural analysis of an interview with elementary students of their private model of the Bohr Atom.

METHODOLOGY

The research was constituted in two specific moments: moment A and moment B, during the two years of the research. The first moment (A) was the accomplishment of 10 classes with students of the fundamental level with the use of PSTU directed to the Elementary School with the use of diverse didactic resources for the teaching of the model of the Atom of Bohr. After the closing of the last class, the interview followed the Report Aloud protocol (Trevisan, Serrano, Wolff, & Ramos, *in press*). The moment B occurred after 11 months of the end of the moment A when there was a return to the researched school for a new data collection by conducting a new interview following the same protocol.

The didactic sequence used in the research, in the second half of 2017, came about through observations made in the previous semester. Between the months of March and July of 2017 was applied to the PSTU students according to the proposals of Moreira (2011c). In the PSTU applied between September and November 2017, there was a change in its structure, using different didactic resources and aimed at the public that is at the end of Elementary School.

Next, it will be described how each moment of the research occurred, as well as in what way the data collection and its analysis took place.

Moment A

During the first semester of 2017, seven PSTU were applied (without modification for their use in Elementary School), and some aspects were observed regarding student

participation and learning. Many students did not remember from previous concepts, just had no predisposition to learn at certain times. In view of this, the idea of modifying PSTU to be applied in Elementary School appeared, and until the present moment of the research, on PSTU were found that were applied at the fundamental level and published.

In this way, the following UEPS for the Elementary School were elaborated:

a) Initial situation: Presentation of situations through play activities, whose objective is to make students remember and express the concepts developed in the previous class;

b) Explanation of content: Introduction of the concept to be developed in class using slides, blackboard or materials to exemplify the content;

c) Activity through CMT mediations (Souza, 2004): Practical activities based on one of four mediations of CMT;

d) Evaluation of learning and teaching sequence: a lesson can be developed based on some type of individual activity, with debates, after class work, play activities or teacher notes regarding student participation, for example.

The first stage of the didactic sequence was aimed at helping students to recall the previously studied concepts. In order to reach this objective and in view of the age range of the students, it was decided to use activities which were called "play activities", in which, through play, it is possible to develop the main concepts. The second stage consisted of the explanation of content through the use of slides or the whiteboard, according to the teachers' choice.

The third step, in the light of the CMT, was intended to elaborate some activity based on one of the four mediations of CMT. More specifically, what was chosen to be taught is the Bohr Atom model. Because it is a model with a specific mechanistic, it was chosen to use all four mediations (Campello de Souza et al., 2012) to be used. The Bohr model was then psychophysically taught by an external mechanism of specific mediation, a model using Styrofoam, balls, and leds representing the Bohr atom. For social mediation, a teacher used the blackboard and drew the model, explaining it later.

For cultural mediation, there was the use of textbooks, which describe the Bohr Atom model appropriate to the elementary level, complemented by videos that the students themselves independently sought. Finally, a computational simulation of the Bohr Atom was used as hypercultural mediation. Finally, the fourth step was to verify, through teacher observations, report delivery, and student participation, in what way the didactic sequence can contribute to the students' learning process.

So for a better understanding of the teaching sequence, the diagram below clarifies the PSTU for Elementary Education drawn up to apply in elementary school.

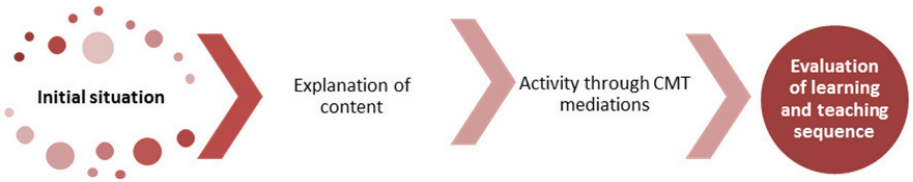

Figure 1. Illustration with the stages of the PSTU for Elementary School.

Moment B

Moment B consisted of returning to school after 11 months of project completion. The same students of 2017 were interviewed; following the same protocol used almost a year from the first moment.

In view of what was put in place and due to the main aspects involved in the search for evidence of meaningful learning and the difficulties faced in this search, it was decided to return to school after a few months and to perform new data collection. Eleven months after the end of the project in November 2017, there was a return to school in October 2018 and were interviewed three (A1, A2, and A3) of the five students participating in the first data collection.

The interviews were carried out in the same way as the previous ones, such as Wolff (2015) and Schittler (2015) in their doctoral research, who interviewed the students after six (Wolff, 2015) and 10 months (Schittler, 2015), respectively.

Data collection in October 2018 was based on three central questions. However, as the interview was semi-structured, new questions arose, as students began to use mental images from the mediations of CMT, and thus from the different didactic resources.

Data Collect

Data collection took place through an interview following the *Report Aloud* protocol (Ramos, 2015), which is an adaptation of the *Think Aloud* technique (Van-Someren, Barnard, & Sandberg, 1994). The difference between the methods is that in *Think Aloud* the interviewer and the interviewee maintain a constant dialogue about what the interviewee is thinking about during the execution of a task, that is, while the student answers the questionnaire and thinks out loud. In *Report Aloud*, the student reports to the interviewer his / her thought process while answering the questions, that is, the student solves the questions and only then, in the end, reports his / her thinking process. A detailed description of the technique is found in Trevisan, Serrano, Wolff, and Ramos (*in press*).

The interviews were conducted and recorded with the students (five at time A and three at time B), then they were transcribed literally through the audits performed by the students, for proper analysis. The analysis was performed by audio analysis and

transcription (verbal analysis) and also by the descriptive gestural analysis of Monaghan and Clement (1999). According to these authors, the movement of the hands can indicate the mental images that the students have at the moment they answer an issue, the gesture being a way of externalizing what is happening in their mind at that moment (Freitas & Serrano, 2018). The combination of the two analyzes reveals the verbal-gestural profile of the student.

This research was approved by the Human Research Ethics Committee of the Lutheran University of Brazil, via Plataforma Brasil under the number CAAE: 73831517.9.0000.5349.

RESULTS AND ANALYSIS

It is observed that most students are able to explain the model of the Bohr atom, the process of emission and absorption of light and provide a concept for the atom, based on representations acquired through the use of hypercultural (simulator) and psychophysical (LED model) of the Bohr Atom model combined. The access of the researchers to the internal representations of the students occurs after the use of the interview and the verbal-gestural analysis described above.

In the 2017 interview, the student A1 imagined the two hypercultural and psychophysical mediations combined. In fact, after almost a year, she stated that in order to explain the content to a colleague she would use psychophysical mediation, even if – in her mind – it is the image of the simulation that emerges (hypercultural). In addition, A1 performed the same gestures when mentioning the image of the electron.

Figure 2. Gestures in relation to the electron mentioned by the student in 2017 and after 11 months.

The student A2, in responding to the first question in the 2017 interview, used the mental images that were obtained, as identified in an interview, through social mediation, to explain the functioning of the Bohr Atom model. After 11 months, in answering the same question he used external mediating mechanisms that represent the Bohr Atom model through psychophysical and hypercultural mediations.

However, the student A3 portrayed the computational simulation in his mind, but under a different aspect. A3 imagined the atom as something "antique". That is, he saw in computational simulation (hypercultural mediation) the description of the atom's image as

shown in The Big Bang Theory series, as he had mentioned in the interview at moment A. When explaining to a colleague, as inquired in the interview, he uses the psychophysical model. Therefore, there is a combination of two models (cultural and hypercultural) and the use of a third (psychophysical) if there is a need to explain to a classmate:

> I: And when you're talking to me, you're imagining the simulation, it's remembering the LED model, the teacher explains...
>
> A3: **In the simulation, I'm imagining the model of the old atom.** Which is the one who has the "twists"?
>
> I: Oh, you're remembering the simulation model of the atom in case.
>
> A3: In the explanation, I'm explaining in the model.
>
> I: Oh, when you perform these gestures, you are imagining the model made with LED, isn't it?
>
> A3: Yes.

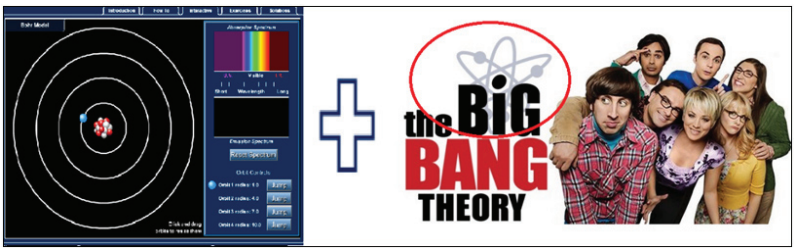

Figure 3. Student A3 uses Computational Simulation in combination with the Big Bang Theory series logo as the Bohr atom model.

The gestures presented in the figure below, performed by student A3 in the second interview, are similar to the gestures performed while explaining the behavior of the jump from one orbit to another, with the same direction.

Figure 4. Gestures related to the jumps from one orbit to another in 2017 and 2018.

The A3 student in the first interview alluded to the didactic cultural resources about the image he had of the atom. In the second interview he retained that image, so much so that when the interviewer questioned the picture, he quoted the series (cultural mediation) and asked the interviewer if he remembered it.

Table 1
Comparison between interviews from 2017 and 2018.

Interview performed in Nov/2017	Interview performed in Oct/2018
I: You saw this somewhere, right? Do you remember where you saw it? A3: In The Big Bang Theory Series.	A3: Because of the simulation I remember a series I saw, remember? Whenever the atom appeared, they used it as an "item" in transition. I: An item in transition. Right.

On the representation of the photon, the student A1 imagined the photon as a ray. In both interviews, he stated that the image he had was derived from a computer simulation.

The A3 student, in his first interview, did not make gestures related to the concept of the photon. He only said that "when he jumps from a higher orbit it absorbs a photon" and then said he thought these jumps as the frame image (social mediation).

In the following figure, there is an example of the student A1, which used a combination of two mediations for electron image representation. A1 imagined, according to the gestural and discursive analysis, the representation of the electron in the LED model (psychophysical mediation) "inside" the computational simulation (hypercultural mediation). It is possible to affirm that it acquired meaningful learning since it used these same representations after 11 months at the end of the research. This was identified by gestural speech combined with the following verbal speech.

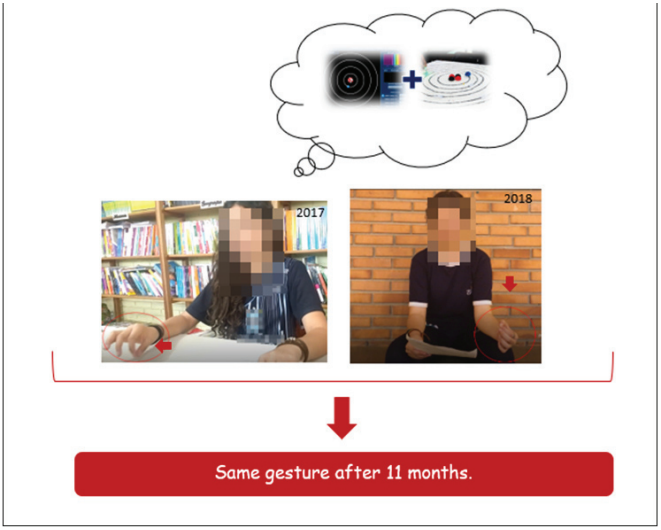

Figure 5. Systematic illustration of the main conclusion of this research.

In the original interview (2017, Moment A), A1 explores his model for the Bohr atom and which mediations provided mental images for constructing his private model:

> I: Do you remember what kind of class? There are even a few that you used and a few things here that the teacher used, that computer thing, that model. Which one came first in your head, a book thing or something that is not here?
>
> A1: First it was the latter (psychophysical model).
>
> I: That model over there?
>
> A1: The Bohr atom model.
>
> …
>
> I: Do they also appear both the computer and the template or one thing on top of another?
>
> A1: Both (psychophysical and hypercultural).
>
> I: Both. Like, one side by side, or the two together?
>
> A1: One beside the other.

At the moment B (2018),

> I: If you were to explain to one of your colleagues now what is the Bohr atom, you would use the simulation or the model?
>
> A1: The model.

I: The model. The model you used to explain to a colleague. But when you imagine, do you think of what?

A1: Hmmm, I think in the computer simulation.

Therefore, 11 months after project completion, not just A1, but all the students interviewed, still remembered important concepts about the Bohr Atom. Although new situations have not been presented to students, they have been able to express their meanings and explain and justify their answers, which, according to Moreira (2011b), are a way to seek evidence of meaningful learning. Not only the gestures and mental images are similar and come mainly from the external mechanisms of psychophysical and hypercultural mediation.

The time factor also helps in the search for signs of meaningful learning. According to Moreira (2012, p.40), "unlike mechanical learning, in which forgetfulness is rapid and practically total, in forgetful learning, forgetfulness is residual." That is, the knowledge that has been forgotten is "inside" the subsumption, manifested itself as a "residue" in this.

Ausubel (2000), as previously mentioned, it brings can only internalize relatively simple learning tasks and these can only be retained for a short time unless it is well seized. Ergo, in this research, it is possible to affirm that there is meaningful learning because if the students had received mechanical learning they would not be able to respond and justify their answers almost a year later, nor provide and explain their Bohr atom models with details and demonstrated safety.

In accordance with Moreira (2011b), unlike mechanical learning, in which forgetting is rapid and complete in meaningful learning forgetting is residual. Even after 11 months, students had the feeling that if they had to, they could relearn that content. It was possible to perceive that the students, when beginning to explain and justify their answers, were able to explain the content to a colleague, that is, they were able to explain what Bohr's atom was and what happened when an electron jumped from an orbit to another. Therefore, the results of the present research demonstrate what Ausubel calls obliteration assimilation.

Still, according to Moreira (2011b), a characteristic of meaningful learning is the interaction between previous and new knowledge. The A3 student states that at first he always remembered the image of the atom related to a television series, more specifically, with the logo of the series that carried the atom. After his participation in the PIBID subproject, the student, during the interview, no longer uses the image he imagined from the series, but begins by mentioning the didactic resources coming from hypercultural and psychophysical mediations. Soon, in the interview in 2018, he imagined Bohr's Atom of the series in computational simulation.

Thus, even though it was almost a year after the last interview with the students, they still remembered the concept of the Bohr Atom through the representations acquired by the didactic resources derived from the four mediations. Therefore, evidence was obtained

of Meaningful Learning of the Bohr atom model with students from elementary school through a verb-sign analysis of the explanation of this model for such students.

CONCLUSION

Responding to the research question, this article brings evidence of meaningful learning of the Bohr Atom model with Elementary School students. This learning was a consequence of the integrated use of the UEPS didactic model and of four different external mediating mechanisms that represent a theoretical model of the Bohr Atom appropriate to the elementary level. The junction between them, even in the face of obstacles associated by the authors from the beginning, brought evidence that the teaching of science is possible and, in particular, physics, with students in the last year of elementary level, providing, thus, a new view of the world of physics and perhaps increasing the interest in him from the Elementary and High School.

Responding also to the auxiliary question, it is believed that it can be said to occur Ausubel meaningful learning through a verb-sign combined analysis, carried out by two taped interviews with considerable amount of time between them (11 months), before details provided by the students of the model, the security of your explanation and the fact that the different external mediation mechanisms that give rise to mental images that make up the mental simulations used as elements of their private models are properly remembered.

It is believed that the way and the integration between UEPS for Elementary School and distinct didactic resources brought three important aspects: a) The combination of different forms of mediation can contribute to the teaching and learning of students; b) Use of a UEPS for Elementary School; and finally, c) Meaningful learning models and consequently concepts related to science for students of elementary school, and to contribute to the students of Elementary School have known physics in a different way than is commonly realized. In addition, it is expected that this didactic model can be used successfully in science education of the ninth grade of elementary school with relative success throughout the country, with positive contributions to this school stage.

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AUTHORS' CONTRIBUTIONS STATEMENTS

The authors, S.A.F and A.S.A.N, performed the field activities and data collection. All the authors analyzed, discussed and elaborated on the version of this scientific article.

DATA AVAILABILITY STATEMENT

Data that supports project data is available for reference only at the following link [https://drive.google.com/open?id=1dRU43vOnl6ss34Q27iCm2ASfjj9-i6ma] but cannot be reused.

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