

The Didactic Transposition in Brazilian High School Physics Textbooks: A Comparative Study of Didactic Materials

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Abstract—In this article, we analyze the different approaches to the topic Magnetism of Matter in physics textbooks of Brazilian schools. For this, we compared the approach to the concepts of the magnetic characteristics of materials (diamagnetism, paramagnetism, ferromagnetism and antiferromagnetism) in different sources of information and in different levels of education, from Higher Education to High School. In this sense, we used as reference the theory of the Didactic Transposition of Yves Chevallard, a French educational theorist, who conceived in his theory three types of knowledge – Scholarly Knowledge, Knowledge to be taught and Taught Knowledge – related to teaching practice. As a research methodology, from the reading of the works used in teacher training and those destined to basic education students, we compared the treatment of a higher education physics book, a scientific article published in a Brazilian journal of the educational area, and four high school textbooks, in order to establish in which there is a greater or lesser degree of approximation with the knowledge produced by the scholars – scholarly knowledge – or even with the knowledge to be taught (to that found in books intended for teaching). Thus, we evaluated the level of proximity of the subjects conveyed in high school and higher education, as well as the relevance that some textbook authors give to the theme.

Keywords—Magnetism of matter, teaching of physics, didactic transposition, Brazilian physics books.

I. INTRODUCTION

THE idea of Didactic Transposition can be illustrated by the following sequence: Scholarly Knowledge (Institutions Producing and using the knowledge) → Knowledge to be taught (Educational system) → Taught knowledge (Classroom) → Learned, available knowledge (community of study) [1]. According to this idea, the knowledge taught in schools goes through a chain of transformations until it is shared between the teacher and the student. In this context, the knowledge produced by researchers (scholarly knowledge) is transcribed to Higher Education books (knowledge to be taught), later to High School books, then arriving as a transformed product in classrooms (taught knowledge). However, during this journey, the original knowledge can undergo mutations, sometimes so severe as to detach itself from the central concepts of a certain theme. In the words of Chevallard: "Throughout the process of schooling, objective (or scientific) knowledge, in order to transform itself into notions susceptible to learning, goes through didacticization - a series of operations polemic to a

certain point, which can lead this knowledge to reductionism and even falsification, because of the degree of distance that separates it from school knowledge. The latter would then appear as knowledge without producer, without historicity and temporality, as it is found with deficiency in textbooks." [2]

In general, the idealizer of the Didactic Transposition proposes that the knowledge present in teaching is not merely simplification of objects taken from the context of research in order to allow its apprehension by the young. It is therefore "new" knowledge capable of responding to different epistemological domains: science and classroom [3].

II. DIDACTIC MATERIALS AND METHODOLOGY

A. Scientific article: Paper 1, Subtitle P_1

Scientific article Title: "As propriedades magnéticas da matéria: um primeiro contato", in English version: "The magnetic properties of matter: A first contact". Author: Giuliano Augustus Pavan Ribeiro. Publication: Revista Brasileira de Ensino de Física, vol. 22, nº3, September, 2000 [6].

Reading research: Initially, care was taken in choosing the didactic material that best represented the topic "Magnetism of Matter". In this context, after reading many scientific articles on the subject, the chosen one, "As propriedades magnéticas da matéria: um primeiro contato", was the one that was able to portray more broadly the central concepts of the theme, since there were sections in it that portrayed the aspects Magnetism, Paramagnetism, Ferromagnetism and Antiferromagnetism, as well as other relevant concepts such as Hysteresis Cycle, Curie-Weiss Law and Weiss Domains. Thus, the recognition of the similarity between the didactic knowledge and the scientific knowledge of the investigated pedagogical objects came from the encompassing of these definitions.

B. Book 1, Subtitle: B_1

Book's title: Introduction to Electrodynamics, 3rd Edition, Publishing company: Pearson, 2011. Author: Griffiths, D.J. Chapter name: Magnetic fields in matter [7].

Reading research: This book is used in the training of physics teachers in their undergraduate and graduate courses at the University of Brasilia - Brazil. With it, the student acquires a great technical mastery of Electromagnetism, due to the mathematical approach offered and allied to its theory. Thus, the content of this book was adopted as another "measurement standard" in order to verify the proximity of high school books with the Scholarly Knowledge.

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C. Book 2, Subtitle: B₂

Book's title: Física Clássica, Volume III, 1st Edition, Publishing company: Atual, in English version (free translation): Classic Physical Volume III, 1st Edition, 2012; Authors: Calçada, C.S and Sampaio, J.L. Chapter name: Magnetic Properties of Matter [8].

Reading research: The authors describe, in detail, the magnetic behavior of the three classes of materials (diamagnetic, paramagnetic and ferromagnetic) when subjected to external magnetic fields, with illustrations and examples of materials belonging to each class. Two exciting examples are reported in which the reader follows the interaction of magnets with diamagnetic materials (with which there is repulsion) and paramagnetic materials (with which there is slight attraction). In the intention of complementing the examples, the authors affirm that the ferromagnetic materials interact with magnets in the same way as the paramagnetic ones, that is to say, there is attraction between them but, now, more accentuated. In order to clarify the aforementioned magnetic properties, the authors make reference to the rotation and translation movements of the electron (diamagnetism is related to the translation and paramagnetism and ferromagnetism are related to the spin rotation of the electron), reporting that the plausible explanation of them comes from Quantum Mechanics, without deepening in this sense. Next, there is the inspection of the microscopic behavior in terms of the electron orbit perturbation in diamagnetism, the spin alignments in the paramagnetism and the discussion on the magnetic domains of the ferromagnetic elements. At the end of the chapter the magnetization curve and a simplistic debate on Hysteresis, Curie Point and Demagnetization Processes are presented.

D. Book 3, Subtitle B₃

Book's title: Os Fundamentos da Física volume III, in English version (free translation): The Fundamentals of Physical volume III 11th Edition, Publishing Company: Moderna, 2015. Authors: Ramalho, F.J, Nicolau, F.G and Toledo, P.A.S. Chapter name: Magnetic Force.

Reading research: In section 6, entitled "Explanation of Magnetic Phenomena", the authors state that magnetism comes from the movement of electric charges (both rotation and translation) showing the equivalence between magnets and circular turns traveled by current. Following this reasoning, we are led to observe the explanation of several facts: The alignment of magnets in magnetic field occurs by the action of binaries of forces - as well as with turns driven by electric current; the attraction and repulsion of magnets can be understood as the attraction and repulsion of turns with current of coincident or opposite senses; the magnet attracts a nail because the magnet induces a polarization in the nail. In section 7, an experiment is described containing a circuit that has three solenoids devoid of metal core, showing that its magnetic fields cannot attract small iron nails. Next, metallic cores, one made of iron, one made of steel and another made of copper, are placed on the central axis of the solenoids. Thus, by reconnecting the circuit, we noticed that the iron and

steel cores caused the nails to be attracted by these two solenoids. When ceasing the current, the nails still remained stuck only on the steel. From these reports, the authors make the separation of the substances in the three magnetic categories (Diamagnetic, Paramagnetic and Ferromagnetic) explaining the alignment of electronic spins and the issue of magnetic domains. Thereafter, the magnetic hysteresis and its use in electromagnets are discussed. To close the topic, the authors briefly describe the influence of temperature on magnetization.

E. Book 4, Subtitle B₄

Book's Title: Física - Contexto & Aplicações - volume 3, 1st Edition, in English version (free translation): Physical Context and Applications volume 3; Publishing Company: Scipione, 2011. Authors: Alvarenga, B. and Máximo, A. Chapter name: Magnetic Fields part 2[9].

Reading research: After presenting the equations of the magnetic field created by a wire, a circular loop and a solenoid and observing that the environment surrounding the source of the magnetic field influences its value, the authors discuss the magnetization and agree that the movement of an electron around the atomic nucleus makes it equivalent to a small elemental magnet. Next, the organization of the elemental magnets is reported so that a material is considered magnetized. Thus, from the interaction of magnetic fields of a source and a material environment and their consequent reinforcement or weakening, it is possible to categorize the substances in: diamagnetic, paramagnetic or ferromagnetic. Then, the authors explain the importance of ferromagnetic nuclei capable of amplifying magnetic fields in electromagnets by discussing their applications in telephones, medicine and high-speed train technology. After, there is the explanation of why the magnet attracts a metallic nail and the discussion about the Magnetic Hysteresis phenomenon.

F. Book 5, Subtitle B₅

Book's title: Compreendendo a Física - Volume 3, 2nd Edition, in English version (free translation): Understanding Physics Volume 3, Publishing Company: Ática, 2013. Author: Gaspar, A. Chapter name: Magnetic Fields [10].

Reading research: In section 2, in the deepening framework of chapter 8, the author addresses the different forms of magnetism (ferromagnetism, paramagnetism, diamagnetism, ferrimagnetism and antiferrimagnetism) and the Curie Point. In chapter 9, in section 7, the magnetization vector and the magnetic susceptibility are discussed, bringing the relation between magnetic permeability and susceptibility beyond the tabulated values of this magnitude. Then, the themes "electromagnets" and "hysteresis" are discussed, including there is a rather interesting deepening chart on elastic hysteresis. At the close of the discussion on magnetic field, the peculiarities of the ferromagnetic elements are presented with the detailed analysis of the magnetic domains and the Weiss hypotheses at the level of the spins in the atomic orbitals.

III. RESULTS AND DISCUSSION

In order to make a comparative and organized study of criteria considered essential to the topic magnetism of matter, we associated captions to the sources of study investigated. Thus, P1 is the Scientific Paper, Book 1 (or B1) is the work of the first author (Electrodynamics), Book 2 (or B₂) is the second work in question and so on, up to Book 5 (or B₅) which corresponds to the last text. Each legend is mentioned in the initial description of the work. The comparison of didactic materials is shown in Table I.

TABLE I
ASSESSMENT CRITERIA FOR DIDACTIC MATERIALS

Treated Concepts	Work	P ₁	B ₁	B ₂	B ₃	B ₄	B ₅
Historical aspects of magnetism		YES	NO	NO	NO	NO	NO
Hysteresis		YES	YES	YES	YES	YES	YES
Induction Current and vector Magnetization		YES	YES	NO	NO	NO	YES
Weiss Domains		YES	YES	NO	NO	NO	YES
Auxiliary Fields (H)		YES	YES	NO	NO	NO	YES
Antiferromagnetism		YES	NO	NO	NO	NO	YES
Magnetic Domains and Ferromagnetism		YES	YES	YES	YES	NO	YES
"Balance YES"		8	6	2	2	1	7

Observing Table I, we see that Paper 1 addresses all the central themes of the subject Magnetism of Matter, so it was adopted as "reference knowledge" and, therefore, 8 "YES" were associated to it in the scale of correlation with the contents. In Brazil, scientific papers are didactic materials widely used in universities and rarely used in high school. However, for the most part, they represent a rich material for the teacher to delve into some topic of interest. Thus, since the constitution of a scientific paper, in most cases, requires research in several sources of information, it has obtained the widest range of content among the works analyzed.

Book 1 is for college students. There are several prerequisites for handling this book. In it, integral and differential calculus are used to solve problems. Physics is presented very rigorously and the teacher is updated with the most challenging problems of the academic world. Book 1 does not emphasize the historical aspects of magnetism or the antiferromagnetism topic. In it, the student acquires its formation based on definitions and the mathematical development. Therefore, its correlation with the central themes obtained "6 YES" (see Table I).

In Book 2 and Book 3, few topics are dealt with, showing marked reductionism of the subject "Magnetism of Matter" to high school students. Book 2 is a book that has enough quality in its theoretical part and in the mathematical part applied to the problems of physics. However, because it is a textbook more suited to teacher training and that has the language of high school, the authors preferred to portray other chapters in greater detail. The manner of exposing the contents of Book 3 resembles that of Book 2. They are excellent quality textbooks that focus on subjects more frequent in university entrance exams. Because of it, some subjects are treated more

superficially.

In Book 4, it is noted that the relevance of the theme to the authors has practically been lost, since most topics are not covered in this didactic material. Book 4 attempts to bring students theories of physics in a more theoretical and didactic way. Thus, some subjects of greater complexity are practically not covered or covered with much superficiality.

Book 5, however, was the only material aimed at high school that did a Didactic Transposition of the subject Magnetism of Matter and preserved its proximity to academic knowledge. Book 5 has a very current focus on physics. It brings themes little addressed by other authors. The writer of this book tries to insert the student in the world of physics with innovative didactic resources with special themes (relativity, quantum physics, structure of matter), capable of connecting science and technology and definitions of modern physics.

In order to facilitate visualization, we plot the results of the comparisons in Fig. 1.

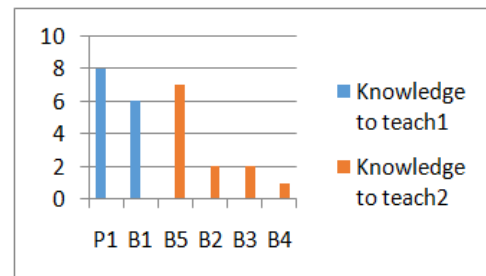


Fig. 1 The comparison of didactic materials

We reinforced with Fig. 1, that only Book 5 presented greater proximity to academic knowledge, because its criteria balance was 7 (7 "YES" in Table I). In the other didactic materials, these balances gradually diminished, which leads us to believe that, in most cases, the information does not keep its original content when it goes from Higher Education to High School.

IV. FUTURE RESEARCH TOPICS

The Didactic Transposition is a phenomenon that began to be investigated in the area of mathematics. Thus, many issues related to the existence of problems in numerical systems and the foundations of algebra at different levels of education for this transformation of knowledge are not very clear. However, a Didactic Transposition is fundamental to bring subjects of high abstraction to the knowledge of ordinary people, such as the themes of quantum physics. Therefore, future work, in all areas of knowledge, should develop the mechanisms of knowledge differentiation to the point of facilitating the insertion of some subjects in the basic curriculum of the schools.

V. FINAL REMARKS

At present, textbooks represent the main, if not the only, source of work as printed material in the classroom, in many

schools in the public school system, becoming a basic resource for the student and teacher in the teaching and learning process [10]. The educational researcher Lopes attributes a classic definition of a textbook that is of being "a didactized version of a knowledge for school purposes and/or for the purpose of value formation [11]" that configure conceptions of knowledge, values, identities and visions of the world. Thus, the textbook is an important tool in teaching. With it, the teacher develops his content, advises the problem solving, guides the student in his research, and prepares evaluations. Not always, the textbook is capable of addressing the specific reality of each community of people, so it is important to adopt other sources of information such as the internet, newspapers, scientific articles, educational videos and others. On the role of the book in the school environment and the attitude of the teachers in front of it, we can highlight the ideas of Santos and Carneiro: "the textbook essentially assumes three main functions: information, structuring and organization of learning, and finally, the role of student guidance in the process of apprehending the outside world. Thus, the latter function depends on whether the book allows an interaction of the student's experience and activities that instigate the student to develop his or her own knowledge, or on the contrary, to induce it to repetitions or imitations of the reality. However, the teacher should be prepared to make a critical analysis and judge the merits of the book that he uses or intends to use, as well as to introduce the necessary corrections and/or adaptations that he deems convenient and necessary" [12]. In this context, any criticism of a textbook approach requires that the researcher take into account the characteristics of the student community and the school goals desired by the student community, since there is no source of full and absolutely infallible information. All the books have as function to take the information and to transform the education, always meeting its authors' peculiarities and visions.

VI. CONCLUSIONS

In this work, we noticed that only one of the high school textbooks corresponded to the concepts involving the topic Magnetism of Matter with Academic Knowledge. The choice of 8 evaluation criteria capable of evaluating the textbooks analyzed was arbitrarily chosen by the researcher. By this fact, another scholar evaluating the same works, according to other standards, could have a different judgment on each book, depending on the target audience of that knowledge. However, comparisons between textbooks are not very common in our literature, which means that the choice of didactic material is made in a particular way by each school, something that does not facilitate the exchange of ideas among the most diverse niches of teachers. We believe that all textbooks treated in this study were written with great commitment and dedication on the part of their authors, which makes us appreciate the contribution of each one to the area of education of our country and especially to the teaching of Physics. Therefore, it is worth emphasizing that the core of this work was to go through the chain of Didactic Transposition, and we saw that,

in this way, the knowledge of the textbooks of Brazilian Higher Education departs from the greater knowledge produced at the University. This fact may be associated with the small degree of relevance that some subjects have for the national authors, or adequacy of the curriculum to their target audience, however, if we think of knowledge as a river, the didactic Transposition would be its relief, capable of modifying which is in its source and what reaches its mouth.

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