The use of Concepts Mapping in the Scientific Paradigm Transposition and the Cognitive Model of Science – The Case of Black Body Radiation

O USO DE MAPAS CONCEITUAIS NA AVALIAÇÃO DA TRANSPOSIÇÃO DE PARADIGMAS E DOS MODELOS COGNITIVOS DA CIÊNCIA – Radiação de Corpo Negro -

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Abstract: Conceptual mapping will be used to perform the analysis of how the knowledge produced in the 'academic spheres' change, adapt, to simplify and consolidate as knowledge to be taught in the classroom. We will study here as the topic of physics called blackbody radiation is transposed into the textbooks. We analyze the main concepts used by Max Planck (1901) in the development of the theory of blackbody radiation and how they were transcribed, filtered and drawn up in textbooks made for the academic course of Bachelor of Science in Physics, for the basic cycle of university course and for high school. That is, as the three (3) chapters of your article condense into a single section in high school textbooks. We will use here Concept Mapping (CM) to analyze how does the didactic transposition of this theory in the generalized sense by Izquierdo-Aymerich (2003) and synthesized by de Mello (2015a) of Chevallard theory (1991). We analyze, using as a theoretical framework the cognitive science theory [Nersessian, 1992; Jhonson-Laird, 1980] and the theory of Scientific Revolutions of Thomas Kuhn (1970), as the fact of the theory for blackbody radiation have been proposed before the paradigm of quantum mechanics have been established affected the epistemological construction of this article and as this fact has been transposed to textbooks. We will see that CM is the natural tool to study the "Transposition Paradigms" in Science. It is demonstrated the thesis that textbooks for high school are a didactic transposition of university books and not from scientific articles.

Key Words: Conceptual Mapping, didactic transposition, scientific paradigm, school scientific activity, the textbook analysis.

Resumo: Mapas Conceituais serão usados para se realizar a análise de como o conhecimento produzido nas ‘esferas acadêmicas’ se modificam, se adaptam, se simplificam e se consolidam como saberes a serem ensinados em sala de aula. Estudaremos aqui como o tópico da Física denominado Radiação de Corpo Negro é transposto para os livros didáticos. Analisaremos os conceitos principais usados por Max Planck (1901) no desenvolvimento da teoria da Radiação de Corpo Negro e como estes foram transcritos, filtrados e elaborados nos livros textos confeccionados para o curso profissionalizante de bacharel em Física, para o ciclo básico do curso universitário e para o ensino médio. Ou seja, como os três (3) capítulos de seu artigo se condensam em uma única seção nos livros textos do ensino médio. Usaremos aqui Mapeamento Conceitual (MC) para analisarmos como ocorre a transposição didática desta teoria, no sentido generalizado por Izquierdo-Aymerich (2003) e sintetizado por de Mello (2015a) da teoria de Chevallard (1991). Analisaremos, usando como referencial teórico a teoria cognitiva da ciência [Nersessian, 1992; Jhonson-Laird, 1980] e a teoria das Revoluções Científicas de Thomas Khun (1970), como o fato da teoria para o Radiação de Corpo Negro ter sido proposta antes que o paradigma da Mecânica Quântica ter sido estabelecido afetou a construção epistemológica desse artigo e como este fato foi transposto aos livros didáticos. Demonstra-se que CM é a ferramenta natural para se estudar a "Transposição de Paradigmas" na Ciência. Demonstra-se a tese que os livros didáticos para o ensino médio são uma transposição didática dos livros universitários e não dos artigos científicos.

Palavras-chave: Mapas conceituais, transposição didática, paradigma científico, atividade científica escolar, análise do livro didático.

INTRODUCTION

In 1980, the mathematician Yves Chevallard (1991) generalizes the idea of Didactic Transposition (DT) originally formulated by sociologist Michel Verret, in 1975, in a theory and applied it in the analysis of important issues in the field of didactics of mathematics. In the 90's the scientist Nersessian (1992), based on Johnson-Laird ideas (1987, 1995), generalizes the theory of epistemology of science of Kuhn (1970), Feyerabend (1975) and others creating the Cognitive Model of Science. In the last decade authors as Izquierdo (1999), Izquierdo-Aymerich (2003), Harrison (2000) and others have applied the ideas of Nersessian (1992) to the study of DT, focusing the DT analysis on the cognitive processes of the human mind and epistemology of science. Along with other recent contribution to theories for science teaching, the theory of "Concept Mapping", suggest the possibility of analyzing with much depth as the knowledge produced in scientific spheres are translated at school spheres [de Mello, 2015a]. It has been shown that CM is for the concepts of science as well as the algorithmic language are for programming, allowing you to check and evaluate the epistemological construction and objectives of the textbook.

Until now the theory of DT was formulated making the simplification that the DT occurred directly from the research environment to high school. But nowadays with the growing volume of information that students must acquire to graduate, forced the creation of university careers specialization and with them the necessity of creation of several educational projects by universities. As an example we have textbooks for physical scientists (Alonso 1968; Halliday 1997) and others for engineers in general (Searwey 2005; Young 2008). De Mello showed (2015a) that in some way these characteristics are somehow inserted in the instructional material produced by them.

De Mello (2015a) showed that the DT suffered by the knowledge produced in scientific spheres (scholar knowledge[1]) to high school (the knowledge to be taught) does not occur directly. But rather that it occurs in stages by the various levels of currently existing knowledge. These are the levels: 1) Research; 2) Postgraduate; 3) Academic; 4) Basic graduation and finally 5) high school.

It has been shown previously [de Mello, 2015a and 2015b] that the simple analysis of the contents of the topics of Modern Physics does not allow us to visualize the conceptual construction that the author or authors used to write their text. It just allows to check the sequence as the themes are introduced. But, through the making, following well-defined criteria, and subsequent analysis of the CM of a given field of knowledge, we can see how the concepts were introduced, as were partitioned throughout the text, and as the author or authors have used it to support or only introduce other concepts. [de Mello, 2015a].

Without key words or key connection concepts we could not understand as the concepts are sometimes anticipated, sometimes postponed, and sometimes partitioned in order to base the contents to be taught. If we only had the flowchart of the text we would not have the connections between concepts and not would notice how they interrelate [de Mello, 2015a]. CM is also the natural and most efficient tool to make the analysis of how the concepts, propositions, theorems and models were used to build or transcribe in a didactic way a given theory [de Mello, 2015a, 2015b]. By analyzing how the Photoelectric Effect theory developed by Albert Einstein (1905) in its 2nd article was transposed into the textbooks, it was possible to show that CM is a tool, an algorithmic language, very efficient and succinct to present and describe as a original conceptual framework is being transposed didactically to different types of textbooks [Mello, 2015b]. Just as a computer scientist need only study a given algorithm of a computer program to understand its purpose, it is argued here that for a theoretical cognitive of science the simply study of CM of a given theory, prepared within strict rules, to understand its conceptual framework.

It is intended in this article, using concept maps, generalize and consolidate the theory of didactic transposition in the generalized sense by de Mello (2015a) and Izquierdo-Aymerich (2003) of Chevallard theory (1991). We analyze, using as a theoretical framework the cognitive science theory [Nersessian, 1992; Jhonson-Laird, 1980] and the theory of Scientific Revolutions of Thomas Kuhn, as the fact of the blackbody radiation theory have been proposed before the paradigm of quantum mechanics have been established affected the epistemological construction of this article and how this fact has been transposed to textbooks. With this demonstrates the thesis that textbooks for high school are a didactic transposition of university books and not from scientific articles. It will be show that the use of CM allows the study and viewing of how the conceptual construction of a given theory, within certain rules governed by a given paradigm, is modified in so far as it is being transposed

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[1] We will use here the Chevallard definitions.

and rewritten into a new paradigm. That is, CM is the natural tool for studying the "transposition of scientific paradigms."

The key idea of this article is to demonstrate the Latour's thesis (1999): i) what school science and the science of scientists have in common is that their theoretical ideas, concepts, were closed and sealed inside black boxes after gaining importance and then to become more "solid" and "strong" that is, after " consolidated ". And such a packaging process leaves out details, explanations and reasons that were necessary to convince others of their "original power to explain" (Izquierdo, 2003); ii) that the physical theories are more fundamental than their explanatory scientific models and that the last depends on the prevailing paradigm.

DIDACTIC TRANSPOSITION (DT).

Didactic transposition (DT) is the theory that studies how the knowledge produced in academic spheres are transcribed into the various levels of education [Chevalllard, 1991; Izquierdo-Aymerich, 2003; Brockington, 2005; de Mello, 2015a]. To understand how the DT occurs we have to know or define what science is and what it is to do science.

According to Izquierdo-Aymerich[2] (2003) when we simplify or define, with didactic purposes, what is science or to do science we can describe it as a way of thinking and acting in order to interpret certain phenomena and to intervene through a series of theoretical and practical structured knowledge. As a result of science education is desirable that students understand that the natural world has certain characteristics that can be modeled theoretically. Because of this we present to them, making a DT, some reconstructed facts, simplified theoretical models, arguments, metaphors and propositions that were previously selected. Obviously, this is not "to do science" but "teach science," and the reason for this behavior can be found in the didactics of science and not just in the science (Izquierdo-Aymerich, 2003). Thus, teachers are generally professionals committed to the teaching of science as this was the truth. Obviously, this is not "to do science" but "teach science." Scientists propose theories, conceptual models and methods to formulate their explanatory goals, but this is not entirely possible to be transposed into the classroom. [Izquierdo-Aymerich, 2003].

Also, if the science class is done in accordance with the principles of meaningful learning (Ausubel 1977, 2003), that is, a well executed didactic transposition (Chevallard, 1991), teachers will be engaged in the task of connecting scientific models to used by the students themselves, using analogies and metaphors that can help them to move from these to the scientific models (Clement 1993; Duit 1991; Flick 1991; Ingham 1991; As cited in Izquierdo 2003).

[2] The following two paragraphs are a collection of statements that together form a definition of that is the DT from the TCC point of view.

After Chevallard to understand deeply how scientific knowledge is transcribed to the textbooks we have to include in this analysis the external environment in which this occurs. According to Pietrocolla, he defines the Didactic Transposition as:

> “an efficient tool for analyzing the process by which the knowledge produced by scientists (the scholarly knowledge) becomes that which is contained in the programs and textbooks (the Knowledge to be Taught) and mainly in what actually appears in classrooms (the Knowledge Taught).”

After the PSSC and Harvard Physics Projects (2006) we are left the impression that the Knowledge to be Taught and the Knowledge Taught are little different from those in the laboratories and research groups. That teaching would be a mere simplification of knowledge. Chevallard [cited Brockington, 2005] points out that the way the Know Taught is derived from the scholarly knowledge is one of the key points in teaching. This transformation takes place within an environment that sets the Didactic system: universities, schools, educational agencies, etc. The educational system assumes such an important role in his theory that he designates it by the name "noosphere". Thus, the noosphere constitutes a place of convergence and debate of several interests in science education.

The ideas and concepts developed by Chevallard (1991) were developed in the study of the passage of the "knowledge" from the research environment to the high school. In this didactic transposition model it does the simplification or considers that the research environment is unique. Namely, that the knowledge produced in the research environment is already produced in final form to be transposed directly (consumed) for high school. But the theory of DT can be applied to higher education since the transposition of the scholarly knowledge begins in this Knowledge sphere (or Epistemosphere) [de Mello, 2015a]. Moreover, this transformation process has fewer steps than the previous one, and thus is somewhat simpler. Here we consolidate the fact that the DT occurs in stages from the research environment to the university environment and from this to the educational system of high school.

We will analyze and classify the process and the steps that the knowledge produced in research spheres suffers when passing through the university environment, epistemosphere, until it get to the high school environment, the noosphere. Let's investigate how the paradigm shift filters out certain concepts and favor others. As this transformation brought about a change in scientific models employed. We will further show how the construction of CM to the knowledge produced and translated into an appropriate language to a certain level of students provides us with information on the conceptual construction of this knowledge.

So let's try to answer the questions proposed by us previously [de Mello, 2015a]: Scholarly knowledge is directly transcribed to ‘Know to be Taught’ or it occurs in stages until high school? How can we 'track' (investigate) the transformation of knowledge as it is being 'streamlined' (like say Prof. Alberto Villani: Diluted) until it reach the classroom?

In particular in this article we will investigate how scientific knowledge produced within a historical and epistemological context of a scientific revolution, in the sense of Kuhn (1970), is transcribed or in the language of this article, suffers a DT for the textbooks in general. We will use CM to make the study of "Scientific Paradigms Transposition."

Scientific Paradigm

It is used here a version of the definition of scientific paradigm created by Thomas Kuhn (1970). Therefore, there is no single definition of paradigm, even Kuhn argues that this definition can never be complete (Chibeni, 2015). So here the paradigm is a concept used to mean a set of "concrete scientific achievements able to provide models from which arise the coherent and specific traditions of scientific research". But also it can be formulated as a "world view" that, assuming a "way of seeing" and "practice", includes a set of theories, tools, concepts and methods of investigation, which is commonly called mature science.[2] [Kuhn, 1970]

The development of the mature science occurs in two phases, the phase of the normal science and phase of the revolutionary science. Normal science is the science of the periods in which the paradigm is unanimously accepted within the scientific community without any kind of dispute. The paradigm indicates to the community which type of research would be relevant, the rules of how to carry out this investigation and limits the aspects considered relevant to the scientific research. [Khun, 1970]

Scientists are limited to resolve problems that the paradigm will giving them or that are appearing, but so that all research is performed inside and in the light of the paradigm that is accepted by the Community. At this stage of normal science, the scientist does not attempt to question or investigate aspects that go beyond the paradigm itself, they are limited to solve difficulties that are appearing. The scientific problems are transformed into “enigmas”, enigma with a limited number of pieces that the scientists will carefully manipulating until them find the final solution. Furthermore, the final solution is known beforehand, only not knowing the details of the content and the process to achieve" [Kuhn, 1970]. In this way, the paradigm that the scientist has acquired during their professional training provides them with the rules of the game, describes the parts to be used and shows you the path or goal to be reached. [Chibene, 2015]

When contradictory experimental facts with the current paradigm accumulate, that is, what Kuhn calls anomalies, and these are accumulating and resist for long periods to the best efforts of the best scientists, bold and creative members of the scientific community propose alternative paradigms. Having the current paradigm lost confidence such alternatives are beginning to be taken seriously by a growing number of scientists. It installs a period of discussions and disagreements on the fundamentals of science. But even during the crisis the paradigm hitherto adopted is not left until come another one that proves to be superior to it in almost every respect.

A Cognitive Model of Science Applied To Didactic Transposition

To the cognitive theoretical scientist is not enough to know how to determine and classify the stages of a given field of knowledge. He is interested in knowing how the nature of the mechanisms underlying the scientific cognition is. His interest is in how it produces, organizes and transmits knowledge. And it in this last point that scholars of DT are interested. (Hacking, 1983; Nersessian, 1992; as cited by Izqueirdo, 2003)

In this article we restrict ourselves on the question of cognitive basis of certain reasoning practices based on model – that is, those employed in creative thinking that leads to representational change through science. CM will be used to investigate how this change in representation at every stage of a DT occurs. This question provides insight into a central problem of creativity in science teaching: how a genuinely new scientific representation is created, since its construction should begin with existing representations? (Izquierdo, 2003)

The cognitive model of science concentrates on how scientists work and communicate (especially through writing), and highlights the semantic aspect of theories. The aim of the scientists is not to reach the truth, but build theories and models that allows us to understand the world (Hacking, 1983). According to some other models proposed by new history and philosophy of science (NHPS), there is no single scientific method, since the validation criteria change over time in response to the problems to be investigated and the paradigm used (Izquierdo, 2003). Theories are the most important entities in science; they are built and modified in order to interpret the world (Duschl, 1990). These issues become even more relevant when discussing theories proposed in periods of crisis and central to the new current scientific paradigm, as is the case of theory of black body radiation and photoelectric effect.

Hesse (1966) states that scientific models allow a theory to be predictive. According to Carey (1992) and Nersessian (1992), the models are a type of mental representation; propositional language that defines a theory. It is the construction of an image or representation of natural phenomena. For Boltzmann (1890) this is a mental or subjective construction. For him it is a representation of an explanation of what occurs in nature. So it is not used to describe the world, but is to build a mental model of it, which is a structural analogue of the real situation. The interpretation of a fact can be a consequence of this be related to similar or analogous facts and that it makes sense for scientists. The initial model thus generated will develop as they explain other known or new phenomena, as will be shown below.

Strengthening this thesis has been the contribution of philosophy of science of Ronald Giere (1988, 1992, 1999; as cited in Izquierdo, 2003) specifically centered on the relationship between theories and facts which they relate. In his work, he stresses the importance of theoretical models in science; these models are considered a kind of mental representations similar to built-in maps of the outside world. (Izqueirdo, 2003)

In general scientific theories are presented in textbooks through the power of explanation of the scientific facts and not as a match or convention.[3] That is, as a set of models related to some facts and some identifiable instruments that give meaning to the theory. Relations between the models and the facts are developed through postulates and theoretical hypotheses, which can be more or less true or false, since they have empirical content. Thus, the theory necessarily contains their applications or domain and can be understood in part as interpreted World (Giere, 1988; Suppe, 1989; as cited in Izquierdo, 2003)

Concept Mapping

Several authors [Novak,1990 e 2006; Moreira, 2010 e 2005; Gilmar da Silva, 2007; and references] advocate the use of concept maps (CM) as potentially useful tools in teaching, learning assessment, analysis of curriculum content and the DT analysis [de Mello, 2015a e 2015b]. We can build concept maps to plot each discipline, a sub-discipline, a specific topic of a discipline and so on.

Joseph D. Novak (2006) defines in a broad way what conceptual maps (CM) are:

> "Concept maps are graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts. Words on the line, referred to as linking words or linking phrases, specify the relationship between the two concepts."

CM provides us with a concise, hierarchical, graphical way to present the key concepts to be taught. Thus CM is a powerful tool for performing curricular analysis [Novak, 2006; Moreira, 2006]. The hierarchical organization of the concepts facilitates the visualization of the optimal sequence of presentation of the contents either by the person who arranges as by students.

When the CM is well built allows visualization and perception of how the key concepts of a particular topic or field of knowledge successively interlace and are

[3] Excludes major scientific syntheses. For example Newton's laws.

organized in the structuring of this knowledge [Moreira, 2006]. So, some authors tried to create some ground rules for the construction and standardization of CM's that can be seen in several articles [Moreira, 2006; Novak, 2006]. Nevertheless, CM is a very flexible tool allowing certain degree of freedom to building it.

It has been shown [de Mello, 2015a and 2015b] that for certain purposes, the CM is a kind of computational algorithmic language. Just as in mathematical logic where we need syntax rules to build a certain predicate calculus, basic rules are needed for construction of CM for study of the conceptual construction of a given theory [de Mello, 2015a].

Concept Mapping and Didactic Transposition

De Mello (2015a) generalized this idea and showed that CM is the natural tool to perform the analysis of the conceptual framework with which textbooks are written. That is, how the knowledge produced to a level of education is transcribed to another. As stated above, the concise, hierarchical and graphics way of present the key concepts makes MC the ideal tool to make the analysis of a topic or a whole book. This allows you to view promptly and succinctly the conceptual framework that a certain author used to concatenate and organize the key concepts that go into the preparation of your textbook. The simple analysis of the index of a book or booklet does not allow us readily see the underlying structure of the conceptual building of a body of knowledge. Thus it is necessary to build a CM showing the interconnection between the concepts inserted and used in each chapter.

By studying the DT of the photoelectric effect, De Mello (2015b) shows that the DT of this occurred systematically and in cascading from the level research for the high school level. He shows that passing from research level for postgraduate or Bachelor levels, the model proposed by Einstein was abandoned by scientific community and replaced by another model that is in accordance with modern theories. And finally it was shown that the DT of the Einstein theory is made from this new model and not from the original. We will now confirm this hypothesis by analyzing from another point of view the DT of Max Planck article (1901).

Concept Mapping and the Cognitive Model of Science

As mentioned above, building a CM to a topic or theory, displays promptly and succinctly the conceptual framework that a certain author used to concatenate and organize the key concepts that go into the preparation of your textbook and enables us compare it with the original conceptual construction or with the most current of a particular scientific theory. This allows also highlight models, experimental data, assumptions, hypotheses and everything else that belongs to the construction of a didactic text, so that allows a scientist of cognitive science distinguishes between theory, model and didactic construction used in a text.

Thus, CM is the natural tool to do the analysis as the theories are developed, disseminated and refined. This is the most appropriate tool for studying the physical theories, as these are structured around concepts. That is, it is the natural tool to do the cognitive study of science and its DT.

Using CM to analyze the theory of Quantization of Max Planck's under the Viewpoint of Cognitive Theory of Science

1 – Quantum Physics – Eisberg and Resnick (1985)

Since we are using CM as the theoretical framework to do the analysis of how scientific theories are constructed and written, CM will be used to guide and standardize the analysis of how the concepts developed in the original articles were transcribed to textbooks. We use here the same "rule" to building CM used by de Mello (2015a).

When the text is too broad or when each chapter or section contains many topics, we will place the main topics in a vertical column and its subtopics will be presented in a side secondary horizontal line. When necessary, glossary of abbreviations can appear in green boxes. We use a bold box in order to highlight a concept referenced in the text. For our purpose, unlike 'traditional' CM, we will not use cross lines to indicate that a well defined concept within a previous chapter or section will be used in a later chapter or section to support another concept. This is expected occur normally in a middle school text, but, as we will see this isn't necessary in the university level. We will use this strategy only when we need to indicate the cases in which a concept is used or cited in a previous section and later defined or introduced. When necessary, in middle school textbook, we will introduce equations in yellow boxes and use as connecting word "math".

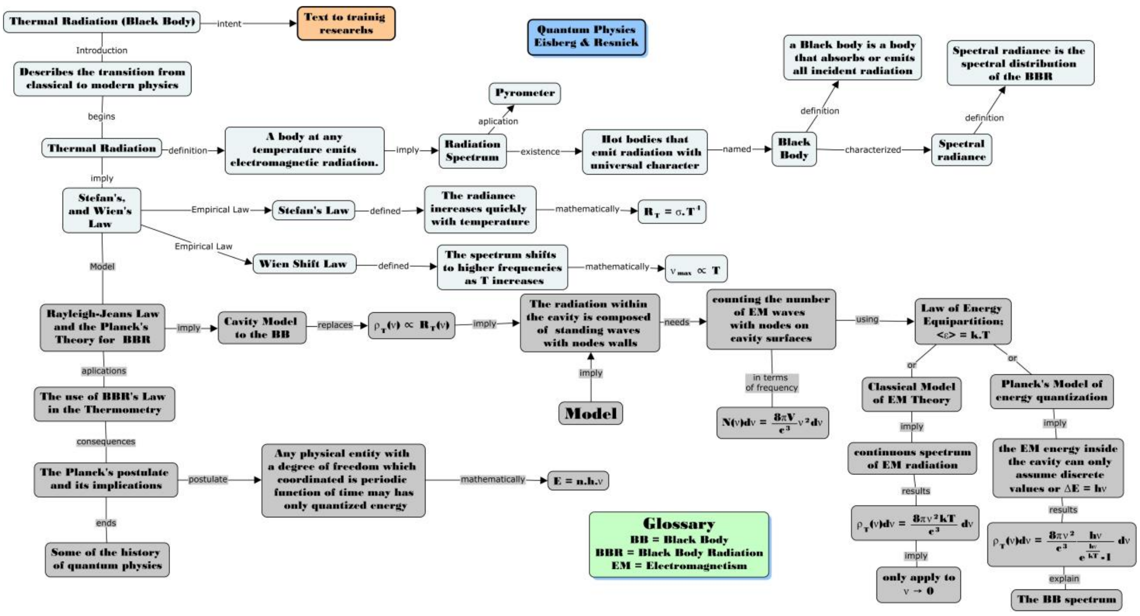

Fig.1 – CM of the Blackbody Radiation theory from the Eisberg & Resnick textbook (1985).

Before analyzing the Max Planck article (1901) let us see under the point of view of modern physics as the currently theory of blackbody radiation (BBR) is teaching and the subsequent quantization of cavity energy. That is, as the theory of BBR is transposed into the paradigm of quantum mechanics. We will use the Eisberg textbook (1985) named Modern Physics as reference in this study. Since this is a book aimed to training scientist and in particular to work in Nuclear and Particle Physics, he describes in detail the crucial experiments and the mathematics involved behind this theory.

We put its CM in Figure 1 to serve as a guide in the analysis of its conceptual construction. Obeying the historical facts, it introduces modern physics through the theory of blackbody radiation. Then it sets the physical phenomenon and what is meant by spectral radiance. Then it defines a "black body" as a body that emits and absorbs all radiation that strike on it. First line of CM.

Then it exposes the empirical laws (Stefan law and the law of Wien's displacement) created in an attempt to describe the phenomenon. Second line in the CM. As Planck's theory is built upon the law of Rayleigh-Jeans he begins by this law and in the sequence they deduced Planck's law. All theory is built on the scientific model that in the cavity there are oscillators, atoms or molecules, which emit and absorb radiation. See the blocks in bold. So we just have to count the number of these radiations that we have on the walls of the cavity. Using the law of equipartition of energy we obtain an expression of the intensity of radiation as a function of temperature. If we assume that the radiation in the cavity was continuously distributed we obtain the law of Rayleigh-Jeans. If we assume that the energy is discretely distributed in packages of h.f (f = frequency and h = Planck's constant) we obtain Planck's theory. The chapter ends with some applications of this theory. See blocks upright on the bottom right of the CM.

2- Max Planck (1901) Original Paper - On the Law of Distribution of Energy in the Normal Spectrum

Let's see how Max Planck (1901) built his theory. First, we need to remember that in 1901 we had the classical mechanics and Maxwell's electromagnetism as mature sciences. Thus, in 1901 only had empirical laws and a 'classical' theory that is forged within the current paradigm to explain the spectrum of blackbody radiation. This theory is the law of Rayleigh-Jeans. For his theory was accepted by the scientific community it should be constructed using scientific concepts accepted by them. These are: entropy, internal energy, temperature and the model of molecules as harmonic oscillators. See central column in the fig.2.

So it begins exposing experimental facts and the Wien and his own attempting to find a universal law that describes the behavior of the spectrum of blackbody radiation. See the two first lines of the CM in Fig.2. Apparently he did not know the law of Rayleigh-Jeans. Then he argues that to replace the erroneous argument in the deduction of the Wien law he must find the universal dependence of the entropy S and the internal energy of the system U. So it says that the distribution of energy in the normal spectrum is completely determined when calculating the entropy S of a vibrant resonator radiation, monochrome as a function of its vibrational energy U, which is the centerpiece of your model.

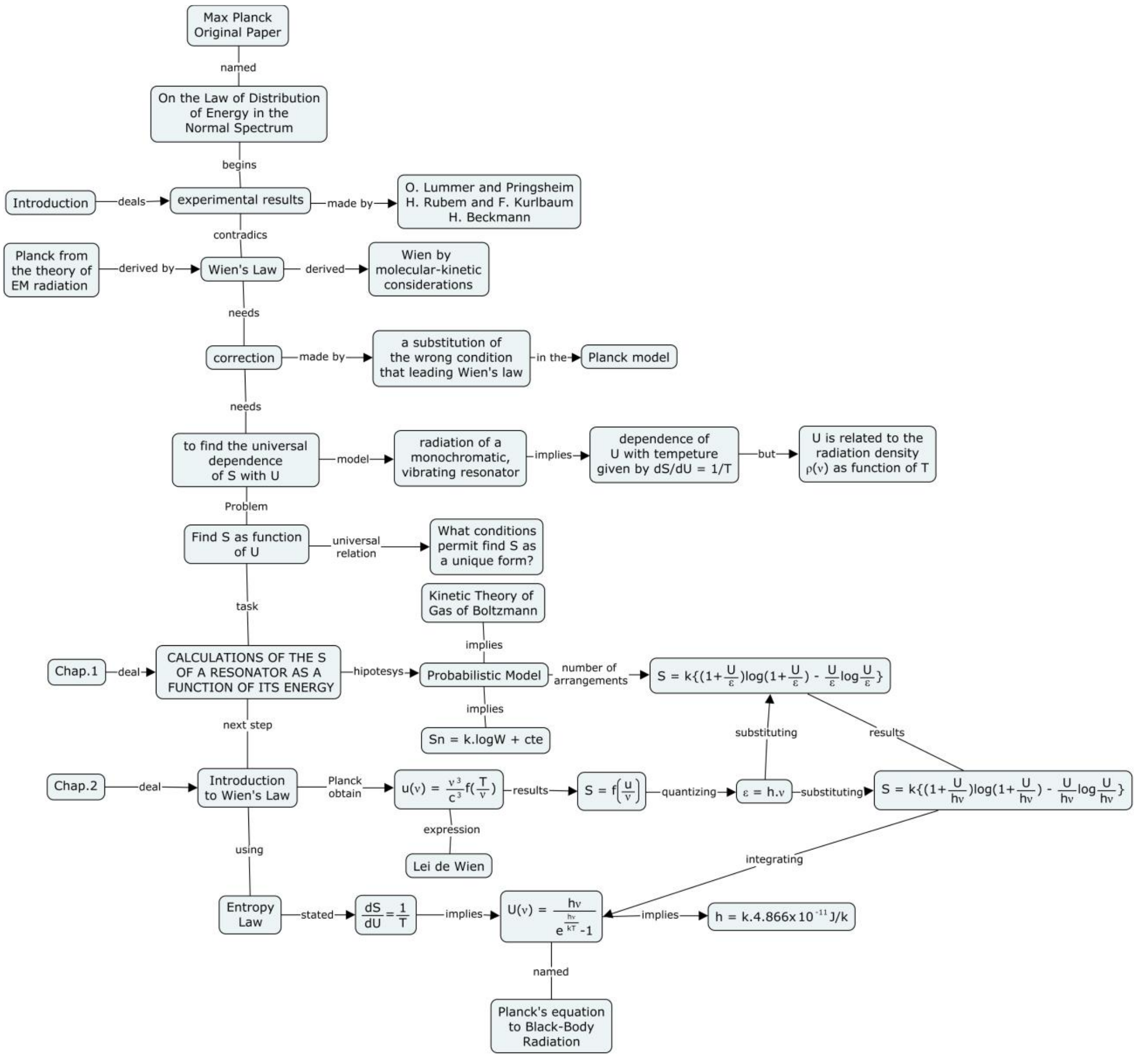

Fig.2 – CM of the Blackbody Radiation theory from the Max Planck original paper (1901).

To find the mathematical expression of his Universal Law he uses the kinetic theory of gases of Boltzmann to find a single expression for S (Chapter 1 of the article, see CM). That is, he needed a model of atoms or molecules as particles oscillating within the blackbody cavity. It should be noted that in 1901 Boltzmann's theory quoted above was not fully accepted, being the target of severe criticism by the philosopher of science Ernst Mach and others [Videira cited de Mello, 2015b]. The consolidation of the theory would only occur in 1905 through the second Albert Einstein's paper [de Mello, 2015b].

Contrary to what is said in the textbooks, he introduces the quantization of energy in hypothesis 3 of Chapter 1 when he reinterprets the meaning of entropy function S. In chapter 2, through the Wien Law, it gets the universal expression between the temperature T and the energy density u and then between S and T. See line Chap.2 in CM. At that moment it uses the E = h.f condition in S calculation as a function of total energy U. Thus, it gets the mathematical expression for the energy distribution of the BBR spectrum, known as the Planck equation for the BBR. Another important fact is that despite the Planck constant being a universal constant it is derived from the Boltzmann constant, $h = k.4,866 \times 10^{-11}$ J / k.

Thus we see, that the paradigm transposition made by the scientific community is summarized basically in replace the model of finding a universal function for the entropy S of radiation of a resonant vibration, monochromatic as a function of its vibrational energy U, by obtaining the total energy in the cavity simply counting the number of EM waves within the CN cavity, and assuming that energy is quantized. We see in this case that the role of scientific model is to provide support to the theory and is based on experimental data. But that can be taken from his explanation, as we shall see.

Consider the following three examples of how this theory is exposed in textbooks for the Academic University course. The first two of the authors Jewett and Serway (2010, 2006) follow the same structure as the Eisberg & Resnick book. As can be seen in its CM placed in the Fig. 4 and 5, they introduce modern physics through this theory, as happened historically. The third text of the authors Young & Freedman (2008) follows an alternative line of reasoning.

3 - "Physics for Scientists and Engineers"- Jewett & Serway (2010)

This book is aimed at training engineers in general. So although this paper does not rigidly following Eisberg text structure, they present the Rayleigh-Jeans theory that the second text does not address. After a brief introduction they define the physical phenomenon of thermal radiation. First line in its CM (Fig.3). Note that the issue of radiation spectrum is crucial for applications in optics. They use the scientific model that in the cavity there are oscillators, charges within the molecules, which emit and absorb radiation to explain the phenomenon of thermal radiation. In the sequence they define a "black body" as a body to emit and absorb all radiation that strikes it. Second line in the CM.

Then he explains the laws created in an attempt to describe the phenomenon and follow the Eisberg model. See their CM in fig.4. They start by Stefan Law and then by Wien's displacement law and commenting that their validity domain is limited, but that both are complementary. To introduce the necessity of Planck's Law they discusses that the classical theory, that is, the Rayleigh-Jeans theory, based on Maxwell electromagnetism, states that the intensity of the radiation goes to infinity for small frequencies. This disagreement is called "ultraviolet catastrophe."

As in the text Eisberg, all theory is built on the scientific model that in the cavity there are oscillators, atoms or molecules, which emit and absorb radiation. See

Box in bold. So we just have to count the number of these radiations that we have on the walls of the cavity. Using the law of energy equipartition to obtain an expression of the intensity of the radiation as a function of temperature. If we suppose that the radiation in the cavity was continuously distributed obtain the law of Rayleigh-Jeans.

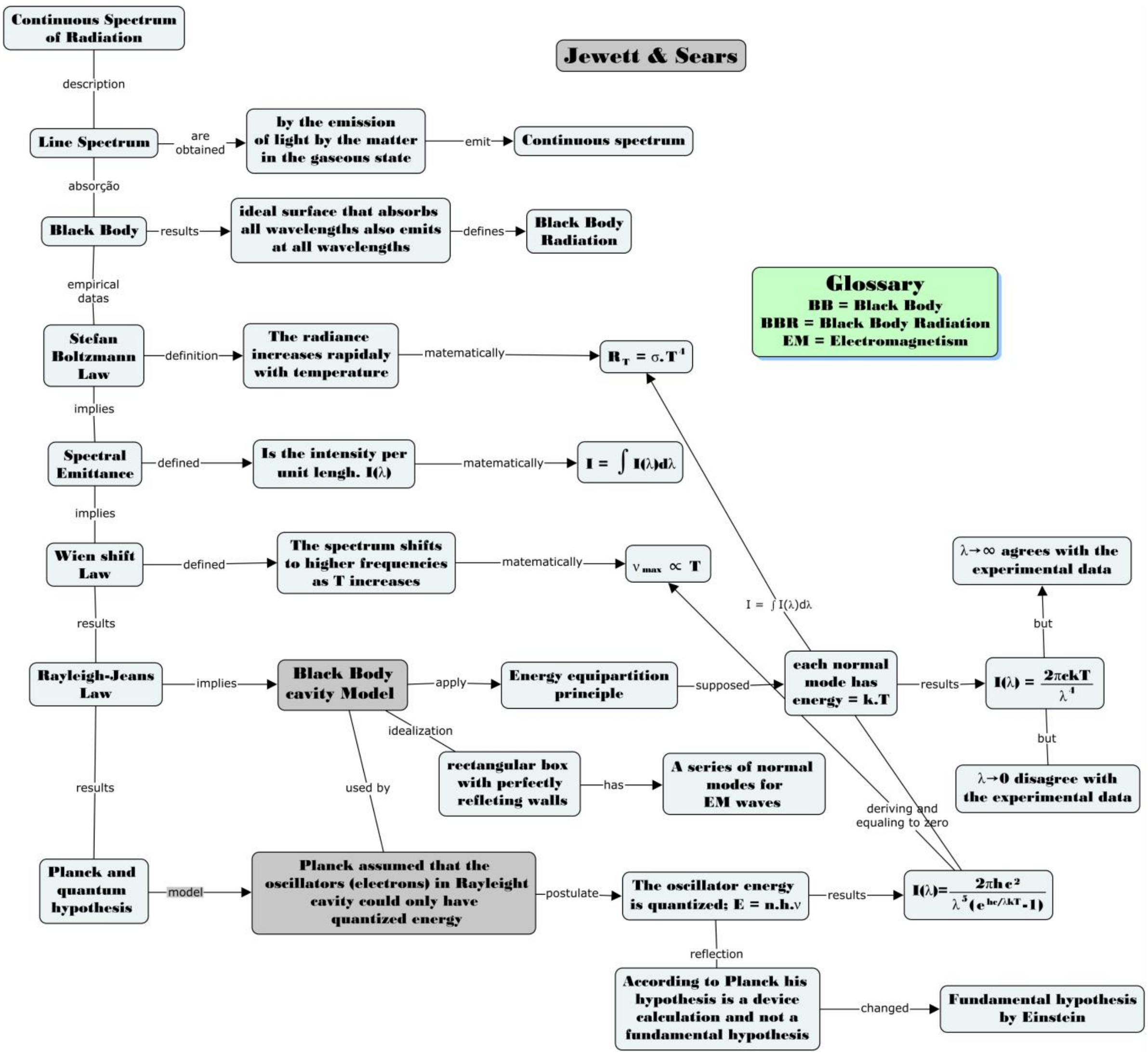

Fig.3 – CM of the Blackbody Radiation theory from the Jewett & Serway textbook (2010).

So they motivate Planck's theory stating the need to have a theory that agrees with the experimental data for all wavelengths and the sequel formulates Planck's law. They summarize the theory saying that Planck made two bold assumptions: i) that the energy is discretely distributed in packages h.f (f = frequency h = Planck's constant); ii) The oscillators emit or absorb energy in discrete units. As they had already explained the spectrum of the hydrogen atom in Chapter 11, we use Planck's theory to complete the explanation of this model. The chapter ends with some exercises.

4 - Physical Principles (vol.4) - Serway & Jewett (2006)

This other book, written by the same authors, is a book written for the basic course in science in general, but that can be used in engineering courses. It has the same structure as the earlier book, but the text is more succinct. As can be seen in its CM, fig.4, they omit the explanation of the physical phenomena of thermal radiation (first line in the fig.3). After a brief introduction they define the physical phenomenon and what is meant by spectral radiance. Then it defines a "black body" as a body that emits and absorbs all radiation that strikes it. In this text they present Planck's law as in the previous text, through the experimental facts, but omit the deduction based on the Rayleigh-Jeans theory. See the absence in his CM, fig.4, the sixth row of fig.3. The chapter ends with some exercises.

We see here that they do not make any observation on the model used by Planck and that DT is made entirely on the paradigm of quantum mechanics.

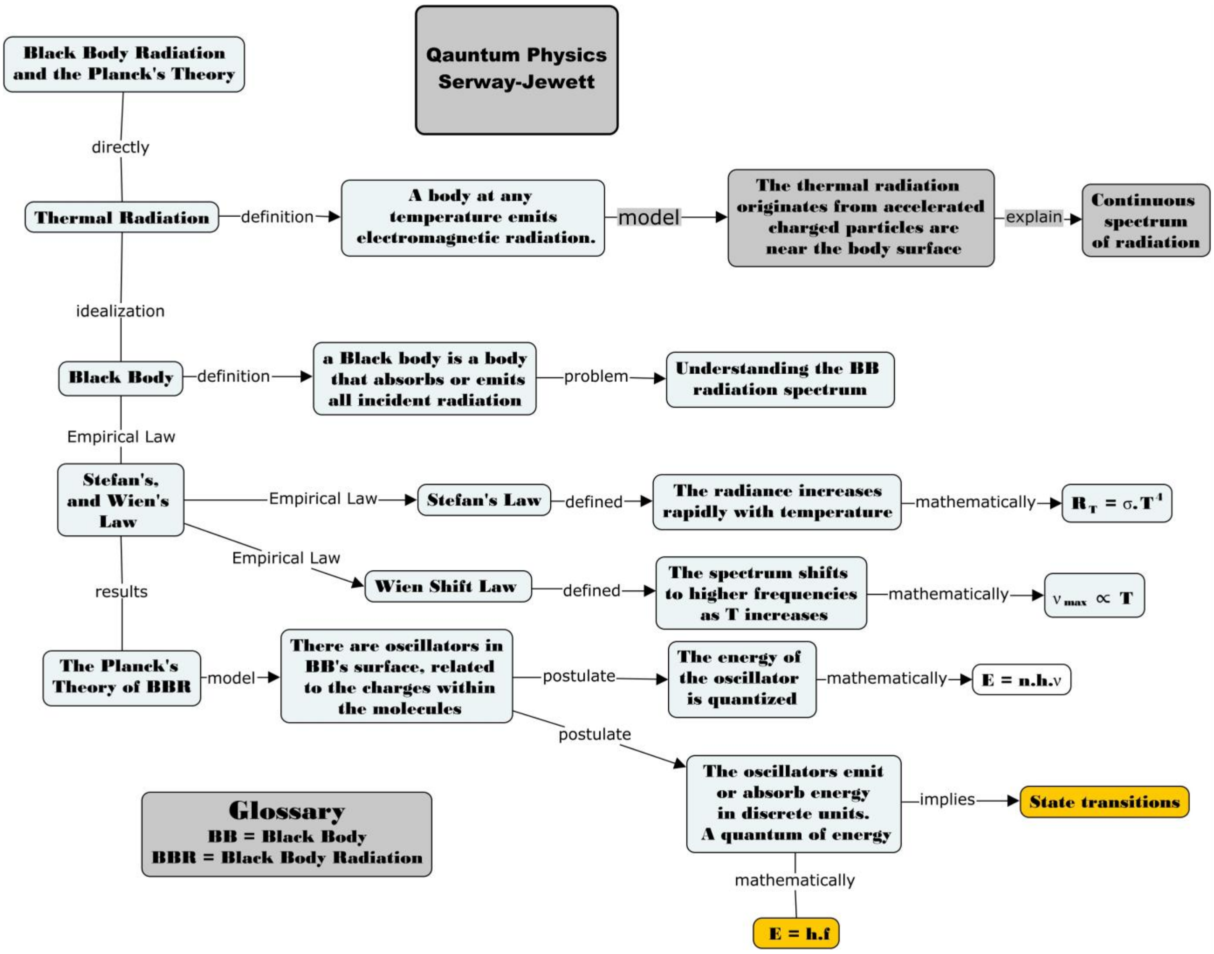

Fig.4 – CM of the Blackbody Radiation theory from the Serway & Jewett textbook (2006).

5 - "University Physics with Modern Physics" - Young & Freedman (2008)

As another example of didactic presentation of the theme was chosen the textbook "University Physics with Modern Physics" of the authors Young & Freedman (2008), because it presents the topic in detail and this does not expose the Modern Physics respecting the chronological order of scientific discoveries. Despite this use the same scientific model that Eisberg (quantum paradigm), this uses another methodological construction in your text. They abandon the structure: Definition→ experimental facts → model → theory → applications.

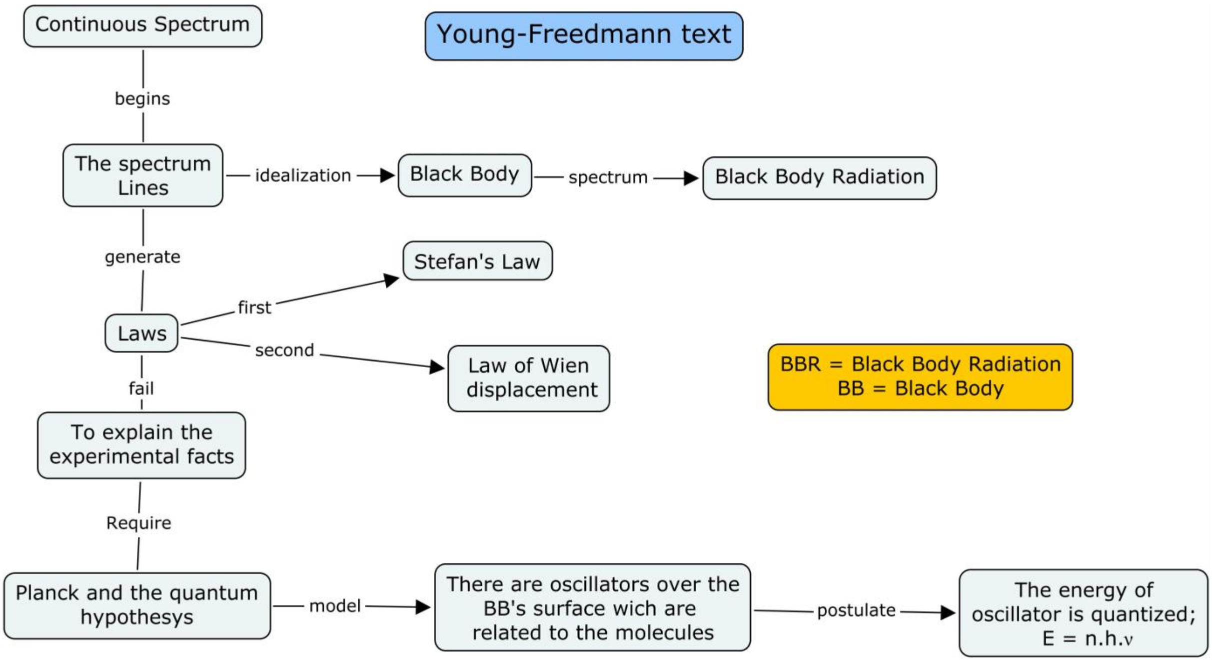

Fig.5 – CM of the Blackbody Radiation theory from the Young & Freedman textbook (2008).

As can be seen in its index the topic "Black Body Radiation" is treated in "Continuous Spectrum" that is found within the chapter 38 called "photons, electrons and atoms". Another interesting fact to note is that it divides the section into two parts: discrete and continuous spectrum. See de Mello (2015a). So it introduces the quantization of energy through the photoelectric effect and not through the BBR, following the current pedagogical tendency to present the energy quantization within the context of that matter and energy are two sides of the same coin. They introduce the theory of Planck when they explain spectrum of x-ray.

This begins by the fact that every heated body emits EM radiation. Then they build the model that radiation originates from accelerated charged particles that are close to the surface of the body that give rise to continuous EM spectrum. See CM in fig.5. After it they define the BBR and pose the problem of understanding this radiation. They follow exposing attempts to formulate laws for this phenomenon. Ends building Planck's law using the cavity resonators model and using the postulates of radiation quantization in the cavity.

Thus, comparing the text of the book "Young & Freedman" with the text of the book "Eisberg & Resnick" and with the Planck article it becomes clear that the didactic transposition of the BBR theory is made from the texts written for the academic level physics course and not from original articles.

If we look at some textbooks as the "Fundamentals of Physics" of Halliday (1997) it can be seen that they introduces the quantization of energy through the theory of the photoelectric effect and neither addresses the theory of BBR. See de Mello (2015a). Currently only some texts of the basic cycle respect the chronological order of scientific development.

6 - “Physics Principles and Problems” - Glencoe Program (2005)

Let us analyze one textbook used in American high school: the book "Physics Principles and Problems" of the Glencoe program. We can see in their CMs, figure 5, his pedagogical project is all grounded in three pillars: 1) Introduction to the theme through the experimental problems (connecting word “puzzle” in brown) that afflicted the scientists at that time; 2) presentation of the theory by describing an experiment rather than the detailed description of the scientific model (bold box); 3) finalization through technological applications.

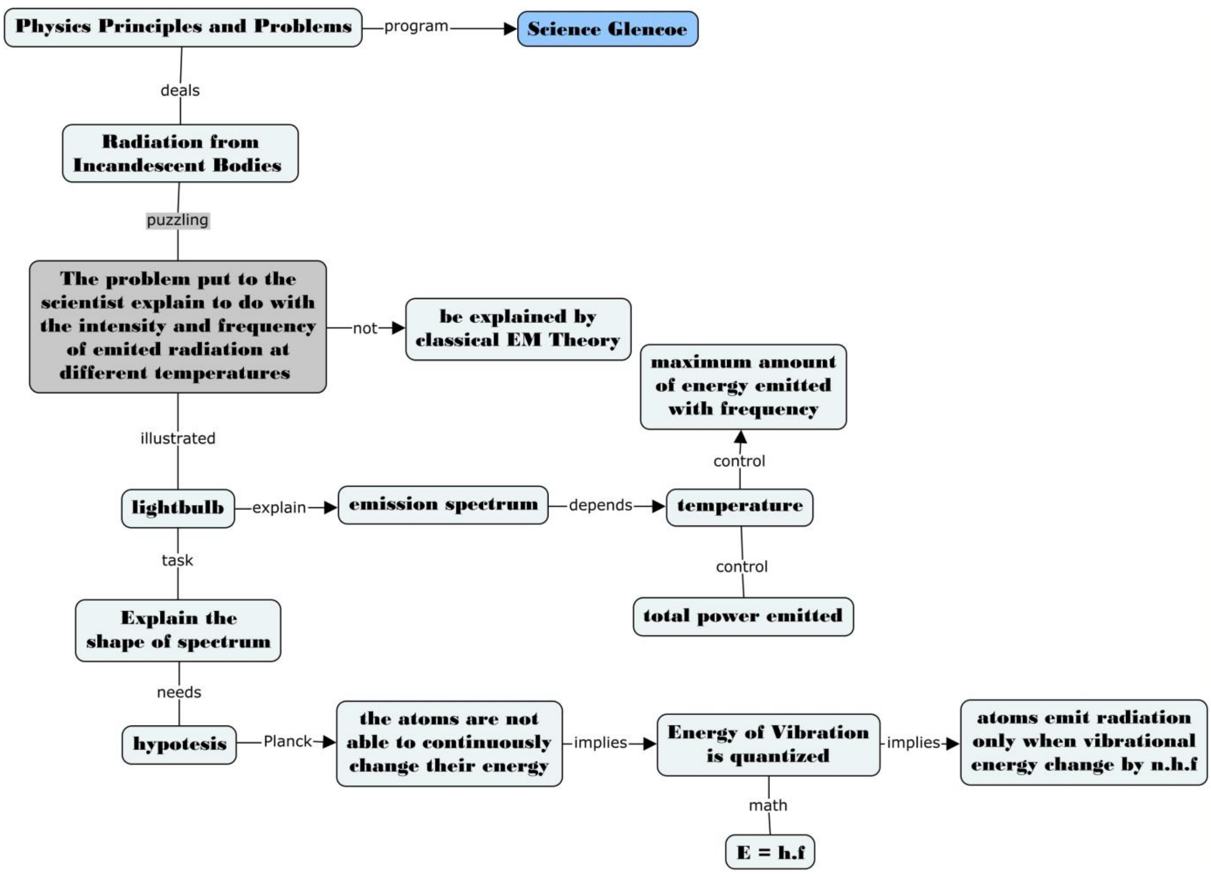

Fig.6 – CM of the Blackbody Radiation theory from the Glencoe Program (2005)

This introduces the energy quantization in the "incandescent body radiation" section without addressing the BBR. See your CM in fig.6. He motivates the text with the central issue at the time of Planck which was to understand the dependence of the intensity and frequency of radiation emitted with the temperature, which could not be explained by classical EM theory. See bold Box called puzzling. Using the example of light spectrum variation of an incandescent bulb they define the dependence between the total power and the maximum amount of energy emitted by the filament. They introduce the energy quantization hypothesis through the fact (still valid today) that we can only explain the shape of the curve of the intensity of radiation from the blackbody if we assume, as Planck, that atoms emit radiation only when the vibrational energy varies discreetly of multiples of h*f. Note that in the text appears only the Planck's theory without mention the previous one, and that they does not define explicitly the physical model of atoms vibrating in the metal surface.

Again, we can see that the didactic transposition of the BBR theory is made from the texts written for the academic or basic level physics course and not from original articles.

DISCUSSION AND CONCLUSIONS

We can see in figure 2 the power of presentation and summarize of CM. We have in the center column of CM of Planck's article the entire logical sequence of construction of his theory. Experimental results → Classical Laws → correction of classical laws → find a universal expression for the internal energy, U (T) → find a expression of S(U) → Planck's Equation. The equation was obtained by the assumption that the integral on the energy need be replaced by a summation. That is, as we said earlier, it promptly show us that if his theory to be approved by the scientific community it must be constructed using scientific concepts accepted by it. These are: Entropy, internal energy, temperature and the model of molecules as resonant oscillators.

Reading comparatively the CM design for the Eiseberg and Resnick textbook (1985) we see promptly that from the classic laws they follow a theoretical model completely distinct of the Planck. See boxes in bold in fig.1. They replace the model of obtaining a universal expression for the entropy in function of the internal energy, by simple counting the number of waves in the cavity and the replacement of the continuous distribution of energy by the discreet distribution - Planck hypothesis or replacement of paradigm. The reason for this is that in the epoch of Planck the theory of atomic structure was not well defined and he had to build his theory in "solid foundations", i.e., to be accepted by the scientific community of his time. The only theory was the theory of Probability and Statistics. The consolidation of statistical mechanics as scientific theory was only made four years later by Albert Einstein (1905). In his second article A.E. rebuilt the deductions of Planck and universalizes the theory of Boltzmann [de Mello, 2015b].

Reading comparatively the CM for the textbook of the authors Sears and Jewett (2006), fig.3, we can see that this follows the same structure of the book of Eisberg. Reading their two last lines we see that it uses the same deduction and paradigm of the latter. If you read the CM of another text of the same authors (201x), fig.4, we see that this follows the same paradigm used by Eisberg, but omits the deductions. Note that the reading of the index of these books not allows us to see this difference. But the CMs promptly inform the differences between the texts without the need of reading the same.

Looking at the CM of the book Young-Freedmann, fig.5, we see immediately the simplicity of the text and the parts removed from the text. Experimental data, law of Rayleigh-Jeans, and the deduction of Planck equation. When we look at the CM of textbook written for the middle school - Glencoe program - we see in this that the classic laws were replaced by the statement that the intensity and frequency of the radiation emitted by a body heated cannot be explained by electromagnetism of Maxwell. They do the deduction of Planck equation from the observation the scientific need to explain the emission spectrum of an incandescent bulb implies in the hypothesis of Planck or quantum mechanics. Briefly: puzzling → experimental fact → hypothesis.

As we can see in textbooks, or directly in the 1905 Albert Einstein article or in de Mello (2015b), the essential part that remained of Planck's work (1901) is his equation, the quantization of energy and part of your model of the resonant cavity. Thus, it notes that the theory of BBR consists of a part that does not change with the development of physics, which are their mathematical laws (if we may say so) and their experimental results (your data, tables and curves). On the other hand, we have its explanatory models that adjust to the new discoveries in physics.

This confirm that from the point of view of the cognitive theory of science we have that the essence of theories is not the formal structure of the model, but that this give meaning to the world. The theoretical models are, therefore, the main entities of scientific knowledge, provided that they are connected to the phenomena and that these be mental tools allowing scientists act [Izquierdo, 1999].

We can see in the CM elaborate for the texts of Freedmann, Serway, Glencoe and others, that the structure of these texts are as follows: motivated from the presentation of experimental facts and empirical models that cannot be describe it in its generality; it is reported that a theory built from the classic paradigm (Maxwell EM) conflicts with the experimental data; then they present the "revolutionary" hypotheses that Planck made in order to develop his theory, and conclude with the law of energy quantization.

So, we agree with Izquierdo (2003) that science education (DT) is designed so that students will understand that the natural world has certain characteristics or empirical laws, which can be modeled theoretically. As we saw above, we presents to them some reconstructed facts, theoretical models, arguments and propositions which are selected previously within the level of education of these. It is interesting to observe that in the majority of texts the experimental facts are presented before the model of resonant cavity. But, this order can be pedagogically reversed, as in fact is done in the text of the Serway (2006).

Thus, due to teaching needs teachers are professionals committed to teaching the current science as this is the truth. Of course this is not "doing science", but "teach science". Therefore, we can reverse the order of presentation or construction of a theory. As we have seen in Planck article (1901), scientists propose theories and methods to achieve their own explanatory objectives, but this is not entirely possible or didactic for students in the school. (Izquierdo, 2003).

In addition, if the text of sciences is design in accordance with the principles of a well executed didactic transposition (Chevallard, 1990), the authors or teachers are also professionally committed in connecting scientific models to the used by the students, using analogies and metaphors that best help them move from the mental models to scientific models (Duit, 1991; Flick, 1991; Ingham, 1991; Clement, 1993).

It is observed studying comparatively the Planck article and the Glencoe book that we have two sciences: the scientists science and the science of school [Izquierdo-Aymerich and Aduriz-Bravo, 2003]. Both sciences have a common cognitive goal: understand the world and communicate theoretical ideas with precision and significantly. But, it has different way to obtain its goal. The first way is communicating ideas, theories under the dominant paradigm and under science rigor. The school science has the goal of do a didactic transposition consisting in recreating the science of scientists in classrooms, according to their own values, institutional conditions, rhetoric tools and educational objectives, to convert it into the school sciences [Izquierdo-Aymerich and Aduriz-Bravo, 2003].

These explanations, that is, theoretical ideas about the world that help to understand it, are structured around concepts. It was showed here through the use of CM that we can put these concepts, knot or links in hierarchical sequence in order to understand the scientific activity. Think of the model of energy quantization and how it was reduced to a small set of propositions, to some equations that allows calculates the spectral radiation intensity and understand the orbital energy levels allowed or, in some cases, only one image.

We saw in the course of this article, as said by Carey (1992) and Nersessian (1992), that the models are a kind of mental representation; the propositional language that defines a theory is not used to describe the world, but rather it is used for the construction of a mental model of the same, which is a structural analogue of the real situation. See the case of definition of universal function of entropy per Planck. The interpretation of a fact can be a consequence of this be related to similar facts or analogous that make sense for the scientists (empirical laws). The initial model thus generated will develop in so far as is explaining other phenomena known or new, as we saw in the case of the model of Planck, being didactic transposed until it reach the middle school.

Currently, in middle school and in the basic university level we have several proposals of teaching methodologies. We saw in the text of the Glencoe that due to the fact of this be writing within the methodology of learning based projects, that instead of them presenting the facts in the form of experimental reports, they use the technique of writing the text in questioning manner. That is, they present the facts as puzzling to be resolved. Thus we see that the DT is not a mere simplification of the theory, but it take into consideration the teaching methodology employed in its preparation.

We have that in some texts written for the basic university level, such as the Halliday textbook (1997) and in many texts for the middle school that the theory of quantization Planck is just quoted, or better, is presented as a law. That reinforces our thesis that in many cases the scientific theory dispense its scientific model.

Finally, we can define "scientific paradigm transposition" as:

> An efficient theory to analyze the process through which the scientific theories produced according to certain scientific paradigm are becoming in current theories in accordance with the evolution of the dominant paradigm, that is, in the scientific knowledge that is contained in the programs and textbooks (the knowledge to be taught).

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Referências

Smith, Adam. *An Inquiry into the Nature and Causes of the Wealth of Nations*. Рипол Классик, 1937.

Adúriz-Bravo, A., & Izquierdo-Aymerich, M. (2009). Un modelo de modelo científico para la enseñanza de las ciencias naturales. *Revista electrónica de investigación en educación en ciencias*, (ESP), 40-49. Accessed online 12/11/2014, at: http://www.scielo.org.ar/scielo.php?pid =S1850-66662009000100004&script =sci_arttext

Alonso, M. & Finn, E. F. (1968). *Fundamental University Physics, vol.3*. Addison Wesley Publishing Company.

Ausubel, D. (1977). *The facilitation of meaningful verbal learning in the classroom*. Educational Psychologist. Volume 12, Issue 2.

Ausubel, D. (2003). *Aquisição e retenção de conhecimentos: uma perspectiva cognitiva* (1ªed.) Lisboa: Plátano Editora. (Writen in Portuguese)

Brockington, G. e M. Pietrocola (2005), M.. *Serão As Regras Da Transposição Didática Aplicáveis Aos Conceitos De Física Moderna?* Investigações em Ensino de Ciências – V10(3), pp. 387-404. (Writen in Portuguese)

Chen, Hsinchun, Roger HL Chiang, and Veda C. Storey. "Business Intelligence and Analytics: From Big Data to Big Impact." *MIS quarterly* 36.4 (2012): 1165-1188.

Chevallard Y. (1991). *La Transposición Didáctica: del saber sabio al saber enseñado*. La Pensée Sauvage, Argentina.

Chibeni (2015), S.S. - Síntese de *A Estrutura das Revoluções Científicas,* de Thomas Kuhn. Accessed online: 10/03/2015, at http://www.unicamp.br/~chibeni/textosdidaticos/ structure-sintese.htm

Clement J. (1993). Using Bridging Analogies and Anchoring Intuitions to Deal with Students». Preconceptions in Physics. *Journal of Research in Science Teaching*, 30(10), pp. 1041- 1057.

de Mello, L. A. (2014). Concep Maps as useful tools for textbooks analyses. *Presented in: CCM 2014 – 6th International Conference on Concept Mapping. Santos. Brazil*. To be Published.

De Mello, L.A. (2015a) - Concept Maps as a Tool for the Evaluation of Modern Physics Contents in Textbooks. *Ensaio Pesquisa em Educação em Ciências.* To be Published.

De Mello, L.A. (2015b) - Concept Maps as a Tool for the Evaluation of didactic Transposition and of Scientific Transposition. The Case of Photoelectric Effect.

DUIT, R. (1991). On the role of analogies and metaphors in learning science. *Science Education,* 75(6), pp. 649-672.

Eisberg, R. e Resnick, R. **(**1985). *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles.* Ed. Jhon Wiley & Sons. U.S.A.

Feyerabend, P. (1975). Against the Method. Carlisle Street, Londres WI. Contra o Método. Livraria Francisco Alves Editora S.A. (1975).

Flick, L. (1991). 'Where Concepts Meet Percepts: Stimulating Analogical Thought in Children', *Science Education* **75**(2), 215–230.

Glencoe Science (2005). Physics, Principles and Problems. The CMGraw-Hill Companies, Inc.

Halliday R., Resnick R. & Walker J. (1997). *Fundamentals of Physics(5th Ed.).* U.S.A., Ed. Jhon Wiley & Sons.

Harrison, A.G. & Treagust, D.F. (2000). Learning about Atoms, Molecules, and Chemical Bonds: A Case Study of Multiple-Model Use in Grade 11 Chemistry. *Science Education*. 84(3), Pg. 352.

Harvard Project (2006). *Uma conversa com Gerald Holton*. Cad. Bras. Ens. Fís., V. 23, N. 3: P. 315-328, Dez. (Writen in Portuguese)

Ingham, A. (1991). 'The Use of Analogue Models by Students of Chemistry at Higher Education Level', *International Journal of Science Education* **13**(2), 193–202.

Izquierdo Aymerich, Mercè (2005). Hacia una Teoría de los Contenidos Escolares. *Enseñanza de las ciencias.* Accessed online 12/11/2014, at: *http://ddd.uab.cat/pub/edlc/02124521v23n1/02124521v23n1p111.pdf.*

Izquierdo-Aymerich, M. & Adúriz-Bravo, A. (2003). Epistemological foundations of school science. - Science & Education, *Kluwer Academic Publishers. Printed in the Netherlands. Pg. 23.*

Izquierdo i Aymerich, M., Sanmartí, N. & Spinet, M. (1999). Fundamentación Y Diseño De Las Prácticas Escolares De Ciencias Experimentales. *Enseñanza De Las Ciencias, 17 (1), 45-59*.

Jewett Jr (2010), J.W. & R. A. Serway. Physics for Scientists and Engineers, vol.2. Ninth edition. Cengage Learning.

Johnson-Laird, P. N. (1995). Mental Models. *6th Edition. Printed in USA. Cognitive Science Series.*

Johnson-Laird, P. N. (1987). Modelos mentales en ciencia cognitiva. *NORMAN, D. A. Perspectivas de la ciencia cognitiva. Barcelona: Ediciones Paidós, p. 179 - 231.*

Kuhn, T. (1970). The Structure of Scientific Revolution*. Chicago. The University of Chicago*. A Estrutura das Revoluções Científicas. *Coleção Debates. Ed. Perspectiva. (1998).*

Latour, B., & Woolgar, S. (2013). *Laboratory life: The construction of scientific facts*. Princeton University Press.

Latour, B. (1999). *Pandora's hope: essays on the reality of science studies*. Harvard University Press.

Merriam-Webster Online Dictionary. Accessed online 10/09/2014, at: http://www.merriam-webster.com/dictionary/science.

Moreira, M. A. (1979). Concept Maps as Tools for Teaching. *Journal of College Science Teaching*, v8 n5 p283-86

Moreira, M. A. (2005). Mapas Conceituais e Aprendizagem Significativa. *Revista Chilena de Educação Científica, 4*(2): 38-44. *Accessed online 10 Jan 2015, at*: http://www.if.ufrgs.br/~moreira/mapasport.pdf. (Writen in Portuguese)

Nersessian, N.J. (1992). How do Scientist Think? Capturing the dynamics of Conceptual Change in Science. Cognitive models of science, pg.3.

Novak, J. D. (1990). *Concept maps and Vee diagrams: two metacognitive tools to facilitate meaningful learning*. *Instructional Science 19:29-52.*

Novak, J. D. & Cañas, A.J. (2006). *The Theory Underlying Concept Maps and How to Construct Them.* Technical Report IHCM CmapTools 2006-01. Accessed online 01/05/2014, at: http://www.vcu.edu/cte/workshops/ teaching_learning/ 2008_resources/TheoryUnderlyingConceptMaps.pdf

Oliveira, J. Mario (2006). Planck e a Emergência da Quantização da Energia. Acessed online 10/10/2015, at: http://fig.if.usp.br/~oliveira/planck.pdf

Planck, Max (1901) - On the Law of Distribution of Energy in the Normal Spectrum. Annalen der Physick, vol.4. p.553. (1901)

PSSC. Physical Science Study Committee. Accessed online 01/04/2014 at: http://libraries.mit.edu/archives/ exhibits/pssc/

PSSC, Física - Parte I, Parte II, Parte III, Parte IV, *Editora Universidade de Brasília, authorized translation with copyright to the Brasil by IBECC-UNESCO.* (Writen in Portuguese)

Serway, R. A. & Jewett Jr., J.W. (2006). Principles of Physics: a calculus-based text; Vol. 4, 4ª *Ed., Belmont, U.S.A., Thomson Learning.*

da Silva, G., & de Souza, C. M. S. G. (2007). The use of concept maps as a strategy of promotion and evaluation of meaningful learning of calorimetry concepts. *Experiencias em Ensino de Ciências. V2(3), pp. 63-79.*

da Silva, G. (2007). Mapas Conceituais Como Instrumento de Promoção e Avaliação da Aprendizagem Significativa de Conceitos de Calorimetria, em Nível Médio. *Doctoral Thesis. 2007. Accessed online 01/04/2014, at: www.nutes.ufrj.br/abrapec/ vienpec/CR2/p251.pdf.* (Writen in Portuguese)

Young, H.D. & Freedman, R. A. (2008). University Physics with Modern Physics, Vol. 2. 12th Edition, Sears and Zemansky's. San Francisco. Pearson Addison-Wesley.