Concept Maps and the Theory of Scholar Scientific Knowledge[1]

Mapeamento de Conceitos e a Transposição do Conhecimento Acadêmico.

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Abstract: We will present here the Scientific Knowledge Theory (SKT) along with one of its possible research methodologies. That is, together with concept mapping as an algorithmic language (CMA). That is, at the moment that a given author produces a given text or hypertext, to be this an educational text, an report, a article or scientific text he "materializes" a set of ideas, hypotheses, explanatory models, theory and/or experimental facts in a written form, implied in its most general form. In this moment we have the occurrence of an "educational fact." It is proposed here that a theory of Knowledge Transposition or Didactic Transposition, provided with a research methodology and based on pedagogical facts constitutes a branch of the social sciences. That this new theory, the "Theory of Scientific Knowledge", can be easily generalized to other forms of knowledge.

Key Words: Theory of Knowledge, Scientific Knowledge, Didactic Transposition, Concept mapping, scientific methodology.

Resumo: Vamos apresentar a Teoria do Conhecimento Científico (TCC) junto com uma de suas possíveis metodologias de pesquisa. Isto é, junto com mapeamento conceitual como uma linguagem algorítmica (CMA). Tem se que no momento que um dado autor produz um determinado texto ou hipertexto, seja esse um texto didático, um artigo, uma reportagem ou texto científico esse “materializa”, subentendido na sua forma mais geral, em um conjunto de ideias, hipóteses, modelos explicativos, uma teoria e/ou fatos experimentais na forma escrita. Nesse momento temos a ocorrência de um “fato pedagógico”. Propõe-se aqui que uma teoria da Transposição do Conhecimento ou da Transposição Didática, munida de uma metodologia de pesquisa e baseada em fatos pedagógicos se constitui em um ramo das ciências sociais. Que essa nova teoria, a “Teoria do Conhecimento Científico”, pode ser facilmente generalizada às outras formas de conhecimento.

Palavras Chaves: Teoria do Conhecimento, Conhecimento Científico, Transposição Didática; Mapeamento conceitual; metodologia científica.

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Introduction

The multiplication and universalization of university careers led to the explosion of the Editorial Market, both in the bachelor degree as in the secondary school. The combination of engineering with the agricultural, environmental, foods and other sciences created the necessity to produce a wide variety of specialized textbooks. This created opportunity to the emergence of several educational proposals for science teaching. In particular we have Physics book with the purpose of training scientists, engineers and biological sciences.

These books and e-books are composed of texts produced according to a teaching methodology with very specific purposes and in accordance with the prior mathematical knowledge of each student. Thus, they are the materialization of a didactic transposition (De Mello, 2016a; Chevallard, 1982) of scientific knowledge and called hereafter the "Pedagogical Fact" (a material object). We will use the term pedagogical fact even if the knowledge is produced in the form of a hypertext or as a figure, graph, table, or website[3].

The theory that studies how this pedagogical fact occurs is called the Didactic Transposition (TD) (Chevallard, 1982; De Mello, 2016d). That is, TD is the theory that studies how the knowledge produced in research spheres are transformed and consolidated in knowledge to be taught both in higher education as in the basic cycle. That is, we will use as theoretical framework the generalized theory of TD of Chevallard, Izquierdo and De Mello called TD-CHIM (De Mello, 2016d).

De Mello (2016b and 2016c) has shown that the best and most efficient way to make the analysis of how scientific knowledge produced in research spheres is transposed to textbooks, consolidating as a pedagogical fact is through the use of concept mapping as this was an algorithmic language (CMA). Using this study tool (CMA) De Mello (2016e) created a research methodology for the TD.

The main objective of this article is to demonstrate that the theory of TD-CHIM together with their pedagogical facts and equipped with the research methodology based in CMA is a social science. We will use as an applying example the quantization theory of Max Planck.

Pedagogical Facts and its Research Methodologies

With the emergence of the World Wide Web, with the democratization and universalization of education and information the knowledge has become an integral and fundamental part of current society - the information society (Masuda, 1980; Burch, 2006). Knowledge is no longer a production and marketing process accessory and has to be a central and decisive part of the structures and rules governing these (Grant, 1996; Ernst, 2002). Similarly, various theories and methodologies have been created, developed and adapted to meet the needs and the development of the media and cybernetics.

[3] Henceforth any materialization of knowledge will be called event or educational fact.

Within this methodology, called data mining, we have several software or applications developed with the purpose to obtain information and manage the market. Among these we have the Oracle software, SAP and others (Chen, 2012). Basically these use resources of statistics along with the operational research theory (a methodology of research) to perform data processing.

From these researches are developed marketing strategies, advertising campaigns, product portfolio, products alteration, etc. Despite the motivation behind this research (according to Adam Smith (1937)) is the greed of the entrepreneur, the knowledge generated by this research (scientific methodology) is prepared in an intelligible form and scientifically. So we can call it a pedagogical fact. Even the design of a home page is made according to certain logical rules based on scientific knowledge coming from psychology and statistics and can be call a pedagogical fact.

Due to the impact of the multimedia, especially by the visual presentation, it caused the publishing companies to invest in the research of the impact of graphic arts over reading and text comprehension (Carney, 2002 and Schnotz, 2008). It has been shown that fully integrated figures into text contribute significantly in the reading and understanding of scientific texts and text in general (Clark, 2010). As this knowledge results in the production of certain kinds of books we may call it pedagogical fact.

In sequence we restrict ourselves to the study of how scientific knowledge is transposed to textbooks and how this becomes a pedagogical fact, that is a textbook (a material object) using concept mapping as a research methodology.

The Chevallard, Izquierdo and De Mello Theory of Didactic Transposition (TD-CHIM).

Briefly the Didactic Transposition Theory is a theory that involves the epistemology of science, cognitive theory of science, didactic teaching and social theories to understand, create rules and study the mechanisms governing the knowledge transformation produced in research environments to suit academic teaching, from this to the textbook and from this to the classroom of basic university course and for mid-level books. In other words, this theory aims to understand how scientific knowledge is transformed in its multiple forms of presentation. That is, as this is rewritten according to certain teaching methods and educational purposes.

The theory of TD studies how the knowledge produced in research spheres, called scholarly knowledge (Chevallard, 1990), is transformed, adapted and reworked in the form of school scientific knowledge, called Knowledge Taught. In the general theory TD-CHIM (De Mello 2016, 2016 and 2016c b) the TD's theory should consider that the knowledge produced in research spheres goes through three steps to get to the middle school classroom. That is, the Scholar Knowledge is consolidated and / or regulated in the post-graduate programs (Knowledge to be Taught), then transposed to the Bachelor level and is finally transcribed or adapted to the level of the textbooks produced for the middle school (Knowledge Taught). This is necessary because currently we have textbooks designed for post-graduate courses and graduation. Strictly speaking we would have to subdivide the bachelor in academic and basic graduation. See De Mello (2016a). So we have to divide the Scholar Knowledge into three parts. Scholar Knowledge (Research Level), the Academic Knowledge (Level Postgraduate) and the University Knowledge (graduate degree).

Scholar Knowledge → Academic Knowledge → University Knowledge → Knowledge to be Taught → Knowledge Taught.

It is within this context that the TD theory deals with the problem to understand, classify and study how the knowledge produced in the academic spheres will be adjusting, adapting and transforming into scientific knowledge taught in the classroom[4]. More details see (Astolfi, 1995; apud Brockington, 2005).

That is, what school science and scientists science have in common is that their theoretical ideas, concepts, were arrested and sealed in black boxes after gaining importance and then become more "solid" and "strong" that is, after "consolidated" (De Mello, 2016b). Tese de Latour (1999). Such packaging process leaves out details, explanations and reasons that were necessary to convince others of their "original power to explain" - both the scientific level and the educational level (Izquierdo, 2003).

De Mello (2016th, 2016c) divides the theory of TD in two parts. One part of the theory deals with the socio-cultural influences on didactic teaching (Chevallard, 1991; Brockington, 2005). And the other is concerned with the epistemological and semantic aspects of the theories and how these are translated to textbooks (De Mello, 2016a, 2016b e 2016c).

Although apparently seem that these two aspects of TD not influence, they coexist and work together. So, we have to include in their analysis the external environment in which it occurs. That is, we have to take into consideration that the school system is part of a larger system - the education system (Brockington, 2005). Chevallard (1991) uses the noosphere word to describe and encompass the elements involved and regulating the selection and determination of the changes that scientific knowledge will suffer to become school knowledge. More details see Brockington (2005) and De Mello (2016th).

Due to the diversity and richness of existing factors in the academic sphere governing the selection and standardization of scientific knowledge De Mello called this environment as epistemosphere. Within this epistemosphere we have, in the case of exact courses, Physics books written for courses based on calculus and others based on algebra. We have Physics books called Conceptual Physics, Physics for Engineers and traditional. De Mello (2016b and 2016c) demonstrated that TD for the basic cycle occurs from these texts and not from the original articles. Thus

[4] Here is meant classroom the class in the basic cycle.

a theory of TD must study and show how knowledge or Scholar Knowledge is transformed into the epistemosphere to transform into Knowledge Taught.

After this phase, knowledge is transformed within the context of editorial policies, national programs of textbooks production and formulation of public policies to achieve the textbooks and be effectively taught in the classroom. Is in this moment that the teaching methodologies and pedagogical proposals come into play. That is, when studying or analyzing the transformations that knowledge suffers to reach the school environment we should consider both the epistemological aspects of science as their pedagogical and methodological aspects of teaching.

Chevallard and e Brockington proposed some characteristics that define the reason that a certain knowledge to be present in textbooks. Chevallard (1991) defines some of these characteristics. In summary these are (Brockington, 2005):

1 - Consensual: The Noosphere members must agree that a given knowledge is definitely established.

2 - Moral Actuality: This must be relevant and necessary.

3 - Biological Actuality: The content taught should be consistent with the theories or current models or accepted by the scientific community.

4 - Operationality: For a Knowledge be implemented and remain in school curriculums this should generate questions, exercises and problems.

5 - Teaching Creativity: Some subjects of science are still taught although they are currently not part of the research field.

6 - Therapeutic: One of the reasons a particular knowledge to stay in school curricula is to your success in the classroom.

Due to the great scientific and technological advances, and needs of the school curriculum updating, Chevallard and Johsua (1982; cited in Astolfi, 1995) has produced five rules for DT (Alves-Filho, 2005). We will list below only their first two, which from our point of view fit within this classification, that is:

7 - Modernizing school knowledge. The curriculum should address current subjects.

8 - Update the knowledge to teach. The noosphere agents must define what knowledge should be removed from textbooks because they are obsolete.

From our point of view the fourth Astolfi rule (1995) is included in the guideline 4 (Operationality) of Chevallard. And the rules 3 and 5 fall into guidelines or suggestions for how the DT should be made.

Didactic Transposition and the Cognitive Model of Science

Recent contributions from epistemology of science for science teaching led to a new approach (theory) of the latter called "cognitive model of science" (CTS) that originates from Kuhn's philosophy of science (Izquierdo, 2003). Along with the theory of "didactic transposition" suggest the possibility to analyze with more depth as knowledge produced in scientific spheres are translated to the school sphere.

Author (2015b and 2015c) demonstrated that to understand how the knowledge produced in research spheres (scholar knowledge) is transposed to the school spheres should take into account what is actually meant by scientific knowledge and to do science.

According to Izquierdo-Aymerich (2003)[5] 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, theoretical models, arguments and propositions that were previously selected.

In addition, if the teaching of sciences is done in accordance with the principles of meaningful learning (Ausubel, 1977), that is, a well executed didactic transposition (Chevallard, 1990), the teachers will be involved in the task of connect scientific models to used by pupils themselves, using analogies and metaphors that may help them to move from the last for the first (Duit, 1991; Flick, 1991; Ingham, 1991; Clement, 1993).

So to teach science we have to teach systems or methods of acquiring knowledge and at the same time, teach how to arrive to this organized body of knowledge from them. But in general it is impossible to reproduce in the classroom (Izqueirdo, 1999). Thus, the question arises: What is to teach science in high school classroom as in the university?

Scientific theories are presented in textbooks 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 supported by experimental facts. Therefore, a scientific theory is a family of models and assumptions together with or postulates establish the similarity of these models with experimental facts.

These explanations, that is, theoretical ideas about the world created to understand it, are structured around concepts. For Latour (1999), these concepts, or what he calls knots or links, are those things that allow us to understand the scientific activity (Izquierdo, 2003). Thus, it is argued here that concept mapping is the ideal

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

tool to do this study. Mainly, how these concepts or nodes or links are inserted, deleted, summarized and twisted to make each text a coherent whole.

If we analyze the textbooks written for high school, from the point of view of knowledge and its method of obtaining, we see that these are classified into two types: a) those who start exposing the theory and then presenting the experimental facts that leads to its formulation or discovery as a mere confirmation of its validity or importance. b) and those that begin exposing the experimental facts that resulted in its formulation and putting the theory as a direct consequence of these facts. With the introduction of modern methods of teaching we have some alternative versions of exposure of textbooks. For example, we have textbooks written in the problem-based learning (Glencoe, 2005) in which each topic is preceded and motivated by the presentation of a puzzle that contextualizes the need of the search or theory formulation.

Like every theory of human and social sciences, DT theory does not contain "closed" Laws or rules defining as a DT should occur or be achieved. Within the current context of science education in the basic cycle and university we can suggest some guidelines for how the DT should be made.

1 – Partition of knowledge: Divide into its constituent parts, that is, between theory, model, experimental facts, applications, historical facts, etc.

2 – Articulate the "new" knowledge with the "old" (Chevallard, 1982; cited in Astolfi, 1995): When teaching a new theory the author and/or teacher should make clear that the old theory is still valid within their limits of validity.

3 - Make a concept understandable (Chevallard, 1982; cited in Astolfi, 1995): We must rewrite or redraft a concept to the level of students understanding.

4 - Making a model significant: To adapt and/or modify the theoretical models, or the scientific models to the level of students understanding. Or connect it to the model used by them.

5 - Simple Math: Scientific knowledge should be redrafted using an appropriate mathematical formalism to every school level.

6 - Pedagogical Actuality: Scientific knowledge must be redrafted in accordance with a teaching methodology.

7 - Functional Actuality: Scientific knowledge should be drawn up according to the type of training required for each course.

To justify the introduction of 6 and 7 guidelines we currently have several university courses with various educational proposals. Some proposes to train scientists in general and others to train professionals for the labor market. A line of educators argue that science education should somehow reflect what is scientific activity and do science. But others argue that science should be taught in an objective manner. That is, it should be taught the concepts, theories and applications without worrying about doing science. Thus, the science teaching at school cannot be strictly based on the analogy of the student as a future scientist, that is, with a strong scientific basis (Izquierdo-Aymerich, 2003).

Concept Maps and Concept Mapping.

Concept Maps is a concise way of presenting and connect concepts (Novak, 1991; Moreira, 2006). As this is a form of mapping it uses linking words to connect ideas or concepts. Due to the variety and freedom to graphically present the concepts we have that MC is the ideal tool to evaluate, present, synthesize and summarize the knowledge (Novak, 2006).

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

> *"*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.*"*

When the CM is well constructed allows the visualization and perception of how the keys concepts from a particular topic or field of knowledge follow one another, intertwine and organizes themselves in the structuring of this knowledge. Thus, we tried to create some basic rules for the construction and standardization of CM's that can be seen in many articles (Novak 2006; Moreira, 2006; de Mello, 2014). As showed by de Mello (2015a and 2015b), in the case of a systematic study we must create some very specific rules for the construction of CM, so that they become a kind of algorithmic language.

Due to its concise, hierarchical and graphical way to present the key concepts to be taught we have that CM are a powerful tool to perform the analysis of the conceptual framework that textbooks are written. The construction of a CM to a topic or the whole book, allows you to see promptly and succinctly the conceptual framework that a particular author used to concatenate and organize the key concepts that go into the preparation of your textbook. Thus, it is necessary to build a CM wich show us the interconnection between the concepts inserted and used, and enables to quickly view the underlying structure used to the construction of a conceptual body of knowledge. More details about MC see Novak (1990) and Moreira (2006).

Conceptual Maps, Didactic Transposition and Cognitive Models of Science.

As stated above, scientific theories are constructed from scientific models, assumptions and theorems that are propose to explain a certain set of events. These explanations are structured around concepts, nodes or links (Latour, 1999), which allow us to understand the scientific activity. (Izquierdo, 2003).

Thus, being CM diagrams of meanings, indicating hierarchical relationships between concepts or between words to represent concepts, these are the ideal tool to map as these nodes or links are prepared and organized so as to create a coherent whole and that make sense to a certain level of schooling. That is, to study how the knowledge produced to a level of schooling is transcribed to another.

De Mello (2016c) demonstrates, for the case of the topic of physics called Photoelectric Effect, currently the scientific knowledge is structured didactically in their transcriptions to textbooks in: a) models; b) the core of the theory; c) experimental facts; d) the key concepts; e) the methodology and f) the application of the theory. Thus, it is necessary to understand how these "pieces of knowledge" are inserted, deleted, and summarized to make each text a coherent whole.

De Mello (2016b, 2016c) showed that in the case when the original theory was built in a period of paradigm revolution (Kuhn, 1970) the theory need firstly be consolidated in the new paradigm before suffer a DT to the high school level. That its originals explicative's models must be adapt or rewritten in this new paradigm.

So, the CM built to analyze how the knowledge suffer a DT must be constructed under some rules. In this the conceptual structure described above should be very clear. Like an algorithm it must be created with the finality of describe the knowledge structure. Thus, the CM builder must be trained in dissect the knowledge in its fundamental parts.

Concept Maps as algorithm to analyze the knowledge

The main objective of this article is to demonstrate that the use of CM was as an algorithmic language to conduct the study of TD or the Theory of Knowledge (TC) is a scientific methodology. That this methodology, together with the theory of TD-CHIM, constitutes a theory of knowledge. As an example of application of the theory of knowledge and its methodology we will present a summary of the study of the didactic transposition of the Max Planck article to textbooks. That is, as through this TD the theory of blackbody radiation (RCN) and the theory of quantization become an educational fact. More details see De Mello (2016c).

The methodology used here will divide the knowledge into its constituent parts and analyze, using MC, and how these parts are arranged didactically to become a coherent whole and that makes sense to a certain group of people (students). To facilitate this task we will use certain rules to perform this mapping. Just as in a flowchart created to describe a computational algorithm we have specific symbols that define specific operations or actions, created in order to facilitate and standardize their reading, we create specific symbols or colors for a particular concept mapping. See De Mello (2016a, 2016b).

In the case of scientific theories, called here the “knowledge”, we have that these consist of a) explanatory models; b) the core of the theory; c) the key concepts; d) methodology; e) experimental facts and d) the application of the theory. So we use green boxes to identify the models. Boxes in blue to identify empirical laws, or its conclusions, or the results. In purple we have the theory. We put in yellow boxes the experimental facts that resulted in the theory. Green bluish the title. Light blue represent all support material, such as equations, deductions, etc. Finally, we put on coral the generalizations or universalizations of the theory. In this case we have no theory applications. See Figure 1.

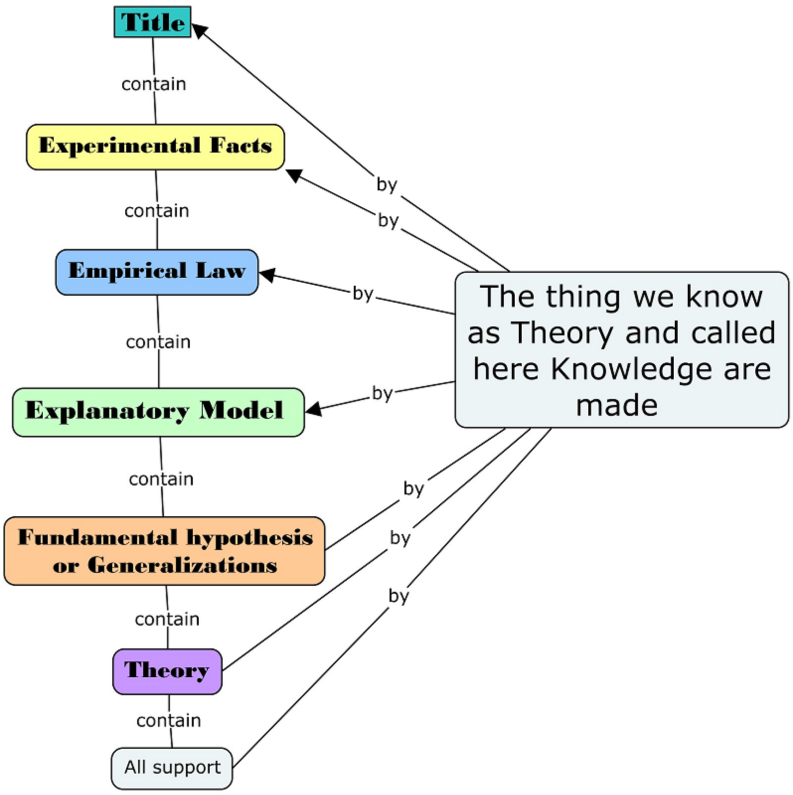

Fig.1 - Figure with symbolic structure of the constituent parts of an CMA to the theory of knowledge.

Example: The quantization theory of Max Planck (1901)

In some textbooks as well as to teach classes at the university basic cycle the theory of Max Planck's quantization is presented, suffering a TD, as merely an ad hoc hypothesis made by Max Planck (1901) to explain the radiation spectrum of blackbody (BBR). There is no exposure of explanatory models nor experimental facts that resulted in the theory[6]. That is,

$$E = h.\nu$$

[6] Because of the tradition we use the name theory for all this body of knowledge. When appropriate we will use the word knowledge as defined by de Mello (2016d).

For example, the book Fundamentals of Physics (Halliday, 1997) is an pedagogical fact (product) arising from this type of TD.

In other texts or pedagogical fact this theory is summarized in definition of BBR, presentation of the empirical laws that preceded the Planck Law and his hypothesis. There is no elaboration of an explanatory model and there isn't a discussion of how this was developed in the old scientific paradigm. See Fig. 2. It is very common to find this form of summarized presentation of the theory of BBR in texts to form engineers in general.

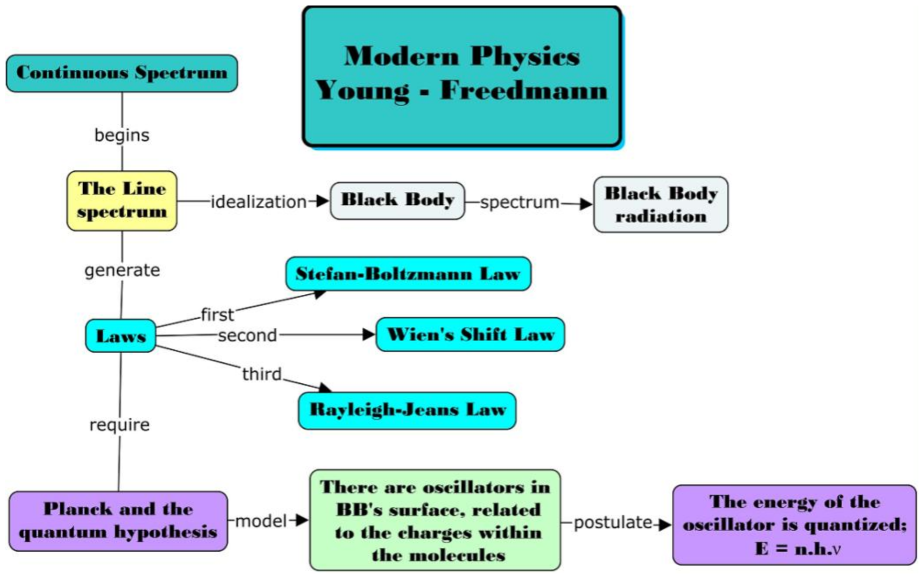

Fig.2 – The CMA to the text of BBR theory of Young-Freedemann textbook.

We put down the CMA of the Max Planck (1901) original article. Analyzing Planck's theory we clearly see the structure and the brilliance of his reasoning. That is: a) Definition of BBR and presentation of experimental facts; b) followed by an empirical law; c) attempt to write the theory from universal principles; d) model in the old paradigm, boxes in green; e) Deduction of universal law.

As an example of an educational fact originated from a didactic transposition we chose the textbook Jewett (2010). Analyzing your CMA we clearly see the yellow boxes scattered and concatenated with blue boxes, and in the last line we see as Planck's hypothesis (new paradigm) is inserted in theory. Despite the greater emphasis given to the explanation of the experimental facts and to the empirical laws that resulted in the Planck Law, we can note that this text was prepared in the same structure of Planck's article, that is: Facts and experimental laws → explanatory model → theory. We see the degree of preparation of the theory presentation of BBR that this book is really designed to train scientists in general. It is easy to note that it would be much harder to do this analysis if we had a CM without the color codes (CM clean).

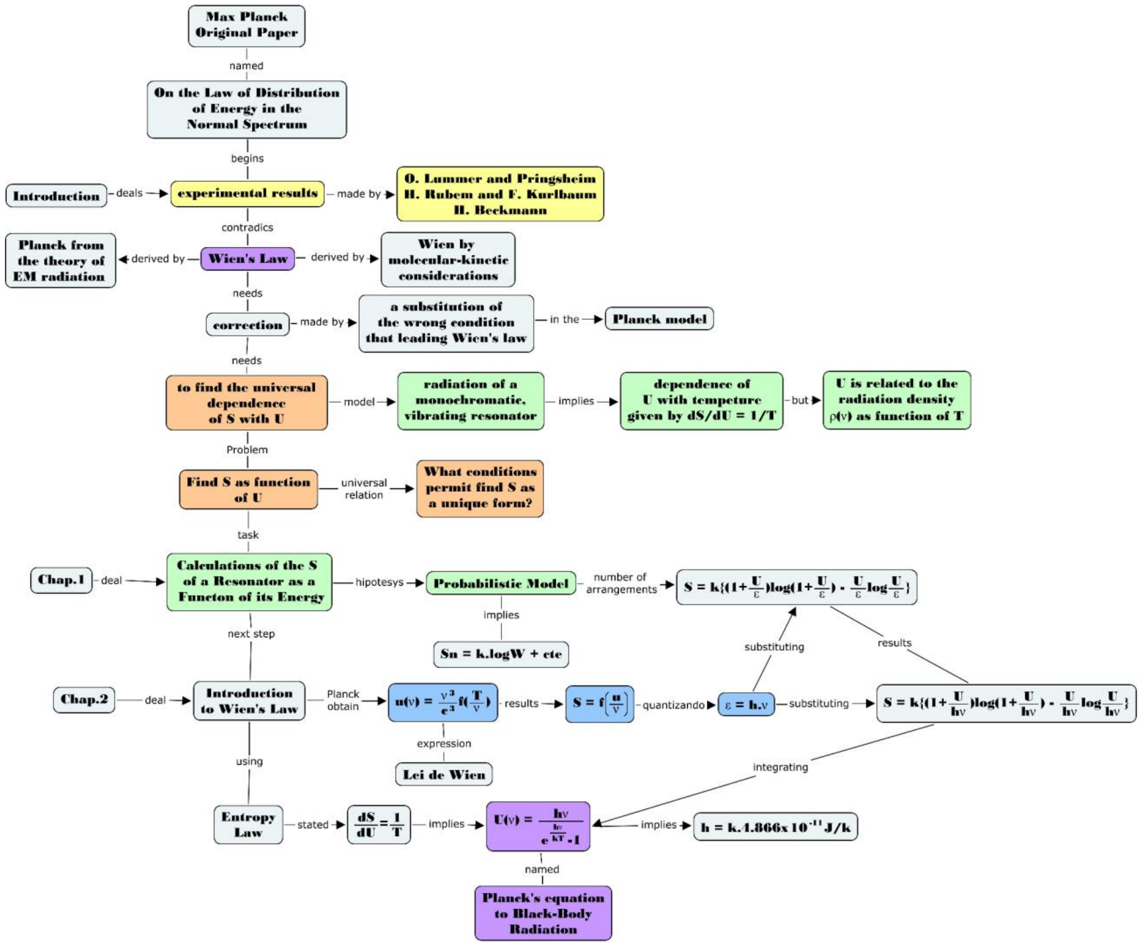

Fig.3 – The CMA of Max Planck article about BBR theory.

Results and Conclusions

We see above that MCA is the ideal tool to make the study of how scientific knowledge is transposed to all spheres of knowledge. This provides a very effective scientific methodology to make the study of the implementation of knowledge.

The TD-CHIM theory provides a general guidelines and rules to determine why certain scientific knowledge perpetuate and update in the school spheres. It also provides rules on how to classify the TD and how it should be done.

The CMA together with the theory of TD-CHIM is a very effective tool to classify, analyze and summarize how scientific knowledge is developed, formulated and transcribed to educational spheres. That is, to classify pedagogical facts.

With the TD-CHIM together with the scientific methodology using CMA we obtain a very effective way to make the study of how scholar knowledge is transformed in scientific environments. They become a science of knowledge.

The CM prepared according to the algorithmic rules provides us a schematic, visual summary and ordered the ideals, concepts and everything that makes up an article and / or book. The colors call the reader's attention to its constituent parts, so that in a first reading in addition to an overview of the content colors of the text, it allows and calls the reader's attention to its constituent parts. What would be more difficult if only we had the CM without color code. If the reader does not know in advance that a given knowledge consists of theory, models, etc. there is a great possibility that pass unnoticed any of these items, and that the reader does not understand in depth all its contents.

The CM in the form of algorithm (CMA) will indicate which sequence the author entered, organized and concatenated the component parts of his theory (knowledge). Moreover, the analysis done for a CMA for a particular textbook allows you to view how these concepts or nodes or links are inserted, deleted, summarized and twisted to make each text a coherent whole (de Mello, 2016a, 2016b e 2016c). Used in a comparative analysis it allows you to check (de Mello, 2016b, 2016c and 2016d): a) as explanatory models are adapted, simplified and deleted; b) how the knowledge of the contents are transposed into a teaching methodology of science, suffering a didactic transposition; c) when applicable, how knowledge is implemented and consolidated in a new scientific paradigm.

Like any field of scientific knowledge, especially human, this is very dynamic and challenging. So that the TD-CHIM presented above should be considered within its scientific and pedagogical actuality. They are based on years of work by researchers like Chevallard, Izquierdo, Pietrocolla, Johnson-Laird, Nerssessian and others.

Although De Mello have achieved through the analysis of textbooks using as a tool conceptual mapping prove some of the ideas proposed here, there may be the need to include, replace or reformulate some of these. It follows, therefore, that the study of pedagogical facts using the TD-CHIM together with the methodology of science CMA is a consistent theory of knowledge.

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