DIFFERENT TEACHING MODELS AND RESPECTIVE KIND OF PROBLEMS AND PROBLEM SOLVING

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Abstract

Different teaching models were being adopted over time that must be classified in four types: the classic teaching by exposition (TBE); the teaching by discovery (TBD), whose version of inquiry teaching is still defended by many teachers; the teaching by conceptual change (TBCC); and the teaching by investigation (TBI). This communication has three objectives: (i) to characterize and discriminate these teaching models, based on epistemological, psychological and didactic aspects; (ii) to show, based on real examples, that the type of «problems» and the problem solving model adopted by teachers in the classrooms, included in the manuals, and adopted in exams, are consistent with the psychological and epistemological assumptions that underlie the different models of teaching; (iii) to describe, and illustrate, with an example, an investigative way of problem solving perfectly integrated in a teaching by investigation, so that it can contribute to meaningful learning, using the knowledge Vee created by D. Bob Gowin, and that is a graphic organizer based on the meaningful learning theory.

Keywords: teaching models; problem solving; meaningful learning; knowledge Vee.

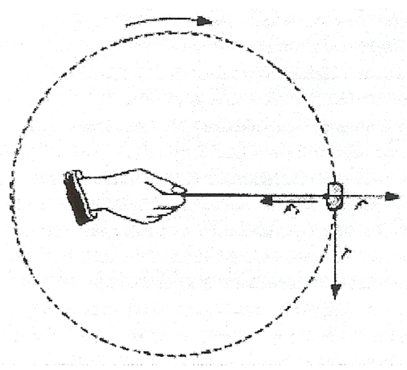
1 TEACHING BY EXPOSITION (TBE)

Until the 70s of last century (in my country) a typical secondary or high school teacher began each class usually dictating the topic of the program to teach, almost always written in the first pages of the adopted book (in Portugal it was adopted by Ministry of Education and was the same for all schools in the country). Then, during a third or more of class time one or more students were submitted to routine questions based on the topics of the previous lessons, and in the remaining time the teacher exposed the topic of the day. The oral exposition of the teacher almost always resulted in a monologue. The teacher had no concern about the understanding of students and if they retained in memory what he said, because what he said was practically the same as was written in the manual.

This teaching model was based on a positivist epistemology that arose with the important work of Auguste Comte, and on a strongly behaviorist educational psychology. Teaching was, and in many cases even today is, overly expositive, without any concern to ensure the cognitive readiness of students, submitted to long oral presentations of content by teachers.

Learning was, in this TBE, just retaining the exposed matter in long-term memory. Sometimes this matter was scientifically incorrect, some ideas were misconceptions, but as the teaching was deeply uncritical, the students memorized the errors and in exams reproduced them.

A real example: Figure 2 and respective inscription were reproduced with all the accuracy from a manual adopted as the unique book of Physics, for the 2nd cycle of Portuguese secondary schools, during the 50s and 60s. But in other consulted books before the 50s, the teaching approach of the subject was quite the same because the strategies were transmitted from authors to authors.



"**Força centrífuga** - À força *centrípeta, F'*, que solicita a pedra para o centro, opõe-se uma reacção, a força *centrífuga, F,* que tende a desviá-la do centro."

The *translation* in English of the inscription is this: "**Centrifugal force** – To the centripetal force F ', which draws the stone for the center, it is opposed a centrifugal reaction, which tends to deviate it from the center".

A simple analysis of the figure and respective inscription shows a scientifically incorrect physical model. The figure and the expression "tends to deviate it" (the stone) means that the centrifugal force is applied in the stone. It is not true. The centripetal force and centrifugal force cannot be both applied in the stone. Under the conditions set by the author, these forces would be balanced and the resultant would be the tangential force T, which by itself would never put the stone in a circular trajectory. The author mixes two descriptions of motion, one of them in an outer inertial reference frame and the other description in an accelerated reference frame attached to the stone. Even if the author considered the centrifugal force exerted on the rope and not in the stone (never wrote that in the inscription and in the main text), this impulsive force T used to explain the circular motion will only strengthen the students' misconception known as «the movement requires force».

Teaching was, in that time, the exposition of curricular subjects (sometimes incorrect), mainly in oral form, without any concern if students had cognitive readiness to understand those subjects.

Written tests (so called «written exercises») were almost totally directed to rote and memory learning, and not to detect and enhance meaningful learning. Two examples of questions:

1. Indicates the names of the ridges of mountains situated in the regions of Trás-os-Montes and Minho.
2. What do you mean by calorimeter? What is its use? Write the formula to apply in work with this instrument (this question was included in the Physics and Chemistry entrance examination to the Pharmacy University of Lisbon (Gazeta de Física, Vol. 1, Fasc. 1, 1946).

The first question was typical of the primary school in Portugal at least until the sixties in the last century. It was necessary memorize the mountains, the rivers, the effluents of rivers, the stations of railway lines that no longer exist, etc.). To answer to the second question was enough memorize the formula of the calorimeter without knowing the symbols meanings (one of them is the equivalent in water of the calorimeter)!

2 TEACHING BY DISCOVERY (TBD)

The teaching by discovery (TBD) has emerged as a response to the unsuccessful teaching by exposition in the USA, in consequence of a profound reform of science education undertaken in that country in the 60s, due to the Sputnik effect, so named for having as origin the launch, on 4 October 1957, of the first artificial Earth satellite by the Soviet Union. This teaching model is based on the idea that students learn best when they discover for themselves, more or less oriented by a teacher or a tutor, what they have to learn [1].The teacher should not expose concepts, it is supposed to be the student to disclose them, working with materials and applying a method known as *scientific method*. This teaching model is based on an empirical-inductive philosophy, which resulted in the nineteenth century positivism and the twentieth century neo-positivism, widely criticized by modern rationalists and the current constructivists. That old empirical-inductive philosophy supported the idea of the existence of this alleged *scientific method* that in physics and other sciences is often designated as *experimental method*. It is known that positive thinking is factualist and nominalist, and that only knowledge of the facts, the observable, the verifiable, is important. So this form of teaching overestimates the power of the experience by making it the source and guarantor of scientific truth. The phases of the «scientific method» were discriminated and applied one by one: **O**bservation, **H**ypothesis, **E**xperiment, **R**esults, **I**nterpretation and **C**onclusions. Therefore, such pseudo method was also known in the educational environment as OHERIC and was considered, by many science teachers, as the method par excellence to produce science [2]. There is not an unique method of constructing the science and nowadays it is defended a methodological pluralism.

The TBD led to the *inquiry-based learning*, whose main characteristics are these: it is of the type "*hands on and minds on*"; is centered on activities undertaken by the students; materials used are preferably simple and easy to obtain; students perform experiments based on questions, trying to answer them without aid; students take responsibility for learning; students are challenged to think; the teacher is advisor and mediator; wakes up the curiosity of students; assessment is included in the process as much as possible.

An example of a question used in the scope of this model:

1. You have in front of you some fruits and vegetables, a kitchen scale, a jar large enough to submerge the fruits and vegetables, a large pan and a measuring cup.

   Choose a product and write and fundament a hypothesis about its behavior when placed on the water.

   With the material you have at your disposition, design an experiment to sort the given products in order of increasing density.

   Performs the experiment and make a table with the products and respective densities.

As the focus of problem solving is in a process, it began to appear some problem solving methods to guide the resolution, assuming that there is an ideal method of problem solving. One of the more detailed comprised a series of stages, each of them with different subphases [3]: (i) analysis and description of the problem; (ii) development of a possible resolution; (iii) discussion of results and resolution. The first stage, analysis and description. of the problem, contains the following steps: a basic description, a theoretical description and an exploratory analysis. And each of these steps also contains sub steps, 3 for the basic description, 5 for the theoretical description and so on. All this do not serve for nothing if the student has not the cognitive readiness to resolve a problem, and if he has the cognitive readiness, is not necessary all this long method to the correct resolution of the problem.

3 TEACHING BY CONCEPTUAL CHANGE (TBCC)

The TBCC is based on the idea that the student is not a *'spirit tabula rasa'* of knowledge and, by contrast, is seen as an individual with previous ideas, their personal ways of representing the world. These are very important in the way the student sees the study objects and extract meaning from them, as discriminates, in a personal way, what has or not to have into account and how faces the knowledge. According to this model, the teacher should value the students' previous ideas, as is based on these they will grasp more or less the scientific knowledge required by teacher. Students gradually acquire skills and capacities to think better and transform information into meaningful knowledge. And so, they will go constructing and (re) constructing their knowledge. The students' previous constructions must be privileged, since are them that filter, choose, decode, as well as (re) draw the information that they receive from outside.

There is no consensus about the mind process of conceptual change, whether this change has a continuous or discontinuous character and about the best way to produce it. The modern sciences and technologies of cognition show that the learner's mind is complex and multifaceted; its components, intellectual, affective and active, combine to change the meaning of human experience. Therefore conceptual change must be seen as a set of processes and outcomes of these processes related to changes of the various contents of 'cognitive structure', not just only the cognitive contents, with a consequent reorganization of this structure.
The most influential model of conceptual change was developed in 1982 by Posner, Strike, Gertzog and Hewson. Based on the contemporary philosophy of science, namely relying on ideas of Kuhn, Lakatos, and Toulmin, this group attempted to substantiate the conceptual changes in learners' rational decisions [4],[5].

Experience has shown that this model did not produce the desired effects. Students' conceptual change is difficult and they drag on for a long time their preconceptions more or less spontaneous and connected to common sense and the language of day-to-day. Among the factors that underlie the non-extinction of students' previous conceptions, Duit [6] highlights the fact that these conceptions proved to be valid in many contexts of everyday life, defending the coexistence of these conceptions with the scientific ones, rather than attempting to replace them. This coexistence is natural and is based on the competition between the personal constructs and scientific constructs that the individuals (re) construct their own knowledge about the phenomena.

The meaningful learning theory, based on the ideas of the educational psychologist David Ausubel, helps us to understand why there is not the extinction of the old concepts in the cognitive structure and the appearance of other concept instead it. It is more correct to say that there is a conceptual enrichment in a student than to say that there is a conceptual change. Indeed, according to the meaningful learning theory, a new concept, while being assimilated, interacts with another previously existing in the cognitive structure – a *subsumer*, and the result of assimilation is an interactional resulting product compound not only of the new information, but also of the modified subsumer, as a consequence of the interaction between them. Schematically,

$$a + A \longrightarrow a'A'$$

where:

a – potentially meaningful new idea

A – subsumer (previously established idea)

a'A' – interactional product

(adapted of [7], [8])

With this teaching model, many questions and problems were designed to detect erroneous conceptions and conceptual difficulties, more than to assess the correct knowledge of the students. The following multiple-choice question is an example of a question integrated in this teaching model:

The diagram represents the numeric value of a velocity as a function of time.

What kind of motion has the particle?

A. rectilinear and uniform
B. curvilinear and uniform
C. uniform
D. not uniform but rectilinear

Many students chose the option A as they confused the line representing $v = f(t)$ with the trajectory.

4 TEACHING BY INVESTIGATION (TBI)

As TBCC, teaching by investigation is a constructivist teaching, because it also assumes that prior knowledge of a student on a particular subject is very important for the enrichment of that student on this subject. However, it attempts to go beyond the academic vision according to which the only purpose of science education is the assimilation of scientifically correct concepts. The major aim of this science education must be to prepare students to face up with the serious problems throughout their lives. To this end, it is necessary to educate students not only "in" science, but also "through" science and "on" science. For this reason, the domain of scientific contents, while important, is not an end in itself, is a means of preparing students for a social and human scientific education. The TBI seeks to be more ambitious than the TBCC and promote scientific education that prepares students to be harmoniously integrated in society. So it is a science teaching in a socially relevant environment, where the domain of scientific concepts is accompanied of the domain of scientific procedures, attitudes and values. It is intended to valorize students with regard to the practice of scientific processes, in view of the development of several key skills for life in society. By learning some of the fundamental skills that characterize scientific research, such as read thoughtfully, consult bibliography, observe, classify, measure and express measurement results, predict, describe, infer, argue, expose, clarify, analyze, formulate cognitive and value claims, they recognize the true scope of scientific work [9],[10]. It also seeks to develop the intellectual honesty and critical thinking in students and, therefore, it also familiarize them with scientific methodologies and the historical-humanistic facet of science, in view of the best way to deal with ideologies, controversies, debates, conjectures and refutations. It is a teaching in a CTSA perspective, in which science is taught based on problems in close connection to

Technology, Society and Environment, throw oriented investigations [11]. The openness of learning situations vary from those projects that are entirely unrestricted, in which the students analyze and problematize situations (like case studies, for example), until those that are focused on problems, objects and/or events as specified by the teacher. Anyway, the strategies will always be centered on students work as structuring elements of their own knowledge and of their skills development. And they can work more or less freely or more or less oriented by teachers. The scientific contents are seen as ways of thinking about the science, the world and the human beings. And if is important the so-called *substantive knowledge*, based on the understanding of concepts, principles, theories and science laws, it is equally important the *procedural knowledge*, the knowledge of the science processes, such as the gathering and processing of information, experimentation, interpretation of results and formulation of knowledge and value claims, as well as the *epistemological knowledge*, related to the epistemological nature of science and its relationship with society, and, not less important, the *knowledge into action* that is applied in day-to-day. It is also essential to develop the power to communicate, as well as the most varied scientific attitudes and values. In summary, with this investigative perspective of science teaching is intended that the student acquire the most varied cognitive-procedural, emotional and social skills, that respects human and social values, finally that learns as much as possible to contribute to a fairer and more humane world. This perspective TBI is very different from the perspective TBD, in which the student is placed in a situation of pseudo-scientist looking for (re) discover science by applying a so-called 'scientific method' linear and stereotyped, that does not exist [12]. They have a very different epistemological basis. While the perspective TBD is markedly empiricist, the teaching by research is constructivist, humanist and surpasses the major antitheses realism-idealism and empiricism-rationalism. It considers scientific knowledge as a not dogmatic body of knowledge, that does not grow up by accumulation, and where what is known at each moment is not necessarily untouchable. And also considers that knowledge is always under construction, without dogmatism and scepticism, based on scientific attitudes that matter cherish and inculcate in students for the good of society.

We said above that the great aim of TBI is to prepare students for the resolution of various problems that will confront lifelong. Therefore, this teaching advocates a *methodological pluralism* in which the use of a variety of teaching strategies and tools contribute to the enrichment of the multifaceted mind of every student in its various dimensions and allow the student to have access to multiple representations of the study object or event. This contributes to the enrichment of the knowledge of that object or event. We have currently many educational resources at our disposition, such as didactically prepared texts, worksheets, photographs and images, audio material, animations and videos, applets, graphical presentations and slides, spreadsheets and databases, e-books and other courseware materials, real or simulated practical activities, the use of history of science (preferably based on original texts) and the graphic organizers such as mind maps, concept maps, Vee diagrams, and so on, to improve the quality of learning by making it more meaningful. When the learning is highly meaningfully, the learner grasp the meaning of the subjects studied.

The last feature just mentioned, the use of graphic organizers is a way to transform, for example, a mechanical process of problem solving into a meaningful problem solving. I finish this work precisely with the presentation of an example to illustrate this fact. I will resort to a tool created by one of the great theorists of meaningful learning, Bob Gowin, called *Vee diagram*, *knowledge Vee* , *heuristic Vee* or *epistemological Vee*.

The Vee diagram has this name for its “V” shape. It is a graphic organizer based on the meaningful learning theory that provides a constructivist model for the developing of an experiment or study, ensuring a strong theoretical and conceptual basis and solid analysis. It is also a thorough way of structuring and representing knowledge about a subject. It is based on an epistemology that surpasses the great antitheses of philosophy of science, empiricism - rationalism, realism – idealism and scepticism – dogmatism. It has a central focus-question at the top that centralizes and focalizes the study. Along the left side are the presupposed ideas and the theoretical and conceptual necessary information, the «*subsumers*» necessary to assimilate the meaning along all process. At the point of the V is the object/event, all which is necessary to concretize the experiment or study. And along the right side are the methodological analysis and evaluation of the experiment in light of the focus question and the conceptual basis.

Let us go to show an example of problem solving based on the knowledge Vee.

The problem is on Physics (the basic study area of the author of this work) and intentionally classic:

“A projectile whose mass is 1,0 kg, thrown vertically upward from a place, returned to the same place 10 seconds after. Exactly 2,0 s after the first projection, a second projectile, with mass 0,5 kg, was also thrown vertically upward from the same place with an initial velocity 5,0 m/s higher than de initial velocity of the first.

Which of the two projectiles returns before and how long before? What are the maximum heights reached by the two projectiles? “

The problem, as a physical situation that is, is transformed in the objet/event block that is one of the components of the epistemological Vee, and the resolution is faced as an investigation where is necessary to respect the epistemology, the psychology and didactics subjacent to this graphic organizer based on the meaningful learning theory [13].

The figure of the next page is the Vee with the final aspect of a problem resolution, but when the problems or other researches are more complex, the Vee is only a synthesis that is followed by the necessary pages to develop all the resolution, with the epistemological blocks clearly exposed.

Many times the methodological component requires changes in the conceptual component and vice-versa. As a matter of fact, in this design all interferes with all. For example, the focus- question interferes with concepts, and many times is necessary to define previously the concepts involved in the question to understand it, because these concepts are not yet meaningfully learned. Other example: the meaning of data and the processing of data depend on the theory and concepts, because without concepts and theories is impossible to gather data, give meaning to them, process the data and extract conclusions and cognitive claims from them.

5 CONCLUSION

In this work were characterized different teaching models and exemplified the kind of problems and problem solving used by teachers following these models.

In the old *teaching by exposition* the teacher transmits knowledge to the students and these store them sequentially in the memory. The learning is quite mechanic. The student has a passive role. The teaching is centered almost exclusively in contents. The curriculum and mainly the manual determine the teacher action. The problems are rote and closed questions that students resolve more or less mechanically.

The *teaching by discovery* the emphasis is in a so called scientific method, inductive, linear and stereotyped. The objective is the students discover the scientific ideas by themselves starting from observable facts. It is much time consuming. The questions are many times centered in scientific processes or simple experiments and some problem solving methods presupposed that there is one only method of solving a problem.

The *teaching by conceptual change* aims to enrich the students' concepts and attaches great importance to students' prior conceptions. It was a consequence of the «movement of alternative conceptions» in which thousands of searches were made in many countries to detect erroneous conceptions of students in various scientific fields. The questions and problems began to focus largely on the detection of misconceptions and various conceptual difficulties of students.

Finally, the *teaching by investigation* aims that students construct the most varied concepts, skills, attitudes and values, is methodologically pluralistic, epistemologically constructivist surpassing the great antitheses empiricism-rationalism, realism-idealism and skepticism-dogmatism, and attempts to foster a transdisciplinary education based on the relationship between science, technology and society. It attaches great importance to metacognition and metacognitive tools based on the meaningful learning theory. The classroom situations and conceptual difficulties of students are exploited as opportunities for students to learn more meaningfully ant the problems are converted in research processes based on the epistemology above mentioned, giving the opportunity to students grasp the meanings of theories and concepts at the same time that are developing their scientific skills

Conceptualization

Theory

When a projectile is thrown vertically upward, its speed decreases at a rate 9,8 m/s in each second until to vanish at the highest point. Then, coming down, the speed will increase at the same rate. Since the distance is the same upward and downward and the rate of the speed change is the same, $t_{up} = t_{down}$, the projectile returns to the starting point with a velocity that is symmetrical of the departure velocity

Principles/laws

Law of velocities (in this case):

$$v_y = v_{0y} - gt$$

Law of positions (in this case):

$$y = v_{0y}t - \frac{1}{2}gt^2$$

Concepts

Vector-position is the vector $\vec{r}$ drawn from the origin (initial position in this case) to the location of the particle, in each instant. In this case is always vertical and upwards in the positive direction of y-axis.

Velocity is a vector that indicates the direction of the position change in each instant (tangent to the trajectory) and the rate of the position change: $\vec{v} = \frac{d\vec{r}}{dt}$. In this case, $v_y = \frac{dy}{dt}$.

Acceleration is a vector that indicates the direction of the velocity change in each instant (is the same of the resultant force) and the rate of the velocity change: $\vec{a} = \frac{d\vec{v}}{dt}$. In this case: $a_y = -g$

Focus – question

Which of two projectiles thrown vertically upward from the same place returns before and how long before, knowing the difference of initial times, the masses, the initial velocity of the first and the flight time of the second?

Methodology

Value claims

It is an ideal situation where it was considered negligible the air resistance, and only in this case the acceleration is the gravity acceleration and the mass is irrelevant. It was not taken into account the variation of the gravity acceleration with altitude

Cognitive claims

The projectile A reaches the ground 3,0 seconds before the projectile B. The maximum heights reached were 122,5 m and 148,8 m, respectively.

Processing of data:

Corpo A:

$v_y = v_{0y} - gt \Rightarrow$

$-v_0 = v_0 - g.t_{voo} \Rightarrow v_0 = g/2.t_{voo} =$
= 49,0 m/s

$y = v_{0y}t - \frac{1}{2}gt^2$ e t_{subida} = 5 s $\Rightarrow$

h_{max} = 49,0 m/s . 5,0 s –
- 4,9 m/s^2.(5,0 s)^2 = 122,5 m.

Corpo B:

v_0=49,0 m/s + 5,0 m/s =
= 54,0 m/s.

$-v_0 = v_0 - g.t_{voo} \Rightarrow t_{voo} = 2.v_0/g$

$\Rightarrow tvoo$ = 11,0 s.

$t_{chegada}$ = 11,0 s + 2,0 s = 13,0 s

Δt = 13,0 s – 10,0 s = 3,0 s

h_{max} = 54,0 m/s . 5,5 s –
- 4,9 m/s^2.(5,5 s)^2 = 148,8 m.

Data

Masses: m_A =1,0 kg; m_B = 0,5 kg
These data are irrelevant (see value claims).
Acceleration of gravity: g = 9,8 m.s^{-2}
Flight time de A = 10 s.
Initial velocity of B = v_{0A} + 5,0 m/s.
Initial time of A: 0 s.
Intial time of B: 2,0 s

Events/Objects

A projectile whose mass is 1,0 kg, thrown vertically upward from a place, returned to the same place 10 seconds after. Exactly 2,0 s after the first projection, a second projectile, with mass 0,5 kg, was also thrown vertically upward from the same place with an initial velocity 5,0 m/s higher than de initial velocity of the first.

Which of the two projectiles returns before and how long before? What are the maximum heights reached by the two projectiles?

REFERENCES

[1] Mellado, V. & Carracedo, D. (1993). Contribuciones de la filosofía de la ciencia a la didáctica de las ciencias. *Enseñanza de las Ciências*, 11(3), 331-339

[2] Cervo, A. & Bervian, P. (1977). *Metodologia Científica*. Lisboa: Editora Mc Graw-Hill.

[3] Valadares, J. & Costa Pereira, D. (1991). Didática da Física e da Química, Vol.1. Lisboa: Ed. Universidade Aberta, pp. 196-208

[4] Santos, M.E. (1991) *Mudança Conceptual na Sala de Aula - Um desafio pedagógico*. Lisboa: Livros Horizonte, p. 186

[5] Duit, R. & Treagust, D. (1998). Learning in science: from behaviourism towards social constructivism and beyond. In B.Fraser & K. Tobin (Eds), *International Handbook of Science Education*. Boston, Kluwer Academic Publisher

[6] Duit, R. (1995). The Constructivist View: A Fashionable and Fruitful Paradigm for Science Education Research and Practice. In L. P.Steffe & J. Gale (Eds.), *Constructivism in Education*. Hillsdale, New Jersey: Lawrence Erlbaum.

[7] Moreira, M. (1994). Cambio conceptual: critica a modelos actuales y una propuesta a la luz de la teoría del aprendizaje significativo. Trabajo presentado en el *II Simposio sobre Investigación en Educación en Física*, Argentina

[8] Moreira, M. & Greca, I. (2003). *Cambio conceptual: análisis crítico y propuestas a la luz de la teoría del aprendizaje significativo*. Ciência e Educação. São Paulo. 9(2), pp. 301-315

[9] Cachapuz, A., Praia, J., Paixão, F. & Martins, I. (2000). Uma Visão sobre o Ensino das Ciências no pós Mudança Conceptual. In *Inovação*, 13(2-3), 117-137

[10] Cachapuz, A., Praia, J. & Jorge, M. (2002). Ciência, Educação em Ciência e Ensino das Ciências. In *Temas de Investigação*. Lisboa. Ministério da Educação

[11] Furió, C. (2001). La enseñanza-aprendizaje de las ciencias como investigación: un modelo emergente. In J. Guisasola J. & L. Pérez de Eulate (Eds.), *Investigaciones en Didáctica de las Ciencias experimentales basadas en el modelo de enseñanza-aprendizaje como investigación orientada*. Bilbao: Servicio Editorial de la Universidad del País Vasco

[12] Trowbridge L.; Bybee, R. (1990). *Becoming a Secondary School Science Teacher*. Fifth Edition. New York: Macmillan Publishing Company, pp.207-216

[13] Valadares, J. & Moreira, M. (2009). A Teoria da Aprendizagem Significativa – Fundamentação e Implementação. Coimbra: Ed. Almedina