# Use of metacognitive graphic organizers in an investigative teaching facilitator of science meaningful learning

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## Abstract

Investigative learning is the latest of several teaching models that were emerging in education since the beginning of the last century. These several models are different and each one of them tried to remedy the deficiencies of the prior one, based on different epistemological, psychological and educational foundations. In the first part of this communication will be characterized, in a manner as synthetically as possible without breaking of clarity, the current investigative teaching, by comparison with the models that preceded it .One of the features of the investigative teaching is to use a methodological pluralism with the use of several strategies for teaching the same scientific subject, so as to allow a student to acquire multiple representations of the same scientific object or event. The second part of this communication will focus on the use of one of many possible strategies to facilitate the meaningful learning in the investigative teaching. It is the use of two cognitive and metacognitive graphic organizers, in an investigative perspective and in a constructivist environment that will be characterized. Those tools are the knowledge Vee, of Gowin, and the concept map, of Novak [1], [2], [3] e [4]. The theoretical reflection performed on the investigative teaching, meaningful learning and the proper use of these two instruments will be illustrated with examples.

Keywords: teaching models; investigative teaching; meaningful learning; metacognition; knowledge Vee, of Gowin; concept map, of Novak.

## 1. DIFFERENT TEACHING MODELS

Although in the late nineteenth century, with Herbart, and early last century, there has been an effort by supporters of the so-called New Schools for the substitution of the classic expository teaching by an active learning where the learners are considered the structuring elements of their learning, the builders of all their knowledge, teaching that was more applied and continues to be applied in many classrooms is the teaching by transmission.

### 1.1. Teaching by transmition

In the classroom teaching by transmission the teacher exposes program subjects often orally, through more or less long speeches, and expect that they are sensory received and assimilated exactly how he explained them. Someone called this model the curious name of tube model, because it is as if the programmatic contents are something that can be passed through an invisible tube from the teacher head to the student head. It is a necessary but not sufficient condition for the student learn meaningfully, that is with attention and has the cognitive readiness needed to understand the ideas that the teacher transmits. But the teacher often does not take into account this fundamental condition.

From the *epistemological point of view*, this teaching is based on a positivist view of knowledge, in general quite dogmatic, in which learning is considered the accumulating of facts linearly absorbed, often stray to the student.

From a *psychological standpoint*, this teaching is based almost always on a behaviorist view of the student. This is considered a cognitively passive individual, whose role is to receive, store and reproduce information in the form of responses to stimuli produced by the teacher, followed by reinforcements, including the notes. The student is an authentic spirit 'tabula rasa' of knowledge.

The *teaching* is often based on long oral explanations, with greater or lesser use of the blackboard, the overhead projector or slides. Students are separated and without any or with insufficient cooperative work in class. The evaluation is eminently summative and normative. Therefore, its main purpose is the comparison of each student achievement with the average achievement of a group of students, whether these be in the same class or in the same year of the evaluated student, exclusively with purposes of classification and serialization.

## 1.2. Teaching by discovery

Teaching by discovery emerged in the 60s and 70s as a response to the failure of teaching by transmission. Based on the idea that students learn best when they discover by themselves, more or less suported on the teacher, what they need to learn [5]. The teacher should not expose knowledge, it is the student who has to find the knowledge working with the materials and applying what is known as «scientific method».

The *epistemological basis* of this teaching is the empirical-inductivist philosophy of Francis Bacon, which resulted in the nineteenth century positivism and, later, in the neo-positivism of the twentieth century. These were the philosophies that supported the idea of the existence of this alleged scientific method, which in the experimental sciences is often known by experimental method.

*Psychologically,* this teaching is also predominantly behaviorist but, unlike the previous model, gives much value to the students' activities as a structuring element of their knowledge. But fails in taking into account the cognitive view of student cognitive structure as an important factor of meaningful learning. Students often end by discovering for themselves factual knowledge, some regularities or empirical laws, but without grasping the deep meaning of what we found. Also fails as do not recognize the importance that the contents have in the production of knowledge, because the "conceptual field" where occur the learning is now considered very important [6] because it contains the situations, problems, contents and relationships that support the conceptualization and of the meanings. It is in each conceptual field that are focalized the subsumers as " specifically relevant contents of the learner cognitive structure" [7]. And the subsumers, which are currently viewed from a perspective not only intellectual, play a key role in meaningful learning.

But this teaching still fails when do not take into account that learning is a personal and idiosyncratic process that is different from teaching, a social process in which the teacher is responsible by the way how confronts the student with the knowledge to learn. Learning can be more or less meaningful, teaching can be more or less by reception or by discovery, but whether by one or other of these ways, learning can be more or less meaningful.

The *teaching* is based on the alleged use of the scientific method as a kind of recipe for science. The steps of the method are discriminated and applied one by one. Someone called this teaching method the OHERIC (Observation, Hypothesis, Experiment, Results, Interpretation and Conclusion). It was considered the scientific method par excellence [8]. The proponents of the discovery learning consider students as inquirers about what is happening around them and this is the reason why this teaching is sometimes included in the "inquiry teaching" that began to be defended in America, in 1962, by Schwab. It is a teaching that in most cases is too much time consuming for so little meaningful learning.

## 1.3. Teaching for conceptual change

Unlike the previous models, in the teaching for conceptual change a student is no longer considered a 'tabula rasa ' of knowledge. It is seen as an individual with previous ideas, personal constructs that are their ways of representing the world and are very important in the way he/she thinks and manipulates the objects of study, as well as influence the personal mode as discriminates aspects that are taken or not in consideration when studying.

The teacher should value the students' previous ideas because they filter, choose, decode, as well as (re) elaborate the information that the subject receives [9]. It is based on them that students are building and rebuilding their knowledge, transforming the information into personal knowledge and gradually reaching, more or less, the scientific knowledge intended by the teacher.

There are authors who see the change of conceptions in an almost strictly cognitive perspective. The designation 'cognitive structure' of the learner may lead to think in that way. However, the current research about the cognition shows that is impossible to dissociate the cognitive component of the mind from its affective sphere and from its social sphere life of each human being

Still there are discussions whether new ideas are in continuity or more or less in rupture with the earlier ideas.

We, who defend the meaningful learning theory with roots in Ausubel, advocate a progressive vision of the conceptual change. As a matter of fact, we prefer to use the term «conceptual enrichment» rather than «conceptual change». We believe that in the meaningful assimilation, the subsumer A integrates the new knowledge a, resulting a cognitive product A'a ':

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

The subsumer is not quenched, it is enriched by virtue of the assimilation of new information. Namely: the prior knowledge is modified, enriched, but is not replaced by another. We are able to distinguish the old knowledge from the new one, that is, we dissociate them in the form A ' + a' and not as A + a, because the psychological meaning (in the cognitive structure) of the new knowledge is personal and not necessarily equal to the logical-scientific meaning.

The most influential model of conceptual change was developed in 1982 by a group of authors, educators and philosophers of science, Posner, Strike and Gertzog and Hewson. According to this model, the four fundamental conditions for a conceptual change to occur in an individual are the following ones [10]: (i) there must be a dissatisfaction with existing conceptions; (ii) a new conception must be intelligible; (iii) a new conception must appear initially plausible; (iv) and should allow not only create problems generated by previous conceptions, but also have the potential to extend them to other areas in order to broaden the scope of research on the individual. These authors believed that is possible the replacing of the students erroneous conceptions by new scientifically correct conceptions.

In 1997, Monk and Osborne presented another model based on eliciting students' ideas and their predictions or hypotheses about how the phenomena under study based on their predictions are developed. They also advocated the use of historical sources to help students change conceptually.

Syntheticaly, we can translate their model into the following phases: (i) presentation of the phenomenon under study; (ii) elicitation of the students' ideas and formulation of predictions or hypotheses about how the phenomenon will be unfolded; (iii) recourse to the history of science; (iv) planning of experimental checks (with or without using a computer); (v) introduction of scientifically correct ideas and verification of its operation, revision and evaluation

e formulação de *previsões* ou *hipóteses* acerca do modo como o fenómeno se vai desenrolar; (iii) *recurso à história da ciência*; (iv) planeamento de *verificações experimentais* (com ou sem recurso ao computador); (v) *introdução das ideias cientificamente corretas* e verificação do seu *funcionamento*, *revisão* e *avaliação* [11].

## 1.4. Investigative teaching

Learning is now considered much more than a conceptual change. It is a change of culture, from the everyday culture for the much more rigorous, scientific culture, with all that this change means: not only a change of concepts, but also a change of various interdependent components: the axiological, the methodological, the epistemological and the ontological [12]

The current investigative teaching has present this holistic view of learning and its goal is to help students to learn, not an academic science, without its cultural and social facet, but a science historically seen in an externalist perspective, stuffed with ideologies, values, social upheavals, controversies, debates, conjectures and refutations, a science that must be seen in close connection with Technology, Society and Environment - CTSA perspective, preparing students for the resolution of various problems that will have to face throughout life.

Teaching for conceptual change, despite positive aspects that the investigative teaching retains, as, for example, the importance assigned to each student's cognitive structure, in addition to the fact of not correspond to the expectations that generated, is far from giving an authentic vision of science and instill in students a scientific culture that will prepare them adequately for life in society.

From the *epistemological point of view*, we advocate a constructivist teaching not radical, that is, we believe in the value of scientific representations of reality and we are not skeptical about the validity of these representations.

It is investigative, but without being based on an empiricist or rationalist view of knowledge production, but overcoming these two antithetical visions.

Its psychological basis is not behaviorist, it is cognitivist, but sees the cognition in the perspective proportionated by the cognition sciences, that is: thoughts, feelings and actions are combined in human cognition.

The didactic of the investigative teaching is centered in the problems solving with interest that go beyond the academic area, as much as possible related to the experience of day-to-day. It relies on a guide program of activities, based on the following ideas [12]: i) students should be involved in the definition of the overall objectives to be achieved; (ii) the teacher should take into account the conceptions, the worldview, the skills and attitudes of students and go as far as possible, to meet their study interests; (iii) the activities should be interesting to students, relevant to the aims and objectives and be in line with their capabilities; (iv) the scheduled activities should focus on problematic situations framed in the CTSA perspective and be felt by students and teachers as real and important activities.

Unlike the learning by discovery in which the student was placed in a situation of pseudo-scientist looking for (re) discover science by applying a linear and stereotypical 'scientific method' that does not exist [13], this teaching uses, whenever possible, a methodological pluralism where several strategies and resources are adopted for learning the same topic, so that students can acquire multiple representations of the same object or event.

Students, sometimes individually, sometimes in small groups, sometimes in the class group, are engaged in a work of reflection and action, mediated by the teacher, which helps them to familiarize themselves as much as possible with scientific work, to recognize the true scope of scientific literature, to learn some of the fundamental skills that characterize scientific research (read reflectively, consult bibliography, observe, classify, measure and express measurement results, predict, describe, infer, argue, explain, clarify, analyze, judge, refuting the grounds, etc.), in short, to develop many different skills that are fundamental to their social life.

This teaching implies a *new vision of the evaluation*, more formative and proactive than the traditional assessment, fully integrated in the teaching process. To do this, the teacher should seek to develop in students the ability to monitor their own learning process and the whole class running. To do this, they may share with individual students or groups some guidelines that describe the criteria that will be used to assess their achievement.

The student learning may involve greater or lesser demand and organization of information, the use of various Internet resources, classical or digital libraries, interactive museums, individual and cooperative work based on materials with scientific and didactic quality adopted or prepared by the teacher, commented individual readings, real and/or simulated experimental activities, experimental demonstrations, simulations and modulations accompanied by a debate moderate debate by the teacher based on questions, construction and negotiation of progressive conceptual maps of Novak, Vee diagrams of Gowin and other metacognitive graphic organizers discussed in groups or in all the class-group, projections of videos followed by discussions or responses to questionnaires, several field works, visits to museums and factories conveniently prepared, participation in debates and conferences that are justified and are enriching, etc.

## 2. ONE OF THE MANY POSSIBLE METHODOLOGIES: A COGNITON AND THE METACOGNITION BASED IN GRAPHIC ORGANIZERS THAT FACILITATE THE MEANINGFUL LEARNING

### 2.1. The Vee of knowledge as a metacognitive tool and its foundation

Graphic organizers are used for educational purposes for several years. Thus, there are organizers of cause-effect, comparison-contrast, problem-solution, of chronological order, etc. [14]. As traditional examples we can mention the vector diagrams and flowcharts. A vector diagram in Physics can clarify, for instance, how to determine the resulting forces and the resulting displacement of a boat in a river. A flowchart can translate, for example, the chronological sequence of instructions in a computer program.

Underlying graphic organizers are certain theories. In the case of vector diagrams, for example, the theory is the vector calculus. The same happens with the organizer of the problem-solution type that will be referred below that is based on the meaningful learning theory: it is the Vee of knowledge or Vee of Gowin, which, by its nature and potential is also called epistemological Vee or heuristic Vee.

It is one of the graphic organizers that fit perfectly in the meaningful learning theory and that, according to Trowbridge and Wandersee [15] are graphical tools of metacognition and metalearning that help the teacher to play his significant role in facilitating student learning. Its iconic features and all the interactivity and sharing of ideas that provide, helps motivate students. And when the motivation grows, following the enrichment of their ideas and the success they will have, they are increasingly psychologically predisposed to learn meaningfully by active reception or discovery more or less guided.

The Vee of Gowin is therefore a powerful metacognitive tool that helps students to reflect on the construction of knowledge. It is very suitable to investigative teaching and, when well used, facilitates the meaningful learning of science

Quite as well to build correct diagrams of vectors is essential to know minimally vector calculus, also for exploring the Vee of Gowin (and also the concept maps of Novak) is important to know the theory of meaningful learning started with David Ausubel in the 60s and later worked for a community of researchers and teachers.
Without devaluing the role that the memorization and the reinforcement through practice have in the learning, it is essential that students associate new ideas to the ones that already have in their cognitive structures, because only then attach correct meaning to what they learn, so learning in a manner meaningful and scientifically correct.
The theory of meaningful learning, like all good theories, has some solid underlying principles, some definitions and a good epistemology. A principle that Ausubel established in a manner clear and consistent was the following: the single and most important factor of which depends on the learning of a student is what he already knows, that is, what is incorporated into the personal cognitive structure.
*Meaningful learning*, whether scientifically correct or incorrect, is a process by which new information is related, in a substantive and not arbitrarily manner, with specific concepts pre-existing in the cognitive structure of the learner (the so called subsumers). If, for example, a student does not substantially assimilated the concepts of linear momentum, time, and the derivative is substantially incapable of assimilating the concept of force acting on a particle because it is just the derivative of the linear momentum of the particle with respect to time.
The essential characteristics of meaningful learning are the substantivity and not arbitrariness, opposing the superficiality and mere literalness characteristics of mechanical or routine learning of facts, names, symbols or statements. Many of the human being ideas, learned intuitively, spontaneously, uncritically, and incorrectly in early stages of the cognitive development, were learned meaningfully, constituting often blockages to the scientifically correct learning. Some examples are the energy as substance, the heat as something contained in a body, cold as something that comes through the doors, confusion between force and speed, etc. All these ideas are scientifically unacceptable, but were learned meaningfully, based on the deceiving senses and the language of everyday, itself a form of expression but also of thinking. But it will be through a meaningful learning that the erroneous meanings of human being about the world will be increasingly enriched, the way to the exact and correct meanings, of the scientific point of view.
The students learning will be as more meaningful, no matter how they are confronted with what they will learn, as more the following conditions are met: (i) the matter to be learned must be potentially meaningful (anyone can learn meaningfully illogical , incoherent subjects); (ii) have adequate subsumers to what want to learn; (iii) and the methodology used and the willingness of the student to join so he strives psychologically in the relationship of new ideas to subsumers already grasped in the cognitive structure.
Meaningful learning systematically combines two mechanisms: a *progressive differentiation* of more general and broad concepts, which will be branched and specified progressively; and *integrative reconciliation* of concepts already sufficiently differentiated and specified to yield more general concepts. To this end, it is necessary to develop the effort to deepen ideas, to look for similarities and differences between ideas, to related subordinate ideas, to reconciliate apparent inconsistencies between ideas, to search superordinate ideas. The adequate content organization and the consolidation of the concepts are very important, which relies heavily on the curriculum and teaching strategies used [16].
The classroom environment is important and it should be based on dialogue and discussion and sharing of ideas among students mediated by the teacher. The more or less meaningful learning of science in the classroom involves cognitive but also affective relationships. The emphasis must be on the active and meaningful construction of knowledge, rather than its passive internalization and reproduction of memory.
The constant critical reflection of students during their activities should be encouraged by the teacher. It should be promoted collaborative knowledge builded through the negotiation of ideas without prejudice to the individual reflection that every student has to do, because students have rhythms and different learning styles.
The assessment should be as formative as possible. It should be directed not only to regulate the learning of each student by the teacher, but also for the personal, self-assessment and self-reflection of learning. Questions, short quizzes, reports, etc. should be frequent, because the evaluation moments are always great moments of learning by providing feedback to students

## 2.2. O uso do Vê do conhecimento numa perspetiva investigativa como facilitador da aprendizagem significativa

The meaningful learning theory is based on a trivial and humanist constructivist epistemology that assumes towards the essence, the origin and validity of knowledge a position not too idealistic or naive realist or clearly empiricist or manifestly rationalist nor too skeptical nor dogmatic [17] [18].

The Vee created by Gowin has this same epistemological position. It is important that science teachers have an adequate epistemological position in the classroom, because it will influence the science learning of their students, in its various facets, including the image that they have about the nature of scientific knowledge. The Vee diagram can help teachers to adopt a proper epistemological position and carry out an investigative teaching. This diagram is a research instrument in which the research is seen as a way to generate structures of meaning, passing essentially by the intimate connection between concepts, facts and events.

> The search process can be seen as a structure of meanings. The elements of this structure are events, facts and concepts. What research does, through its actions, is to establish specific connections between a given event, the records of the event, the factual claims derived from such records, the concepts that focus regularities in events and the conceptual systems used to interpret these claims in order to reach the explanation of the event. Create this structure of meaning in a certain investigation is have done a coherent research [19].

Today we know that the *concepts*, that translate regularities, cannot be dissociated from conceptual fields where they are inserted. The conceptual systems are sets of concepts that are logically related to each other, allowing the general pattern of reasoning about a particular conceptual field. *Theories* are descriptive conceptual systems, more or less comprehensive and interpretative, based on principles of affirmative and axiomatic character. The *facts* may have three different meanings that are related to each other. Thus, the fact corresponding to an event that occurs naturally or is made occur by a researcher, may mean the event itself, the event record, which is critical to research on it, or can mean the set of verbal or mathematical claims, based on the event record.

The core part of the research process arises when one gives the connection between the event/object under study, the conceptual framework that dominates the research and the facts gathered from the event/ object. The importance of this connection led Gowin to the idea of the Vee format of his graphic organizer. This format shows immediately the *inseparability of theory and practice* as well as the importance of the *study system* and the *problematization* that is made about the same. Thus, the vertex of the Vee points to the *events / objects* where is focused the construction of knowledge. It's about them all the reflection and / or research and without them there would be no data to process. But early, at the beginning of the process, and in a central position in relation to the sides, is the *focus-question* that translates the research problem and determines the choice of objects / events, whether natural or artifacts. The research about the objects and events both have to do with the left side how the right side of the Vee.

On the *left side* are the epistemological blocks that constitute the *conceptual component* of the research process. It contains the *concepts* and *conceptual systems*, fundamental for the research. It is based on them that is possible to assign meaning to what is observed, render meaningful data collected, the data processing, achieved results and cognitive and value claims. Such conceptual systems consist of theories, which have inherent principles and laws, which, in turn, give rise to theories, but also have certain underlying value systems, worldviews and philosophies. This left side corresponds to the thinking field of the research.

The *right side* of the Vee has to do with the facts in the triple sense that Gowin assigns them: events such as are observed by the researcher, records made and the cognitive and value claims formulated. It refers to the *factual component* of the research, designated by *methodological component*, to include beyond the facts all the methodology that is followed in the production of knowledge. The *data* gathered from the events are *methodologically transformed* in reach *conclusions* that are the basis for formulating *knowledge* claims that constitute the knowledge produced in response to the question or questions investigated. In turn, all the epistemological blocks of the Vee, mainly the knowledge claims, are the basis to formulate value claims, that have to do with the value and applicability of the knowledge produced, the detection of the strong and weak parts, the errors and uncertainties in the research, the degree of confidence in the results, and so on. This *left side* corresponds to the *field of doing*.

It is essential to bear in mind the *constructivist nature* of the process based on the epistemological Vee, in which all the blocks interact with each other.

The Vee diagram design respects the way it was being constructed scientific knowledge.

The *investigative teaching* is based on a spatial kind of *problem solving*. The word «problem» in this context means a question that has something new on matters other questions already resolved by the students and, therefore, require the 'transfer' of what they have learned to new situations for them. Therefore it is not a routine question.

The Vee of knowledge, created by D. B. Gowin, allows that a given problem can be converted into a research activity in which students are engaged in order to learn meaningfully with that problem, as first showed my Physics Colleague Prof. Ricardo Chrobak.

Adapting the idea of this Colleague, we can transform a problem on a research activity and even introduce irrelevant data to make the students disentangle relevant data from irrelevant data.

Is, for example, the following problem:

> Two projectiles of masses 1.0 kg and 0.5 kg, were launched successively and vertically from the ground in a place by the sea and at the approximate latitude of 45º with a time interval of 2.0 s. Knowing that the first remained in the air 10 seconds and the second projectile was launched with an initial velocity that exceeded the first at 5.0 m / s, which of the two first returned to the soil and how long before the other? And what were the maximum heights reached by the projectiles?

Students should begin by interpreting the problem and start the construction of the Vee by the events under study and by the focus questions. Then must reveal whether they have the necessary subsumers to solve the problem in a meaningful way and learn meaningfully with it. For that, they must fill in the epistemological blocks of the theory, principles, laws and concepts, all well-defined and explained. Existing important and irrelevant data, they will have to register on the appropriate block only the important data. And all calculations and the reasoning should be included in the block designated to transformation/analysis of the data, before the formulation of cognitive claims as responses to the problem and the value claims which here take the form of considerations about the nature of the problem and its largest or less adaptation to reality.

On the last page of this work it is possible to see an example of a knowledge Vee adapted to this problem that can serve as a reference.

## *REFERENCES*


[1] Novak, J. & Gowin, D. (1991). *Learning how to Learn*. Cambridge: Cambridge University Press

[2] Gowin, D. (1990). *Educating*, 2nd ed. Ithaca, N.I.: Cornell University Press

[3] Gowin, D. & Alvarez,M. (2005). The Art of Educating with V Diagrams. Cambridge: Cambridge University Press

[4] Novak, J.D. (2010). *Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations* (2nd Ed.) NY: Routledge

[5] Mellado, V.; Carracedo, D. (1993). Contribuciones de la filosofia de la ciencia a la didáctica de las *ciencias*. *Enseñanza de las Ciencias*, 11(3), p. 331-339.

[6] Vergnaud,G. (1993). Teoria dos campos conceituais. In Nasser, L. (Editor). *Anais do 1º Seminário Internacional de Educação Matemática do Rio de Janeiro*, p. 1-26.

[7] Ausubel, D. (2003). *Aquisição e Retenção de Conhecimentos: Uma Perspectiva Cognitiva*. Lisboa: Plátano Edições Técnicas, p. 71.

[8] Cervo, A.; Bervian, P. (1977). *Metodologia Científica*. Lisboa: Editora Mc Graw-Hill, p. 20-35.

[9] Cachapuz, A. ; Praia, J.; Jorge, M. (2002). Ciência, Educação em Ciência e Ensino das Ciências. *Temas de Investigação*. Lisboa. Ministério da Educação, p. 153).

[10] Posner, G., Strike, K., Hewson, P., Gertzog, W. (1982). Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. *Science Education*, 66(2), p. 211-227

[11] Monk, M.; Osborne, J. (1997). Placing the history and philosophy of science on the curriculum: a model for the development of pedagogy. *Science Education*, 81, p. 405 - 424.

[12] Furió, C. (2001). La ensenanza-aprendizaje de las ciencias como investigacion: un modelo emergente. In Guisasola J.; Pérez de Eulate L. (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, p. 26).

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

[14] Mintzes, J.; Wandersee, J.; Novak, J. (2000). *Ensinando ciência para a compreensão*. Lisboa: Plátano Edições Técnicas, Colecção Plátano Universitária, p.103.

[15] Trowbridge, J. e Wandersee, J. (2000). Organizadores gráficos guiados pela teoria. In Mintzes, J. et al. (ed.) *Ensinando ciência para a compreensão – uma visão construtivista*. Lisboa: Plátano Edições Técnicas, p. 100-104; p. 116-125.

[16] Ausubel, D. (2003). *Aquisição e Retenção de Conhecimentos: Uma Perspectiva Cognitiva*. Lisboa: Plátano Edições Técnicas, p. 166-173.

[17] Valadares, J. (2007). *Didáctica da Física*. Lisboa: Universidade Aberta

[18] Valadares, J. & Moreira, M. (2009). *A Teoria da Aprendizagem Significativa: Sua Fundamentação e Implementação*. Coimbra: Almedina

[19] Gowin, D. (1970). The Structure of Knowledge, *Educational Theory*, 20(4), p. 319-328

**Focus – question**

When two projectiles, A and B, are separately launched from the same point on the soil, which of them returns first to the ground and how long before? What are the maximum heights reached by the projectiles?

## Conceptualization

### Theory

When a projectile is launched vertically upward, its speed decreases at the rate of 9.8 m / s every second to vanish at the highest point. Then, coming down, its speed increases at the same rate until the soil. As the distance is the same, upwards and downwards, and the rate of change of velocity does not change, $t_{down} = t_{up}$, returns to the starting point with a symmetrical velocity of that with which he departed

### 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

- *Position-vector* $\vec{r}$ - vector with the direction from the initial position to the position of the particle at each time. In this case is always directed vertically upward in the positive direction of the y-axis.
- *Velocity* – vector that indicates the direction of the instantaneous displacement of a body, and at what rate its position is changing: $\vec{v} = \frac{d\vec{r}}{dt}$ .

In this case only has the component $v_y = \frac{dy}{dt}$ .

- *Acceleration* – vector that indicates that indicates how varies the velocity and the rate of this variation, $\vec{a} = \frac{d\vec{v}}{dt}$ .

In this case the acceleration is due to gravity and is always $a_y = -g$ .

## Methodology

### Value claims

This is one resolution in an ideal situation in which the air resistance is considered negligible, because only in this case the acceleration is equal to the acceleration due to gravity. Also was not taken into account the variation of the acceleration due to gravity with altitude

### Cognitive claims

The projectile A reaches the ground 3.0 seconds before the projectile B. The maximum heights reached were 122.5 meters and 148,8 meters, respectively

**Transformations**:

*Body 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.

*Body 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

$\Delta t$ = 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 considered irrelevant (see value claims)

*Acceleration due to gravity:* $g$ = 9,8 m.s$^{-2}$

*Flight time of* A = 10 s.

*Lauching velocity of* B =
= $v_{0A}$ + 5,0 m/s.

*Launch time of* A: 0 s.

*Launch time of* B: 2,0 s

## Event/Objects

Ascension and fall of two different bodies.
A projectile is launched vertically upward from the ground and fall at the same place
Sometime after the first launch, occur a second launch of the same place.