METACOGNITION AND DIDACTIC TOOLS IN HIGHER EDUCATION

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ABSTRACT

Most of the publications related to teaching in all educational levels show that the use of instructional models is just scarcely able to attain the desired objectives. To improve this situation, many attempts have been made with only parcially successful results.

This work attempts to analyze the possible contributions of metacognition and to start the path towards the elaboration of a scientific instructional model based on theories on human learning and their applications to the classroom experience. A number of metacognitive tools which draw on human learning theories have been developed; however, the effective use of these tools is not still totally understood by most educators.

Our objective is to gather valid arguments that confirm the benefits of the use of metacognitive tools (e.g. concept maps and the Gowin´s VEE) for the achievement of the students´ meaningful learning.

The **event** to be studied is to develop a scientific theory of the education i.e.:

"A teacher, teaching meaningful materials to a student that grasps the meaning of the materials under humane conditions of social control" (Gowin, D. B., " Educating ", 1981)

INTRODUCTION: METACOGNITION, WHY?

It is known that students are not aware of the importance of reflecting on their own knowledge construction and the way learning occurs. Generally, they ignore also the epistemological factors that take part in the formation and development of the students' cognitive structures. These factors are of great value if we want the students to change their scientific conceptions from spontaneous or alternative ones. For this to happen, we believe it is necessary to consider learning how to learn tools and techniques as part of the process.

There are many reasons that justify the use of these tools. We can mention Dr. Richard Feynman's description, (Physics Nobel Prize, 1965) that perfectly illustrates the fact we want to point out: a student who was about to finish his studies about Greece is asked in an exam: What did Socrates think about the relationships between Truth and Beauty? The student remained literally silent. Nevertheless, when he was asked: What did Socrates say to Plato in the Third Symposium? he began to speak without interruptions remembering in a perfectly marked Greek, everything Socrates said in the Third Symposium. But, in the Third Symposium, Socrates spoke about the relationship between Truth and Beauty!

This example clearly shows that rote learning can be really narrow, or, in other words, what may happen when students are not guided to find the necessary rules to understand the topic they are studying, and exercise the form of transferring their learning results. It is evident that they have no idea of the importance of achieving meaningful learning (Ausubel, 1968).

It is very common to observe in classrooms, that students learn a language with the help of pronouncing letters, then, words, sentences and

finally, paragraphs. Thus, they are able to recite complete texts without hesitating, but also, without meditating on the meaning of the words. Students must understand that letters are not only symbols used to emit special sounds. What teachers have to do is to explain the meaning of the words in such a way that students can understand the concept they represent. There are just few people who recognize that a person has understood a concept or proposition when he/she is able to explain it with his/her own words. Certainly, when teachers (or texts) explain concepts, they use scientific words or the ones used by the authors. They are generally different from the vocabulary usually spoken by students. That's why it is so important for the student to explain with his own words the new concepts. This is the only way the student can feel the ownership of his knowledge.

These problems have been studied not only in educational environments, but also in private corporations where competitiveness makes people look for new knowledge. Some of these studies have been carried out by Novak (1998) and Clarck and Palm (1990) -mentioned by Burón J. (1996). Novak analyzed the state of the corporations taking into account what they should learn. He concluded that many of them are "learning disabled", at least if they want to successfully take part in the new society of knowledge. To sum up, coporations' needs are:

1. Systematic thought achievement, i.e. ideas that help people to visualize the problems in a holistic form, e.g. to design a revolutionary automobile, all the factors that compose the vehicle must be considered (the power of the engine, the chassis, suspension, the buyers' desire, etc).

2. Employees' personal growth, for them to be able to clarify and improve their world view, philosophies, theories and principles that sustain these theories, etc. Thus, they learn to be patient and analyze reality as objectively as possible.

3. Better mental models constructions. All human beings have to face the problems with their own reasoning tools, e.g. some teachers believe that the only way of teaching is by means of lecture classes because this is what they have seen in most of the schools and universities. Learning about the existence of metacognition and their applications is a long process.

4. Shared world view construction. Each individual has his own mental models, so it is difficult for them to create an idea together with his co-workers. This is one of the reasons for institutions to be so slow in improving what they need.

5. Learning in groups or teams. This is of vital importance, since in modern organizations, the decisions are made in groups instead or individually. Metacogitive tools can facilitate group learning.

Clarck and Palm, worked in an industrial corporation, on a training program for 1500 managers. The aim was to help them to solve labor problems. They studied a group of managers in order to analyze in a metacognitve form, the process they follow to solve their labor problems. These are their findings:

¨Impulsiveness: quick solutions and illogical deductions.

¨Lack of accuracy while data recording: this makes them ignore the important information and accept the insignificant ones.

¨non definition of the problem: sometimes, they do not recognize the existance of a problem.

¨egocentric ways of communication: they do not take into account other points of view.

¨Lack of precision when presenting the answers: presentations are usually extensive and the instructions are vague.

Trial and error answers: they are just to prove if there is a good result. There are no planning and they adopt solutions without considering the consequences.

Generally, social psychology teaches us that these same mistakes are made in many other social, labor and political communities. That’s why we can say that the metacognitive processes are involved in all individual and groups processes.

WHAT IS METACOGNITION

Metacognition is a versatile conception, generated during educational investigations, mainly carried out during class experiences (J.J. Mintzes, J.H. Wandersee & J.D. Novak, 1998). Among the different aspects of metacognition, we can highlight the following ones:

> Metacognition refers to the knowledge, control and nature of the learning processes. Metacognitive learning can be developed by means of appropriate learning experiences.

Each person has some metacognitive points of view, sometimes in unconscious form.

Depending on the methods used by the teachers during the class, metacognitive tendencies of students can be encouraged or discouraged.

J.H. Flavell (1978), a cognitive psychology specialist and early writer on metacognition said that: "Metacognition makes reference to the knowledge of one's own cognitive processes, the results of these processes and any aspect that is related to them; i.e. to learn the necessary properties related to the information and data. For example, I demonstrate metacognition if I notice that I find easier to learn A than B"

According to Burón (1996), metacognition stands out for four characteristics:

1. to know the objectives we aim at with mental effort. 2. to choose the strategies so as to get the mentioned objectives. 3. to observe our own process of knowledge elaboration, to see if the elected strategies are the correct ones. 4. to evaluate the results so as to know if the objectives have been achieved.

It is said that metacognition is to know what (objectives) we want to get, and how we can get them. (self-regulation or strategy). Thus we say that a student is cognitively mature when he/she knows what to understand means and how he/she should work mentally to do it. Besides, the development of metacomprenhension, makes us be conscious for example, that a paragraph is difficult to understand and for that reason we control the reading speed so as to be able to deduce the true meaning of the writing. So the knowledge of our own understanding makes us regulate (self-regulation) the mental activity used in the understanding. This is the most important aspect according to most recent investigations.

Metacognitive understanding would allow to answer questions such as what does an inefficient student do wrong or what doesn't he/she do that results in poor learning? What does an efficient student mentally do to get good learning? The answers to these questions give as a result the development of learning and teaching models known as "learning strategies". The results we got let as know about the most convenient techniques that an inefficient student must learn so that they can self-regulate his own learning process. So, teachers can also acquire the necessary knowledge to address learning problems at school.

It is important to say that it is not necessary that students understand metacognition or the scientific research that supports it; they must only learn to learn according to the principles derived from the metacognitive research. This is the same process as when a person learn to speak. Although he does not learn grammar rules, he cannot speak well if he does not use them.

Our institutions pay attention to content, rather than to the way of acquiring knowledge; the metacognitive research proposes a fundamental change in this pattern taking into account not only the learning processes but also their results. We tell our students to attend lessons, to memorize, to do outlines or summaries, etc. but we do not teach them what and how they have to do what we expect. That's why metacognition investigates how students work when they read, listen to the lessons, memorize, write, etc., in order to find out their learning strategies and help them learn how to learn, train them to generate new resources. So they learn strategies to develop strategies. This changes the traditional concept about intelligence tests that measured how much we know how to do, and replace them for others that measure the way we act when we don't know what to do.

Another very important aspect on metacognition is that, if we consider that it refers from the knowledge of our own mind and that it largely directs the different forms of procedures, we will see that metacognition is crucial to the understanding of self-esteem. That's why metacognition is important regarding motivation, because not only does it direct our ways of acting, but also our attitudes, hopes or level of aspiration in life. Research in this area has shown the impact of positive self-esteem in the good academic results, but the relationship between motivation and metacognition has hardly been studied.

METACOGNITION AND LEARNING STRATEGIES

In the last years, and according to the research results about metacognition, methods, programs, technical and strategies on the fundamental aspects implied in the learning have been developed and designed. Their aim is to achieve a substantial improvement of the instruction models and study.

As an example, we can enumerate the most important methods: identification of the main ideas, underlined ideas, summaries, writings, understanding, memory, notes, reasoning, problem-solving, teaching

to think, the art of asking, representations, etc. This separation of mental operations is made as need for clarity the exhibition and a need of research. But this is artificial, since the mind works globally, without detaching one action from the other. For example, it is difficult to separate thinking from reasoning and from the resolution of problems. That's why some programs designed to teach how to learn, can include exercises to develop the memory, the understanding, or other mental aspects.

Having treated metacognition, we should wonder what a strategy is. We will meet with numerous definitions, and not all similar ones. In general, we can accept that the strategy is, in metacognitive literature, "what refers to the forms of working mentally to improve the yield of the learning", or in other words, we could define it as "the group of cognitive processes framed jointly in an action plan, used by a learner, to approach with success a learning task", obviously, metacognition as much as learning strategies are impossible to separate, but nevertheless they refer to two different concepts.

In order to clarify these differences, it is useful to present a classification of the learning strategies, as the following one: **1. Paying attention 2. codification** 2a) Repetition 2b) Elaboration 2c) Organization 2d) Recovery **3. Metacognitive** 3a.) Knowledge of knowledge 3b) executive Control 4. affective reaction

When centering the efforts in identifying effective forms of learning, metacognition research has underlined their self-regulating function, since the strategies are not but different forms of exercising the self-regulation of learning. Those components (that integrate the intelligent behavior) can be separated in four groups:

a) to decide what the nature of the problem necessary to solve is, b) to form a mental representation to guide the execution of the strategies, c) to focus attention and other mental operations, d) to observe the solution processes.

These components are identical to metacognition definition and their functions, so, we can say that intelligence development can be conceived as the development of strategies, of metacognition and of the self-determination (we understand self-determination as the capacity of learning how to be developed through the own effort, in opposition to the dependence of external guides, as parents or professors). In other terms, when we speak of self-regulation, reference is made to the capacity to learn for oneself, to the autonomy and the mental maturity that is achieved with the teaching of strategies. We can conclude that it is necessary to teach metacognitive strategies to achieve changes in the instruction pattern and in the pattern of learning. That change begins with being conscious of the necessity of changing.

The beginning of the change that metacognitive research suggests is in training teachers to 1) to know what they want students do when they ask them to do a certain task. 2) to know how students should work to meet that objective, 3) to teach them to make it and 4) to have resources to check if students know what to do when they are asked.

Thus, it seems necessary to implement the explicit teaching of learning strategies (i.e. concept maps & Vee diagrams), since it would not be very reasonable to continue thinking that students who want to learn how to study can get it for themselves. The data have revealed that: (a) many of them cannot reach their target (b) those that get it can improve their yields (c) although some of them can achieve it very well, an increase in the level of efficiency can be expected.

We could also say that to have good working strategies does not guarantee a good result, since a student can know how to study but does not want to do it. But this is not what commonly happens and the results show that the metacognitive development is mobilizer by nature.

INTRODUCING CONCEPT MAPS

The intention of using concept maps (a metacognitive tool) is to provide the student with an alternative to rote memorization. The following is an instructive for the students to be introduced in the use of concept maps:

You can learn unfamiliar concepts or words by rote memorization. A definition, for example, might be learned by repeating it over and over again until you have the right words in the correct order. You may instead choose to engage in meaningful learning, by integrating the new information with what you already know.

Concept mapping is a method that facilitates meaningful learning. It requires you to make decisions about: (1) the importance of ideas. (2) how these ideas relate to each other, and (3) how they relate with what you already know.

You may already use techniques such as underlining, highlighting, summarizing, or outlining

to assist learning. Unlike concept mapping, these techniques follow a linear ordering of ideas. However, in the human mind, the arrangement of conceptual structures is not restricted to linear order . Concept mapping enables you to make relationships between concepts explicit. You can also relate concepts based new information to your existing knowledge.

Concept maps can be made based on text, lectures, labs, individual topics or whole courses.
To make concept maps, you may follow five steps: (1) Identify the concepts. (2) Establish an order for the concepts. (3) Relating concepts with linking words. (4) Finding cross-links. (5) Examining structure.

(1) Identify the concepts. In doing this you may ask yourself what the definition of a concept is. For most people, a concept involves a general idea, especially about class or category of objects or processes. Another definition is: " A concept is a perceived regularity in objects or events, designated by a label, such as a word or symbol." Now, it is clear that your perceptions depend on what you already know. The attention to perceived regularities emphasizes the importance of your prior knowledge in obtaining a new understanding. Identifying the list of concepts is only a small improvement over rote learning.

(2) Establish an order for the concepts. In this step you are required to make some decisions about the relative importance of the concept you have selected. The concepts Should be placed in an order, ranging from the most general to the most specific. This is called hierarchical ranking. In doing So, different levels of hierarchy will emerge. One of the key determinants of hierarchy is the context. The order of concepts in a hierarchy is not fixed, but is dependent on the context and the relationships between concepts can be altered by the context. All concepts within a level will have a similar degree of generality or specificity.
In a concept map, the hierarchical ordering is pictorially represented.

(3) Relating concepts with linking words. This is to determine relationships between individual concepts. On a concept map, relationships or links, are shown by lines labeled with words that identify an association between individual concepts. These concepts and links are called propositional relationships. The linkages may be a simple logical connective: (e.g. "The speed is a scalar") or it may be a general relationship: (e.g. "Temperature increases with heat". Other connectives may themselves imply concepts, for example, the relationships between thermometers and temperature could be "measures": (e.g. "Thermometers measure temperatures". Here measure involves the concept of obtaining information on some scale. Such links should be carefully examined for implied concepts. If the implied concepts are relevant to the map, you should state them explicitly.

(4) Finding cross-links. A concept map will often have additional relationships between concepts besides those established hierarchy. These connections are referred to as cross-links. This step deals with looking for cross-links between concepts. Recognizing cross-links can be a creative act since new meaning is established for concept and your understanding increases. Identifying new relationships may require thet additional concepts be incorporated into the map.

(5) Examining the structure. This step deals with examining the arrangement of structure of the map, concepts that are not well integrated into a map do not have many connections to other concepts. They may appear to be isolated. These concepts could be less important for a particular context. Poorly integrated concepts may be those that are not associated with your prior knowledge. Recognition of this possibility helps you focus on areas where you may need additional learning. Learning is an active process. You can learn by rote, but a more meaningful way to learn is to integrate new knowledge into what you already know. This method of learning is more active because you are consciously using prior knowledge to construct new knowledge.

In summary we can say that concept mapping facilitates meaningful learning.

PROBLEM-SOLVING SKILLS. APPLYING THE VEE DIAGRAM

A heuristic is something employed as an aid to solving a problem or understanding a procedure. The Vee heuristic (a metacognitive tool) or Vee diagram was first developed to help students and instructors clarify the nature and purpose of laboratory work in

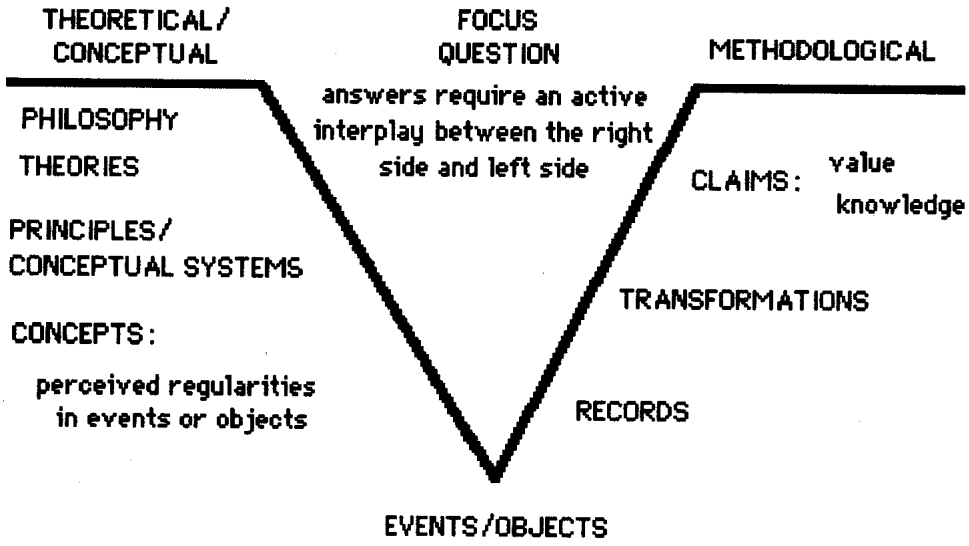

Figure 1: A Vee diagram, showing the main epistemological components (Novak & Gowin, 1986)

science. Figure 1 below contains the key elements necessary to understand the nature of knowledge and knowledge production.

At the point of the Vee are events or objects, and this in one respect is where the knowledge production begins. If we are to observe regularities, we may find it necessary to select specific events or objects in our environment, observe them carefully, and perhaps make some kind of record of our observations. This selection and record making process will require concepts we already know; the concepts we possess will influence what events or objects we choose to observe and what records we choose to make. These three elements -concepts, events/ objects, and records come together and are intimately related as we try to make new knowledge.

The organization of cognitive structure, plays a major part both in our individual learning and in problem solving. It also forms the basis of your knowledge of physics and can be used to solve physics problems. Two types of concerns are used in conjunction with the intent of solving one problem. They are the conceptual and methodological activities. The conceptual side of the "V" indicates the appropriate questions to ask, and what theories, principles, and concepts bear on that question. The methodological side identifies what has been observed and how can it be manipulated to reach the answers to the problem. The objects and events that occupy the bottom of the "V" binds these two activities together and represents the basis of the analysis.

Vee diagram instructions:

Especially in solving mechanical problems, we can use the Vee diagram to clarify our under- standing of both the questions and the main concepts to apply during the process.

In doing so, it is helpful to follow these steps:

1.-Identify the system of study, which is facilitated by working on both the ..focus questions.' and the "events/objects".

2.-Look along the system boundary for objects that exert influence (forces, friction, etc.) on the system. This task is associated with the conceptual side of the "V".

3.-Draw a sketch of the object(s) in the system and arrows representing all forces acting on the object(s). This sketch will represent the "event" under study and must be done at the point of the "V" diagram.

4.-Choose a coordinate system. In the case of kinematics it is convenient to make the positive direction of the coordinate system coincident with the motion's direction.

5.-Having identified the needed concepts, formulas, and unknowns, start to work on the records and transformations. These are the crucial part of the process. If well done these will let you reach the answer to the focus question. If not, start again the analysis in 1-4 above.

6.- Once you have finished the transformation process, it is possible to write down the knowledge claims. These are the answers to the focus questions that were asked at the start, and as such, provide the necessary information. Also they can suggest new questions that can lead to new insight about the problem. (To familiarize yourself with the structure and function of the "V", take a look at several "easy" problems and "lay them on the “V”. It is only through this activity that the simplicity and power of this device can be fully comprehended.)
Figure 2 below shows an example of "Vee" diagramming utilized in the problem solving task.

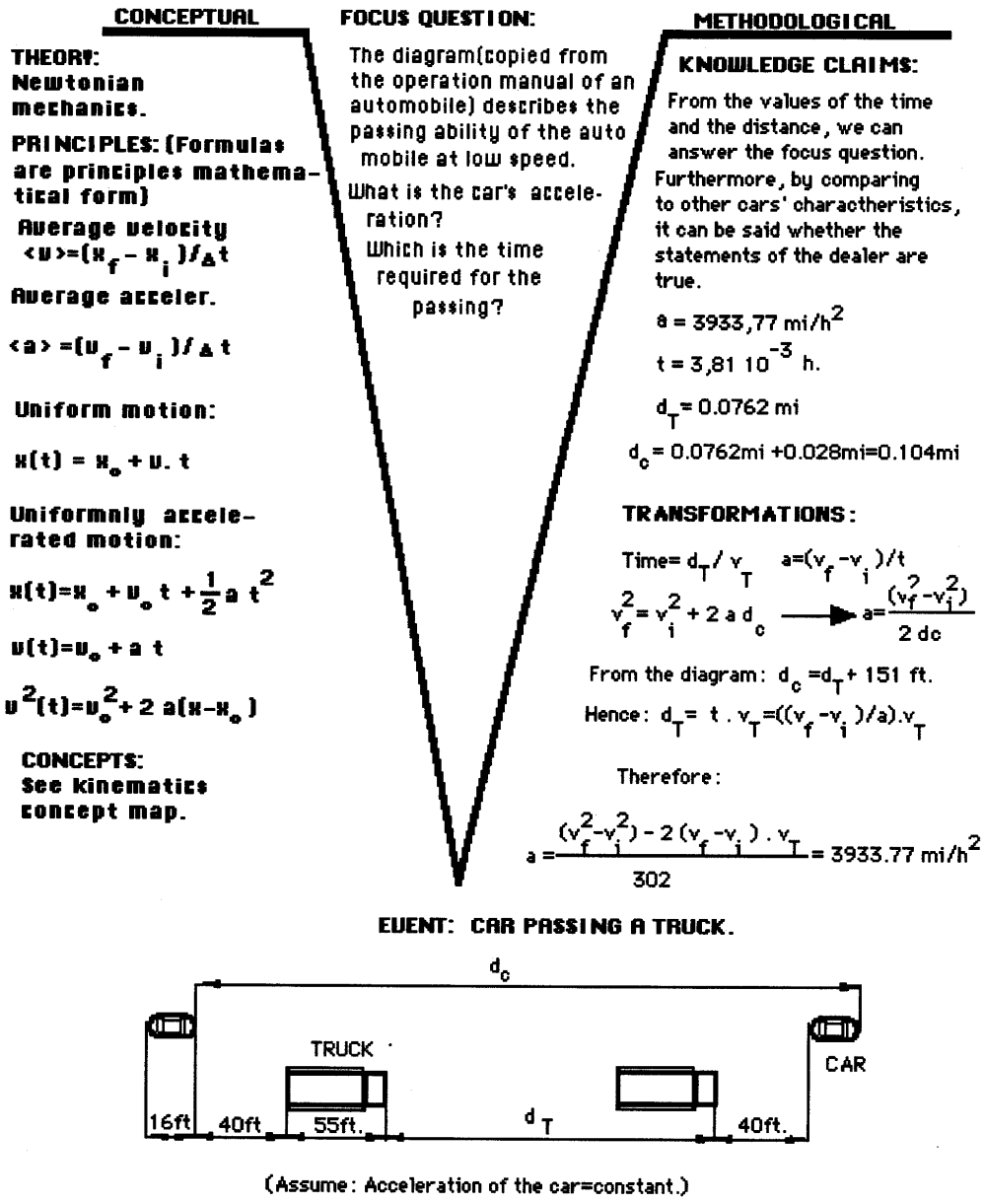

Figure 2: A Vee diagram, used to solve a kinematics problem

In summary, to became a successful problem solver, the following advice may be useful:

-Be decisive! Pay attention to and comprehend the directions.
-Be careful and systematic in the approach. -Formulate and delimit the problem before trying to solve it.
-Draw pictures of the problem whenever appropriate.
-Avoid the narrowing of attention to a single aspect of the problem.
-Abandon unpromising leads, and explore other alternatives.
-Question the reliability of your data.
-Distinguish clearly between data and inference.

-Accept with caution conclusions that agree with your own opinions.
-Check to see if your answer(s) are reasonable.
It is not uncommon that once you have tried all the above stated steps, you still are unable to reach the solution. Do not be discouraged and remember:
Never do a problem only one way! the point is that problems should be attacked in several ways, usually by finding a first approximation or a "ball-park solution", and then using a more precise method. Frequently, the quick and easy approximation serves not only as a check on your final answer but also as a guide to how to get it.

CONCLUSION

In summary, we can conclude that applying these two tools helps all the students in their task of learning how to learn (metacognition) and to overcome the epistemological ruptures students may have.
These recommendations are based on the idea that any attempt to improve the efficiency of the instructional process must be based on some learning theory. Instructional models based on learning theories are potentially a better guide for teaching than those that only relay on instructor's experience and concern.
Concept maps and Vee diagrams are mechanisms for the students that progress enriching their autonomy and efficiency in their processes of construction of knowledge, being capable of :

· to Detect the changes that take place in their cognitive structure in a certain period of time (before and after the instruction).

· to Quantify the results and the advance in their learning.

· to Aspire to the achievement of meaningful learning that contribute to improve their self-esteem, when feeling owners of their own knowledge.

· to Desist of the common practices that take to the rote learning.

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