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CONCEPT MAPS AND THE DIDACTIC ROLE OF ASSESSMENT

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Abstract. The assessment is presently looked at not only as a process of evaluating the student's knowledge of a specific subject, but at its own didactic function. As such, the assessment allows the teacher to organize and regulate the teaching process and, with the simultaneous access to assessment and metacognition tools, it seeks to reinforce the student's control over his learning process, hence facilitating the student's meaningful learning.
In this communication, several examples are given that show how conceptual maps may be useful in an assessment that seeks not only to find if the student has acquired the knowledge that is a part of the objectives previously defined, but also find out what the student knows, understands, or is able to achieve on his own. The students' creation of conceptual maps not only contributed to a refinement of their cognitive structuring, but also improved their emotional and social behaviour.

1 It is important to reinforce the didactic role of assessment

It is classically known that assessment had eminently social functions such as classification, selection, certification and students' placement. With the advent of cognitivism and upon recognizing that assessment was fundamental in the development of the teaching process and that the time during assessment could (and should) be used as an excellent time for learning, a reinforcement of the assessment's prescriptive character occurred, and henceforth assessment began to have a relevant didactic character. As such, assessment started to assume important roles such as organizing and regulating the teaching process, reinforcing the student's control over his own learning and facilitating meaningful learning.

Assessment assumed its condition of an intrinsically subjective process (even the so called objective instruments only eliminate subjectivity related to correction, not classification criteria or elaboration options) and became a much more multifaceted process that assumed several forms and employed various instruments as needed to reach specific goals. While classic assessment favored grading and ranking aspects, primarily for administrative purposes, modern assessment favored didactic aspects, hence becoming much more prescriptive.

Besides involving a sound conception, widening the process of gathering and interpreting information, and making well founded judgments, assessment assumed the need for making the right decisions, based upon well founded thought (Beeby, 1977, Tenbrink, 1981), becoming more formative, and even more forming. In fact, traditional formative assessment ("évaluation formative", in French), which is very retroactive in nature and primarily related to the teacher's pedagogic strategies, in which the teacher seeks to control the student's process, is being supplemented by a forming assessment (évaluation formatrice"), where the emphasis resides in the student's learning process under the student's control, therefore becoming more proactive than retroactive (Bonniol, 1986, p. 126 and Abrecht, 1994, p. 49).

Nowadays, in addition to a converging assessment that focuses on finding out if the student knows, understands, or is able to execute a predetermined task, the emphasis is shifting towards the need to also assume a divergent assessment with the goal of finding out what the student knows, understands or is able to do.

2 What are concept maps?

Novak's concept maps are tools that represent knowledge, and were first developed in 1972 by Novak and his collaborators at Cornell University (Novak, 1990a, 1997; Moreira, 1997). They are directly related to Ausubel's original theory and have been proven useful in facilitating meaningful learning (Novak, 1990a, 1991; Moreira, 1997; Moreira and Buchweitz, 1993). They consist of hierarchic diagrams that represent concepts and how these concepts interrelate, focusing on showing the concept's organization within the cognitive structure of an individual on a given subject (Moreira and Buchweitz, 1993; Novak and Gowin, 1999). Although usually hierarchically organized, concept maps should not be confused with organigrams or flow diagrams because they do not imply a sequence, time frame, or a sense of direction, nor do they set organizational or power hierarchies (Moreira, 1999). The fact that two concepts are linked is important since it shows that, for the person creating

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the map, there is a relation between these two concepts. Arrows may be used on these lines to provide a sense of direction and association, but that is not mandatory. What is important is for the map to become an instrument that clearly shows the meanings attributed to the various concepts and how these concepts relate to each other within the context of a given body of knowledge. Concepts, and the words linking them, create an assertion that projects the meaning of the conceptual connection (idem).

Concept mapping is a technique that exposes the concepts and assertions hidden within the cognitive structure of each student and it is of great importance since it shows the changes occurring in this cognitive structure, clarifies misconceptions and superficial interpretation in the teaching/learning process, and allows the teacher and student to exchange points of view on the validity or absence of a link between two concepts. In addition, the process of creating concept maps may also contribute to the development of a cooperation between the student and teacher in the sharing of meaning, where "making and remaking concept maps, and sharing it with others may be considered a team effort in the sport of thinking" (Novak, 1990a).

The importance of the concept map role in Science Teaching has been demonstrated since the publication, in 1990, of a special edition of the Journal of Research in Science Teaching about this subject that includes an article by Al-Kunifed & Wandersee (1990) citing around one hundred references related to the use of the maps. Since then, considerable research has validated the usefulness of concept maps in meaningful learning.

3 Concept Map Analysis

Although Novak and Gowin (1999), based on Ausubel's learning theory, proposed several criteria that allow the rating of concept maps, we believe that what is most important is to try to interpret the information that the maps provide us regarding the manner in which students structure, prioritize, differentiate, relate and integrate concepts and exhibited misconceptions. Concept maps are analyzed primarily under a holistic perspective, emphasizing the order of concepts and the meaningful connections between them (Valadares and Graça, 1998).

Therefore,

- An overall analysis of the concept map is performed to verify if it is:
  - primarily linear, exclusively or almost exclusively from top to bottom, which manifest a poorly defined cognitive structure, with problems regarding the links between the concepts;
  - or extensively branched out, which may indicate a rich cognitive structure, if concepts are well linked, progressively defined and integrally inter-linked.
- A detailed analysis is then performed to check;
  - if the links between the various concepts are correct or if they show misconceptions:
  - if the map is well laid out, that is, if it shows a progressive differentiation in a correct and effective manner;
  - if there are valid and meaningful cross-links, that is, if it shows correct
  - integrative reconciliation;
  - if there are valid examples along the bottom (with an hierarchy from top to bottom) or on the outer edges (with an hierarchy from the center out).

4 Concept maps as metacognitive instruments in a "forming" assessment

"Forming" assessment ("évaluation formatrice", in French) was postulated by a group of researchers at d'Aix Marseille Academy (Abrecht, 1994, p. 48). It focuses on "control assured by the student" rather than the traditional formative assessment where "control is primarily related to the pedagogic strategies of the teacher" (J. J. Bonniol, 1986, p. 126, in Abrecht, 1994, p. 49). So, concept maps are excellent tools that help the student in learning how to learn and in gradually taking control of his own learning. We agree with Novak (1991) that the teaching of science is "conceptually opaque". This means that the materials provided to students have little or no value in assisting students to visualize the structure of the subjects they study, that is, the links between concepts. It is clear that people think with concepts and it is the scientifically correct links between them that give meaning to the statements memorized by students and to the problems that are solved using "formulas". Meaningful content must be made conceptually transparent to students to allow for meaningful learning. Students need some help in constructing and reconstructing their conceptual structures, and, based upon these structures, they interpret facts, postulates, and memorize rules.

Concept maps assist teachers in controlling the students' learning since "they may be used to map out a route for organizing and presenting knowledge to students, as well as for finding students' alternative conceptions" (Novak, 1991, p. 38). It is also important that they become excellent tools in helping the student control his own learning. Actually, besides helping in building new knowledge and learning key concepts, concept maps will help the student with learning how to learn (Novak, 1988b, 1990a, 1990b, 1991; Novak and Gowin, 1999).

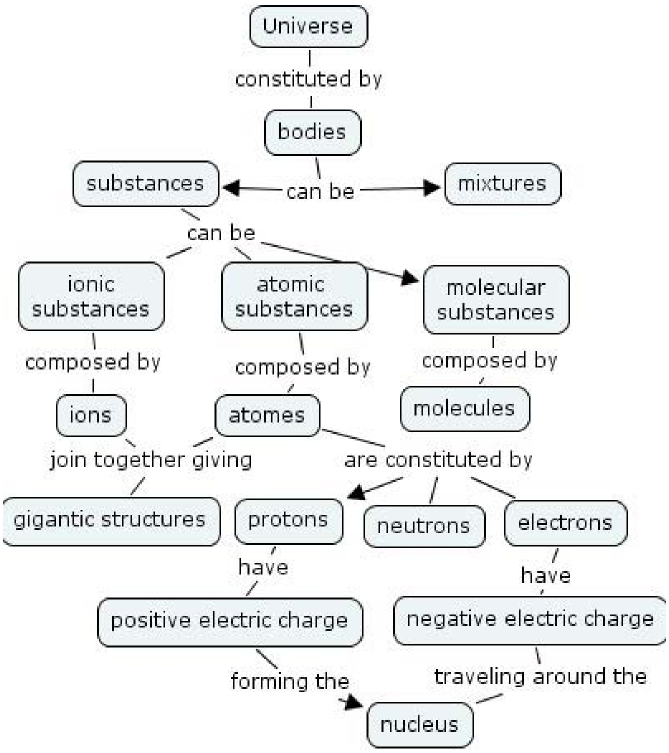
Also, concept maps are shown to be excellent in assessing students' prior knowledge, which is of great importance since, according to Ausubel (1980), prior knowledge is a determining factor in subsequent learning. If we take into account that student pre-conceptions are persistent and that conceptual change is a slow process, teachers should be motivated to search for more efficient teaching strategies that allow students to openly express their pre-conceptions (Driver, 1996). According to Novak (1997), investigating pre-conceptions and misconceptions revealed that traditional teaching does little to change them, and that meaningful learning and strategies to promote it are necessary to overcome such conceptions and build new and more meaningful ones.

5 Concept maps and the learning of Chemistry

We created the maps presented below using CmapTools from the Institute for Human and Machine Cognition. They faithfully depict hand drawn concept maps created by some of our students.

5.1 A map that helped in detecting a teaching deficiency

This map was created by a student in his eighth year of formal education during a chemistry class on materials and their classification.



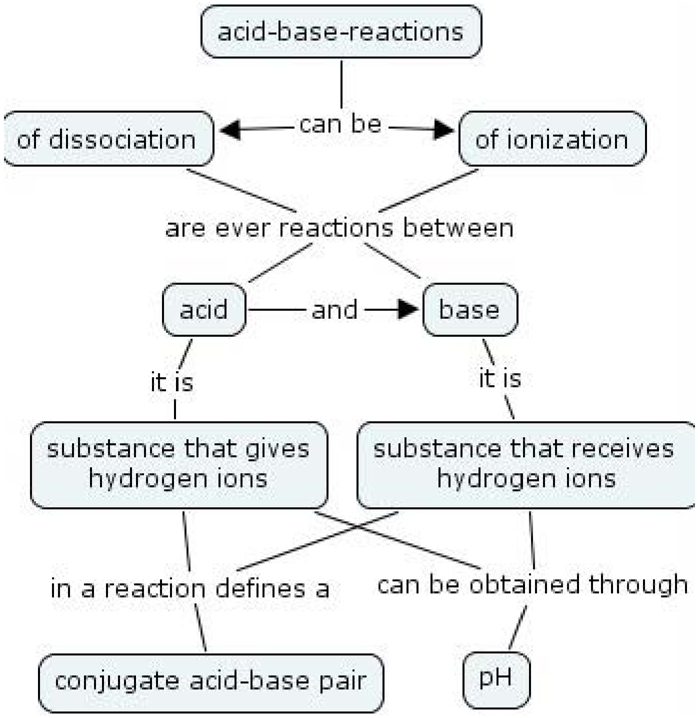
An analysis of this and other maps created by the students revealed two important teaching deficiencies. First, enough emphasis had not been given in differentiating the concepts of body (an amount of matter with a given mass) and material (classified either as a substance or a mixture). Secondly, the giant structure designation had only been addressed regarding ionic and atomic crystals, not regarding molecular crystals such as ice.

These subjects were then taught to the students, and subsequent maps did not reflect the previous deficiencies.

5.2 Two maps that show significant progress in the understanding of the acid-base subject

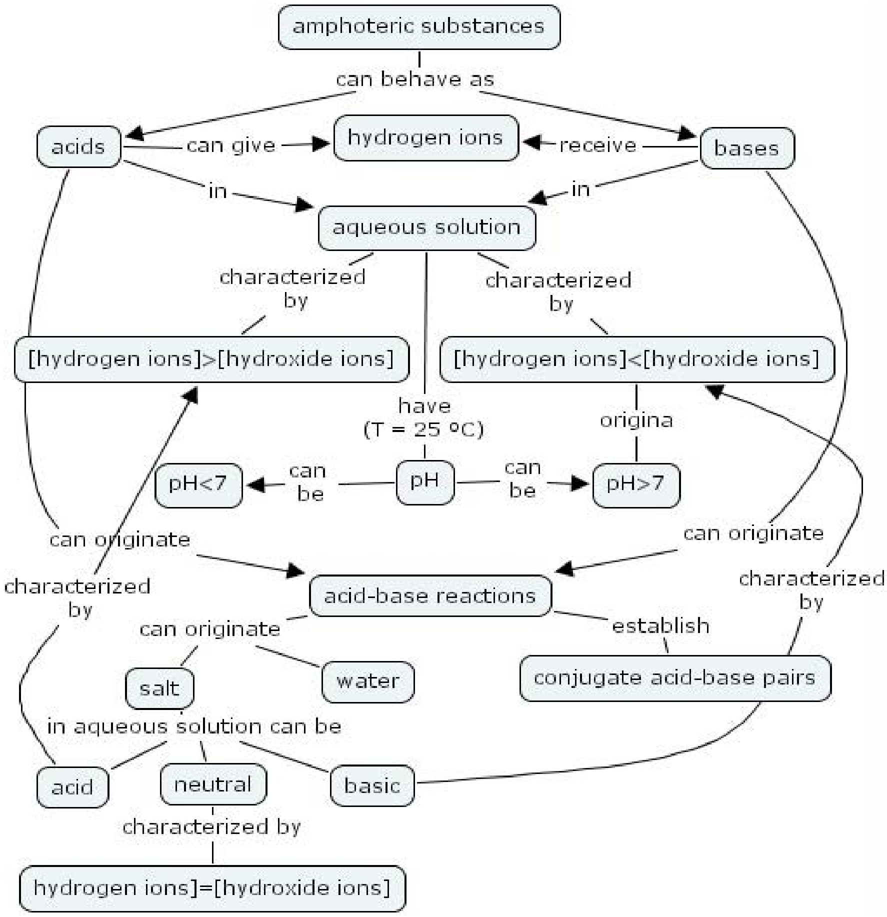
In order to analyze the effects of implementing a learning strategy in a constructivist environment for teaching the acid-base subject, the performance of two tenth grade classes deemed equivalent at the outset were compared. In one of the classes, particular attention was given to the construction of concept maps by the students, both individually and as a team; this became the experimental group. The other class was subjected to a traditional classroom teaching environment and was used as a control group.

The following map was created by a student in her tenth year of formal education, during the first phase of learning about acid-base reactions.



An analysis of this map pointed to the fact that the student did not yet have a clear and correct understanding of the differences between dissociation and ionization reactions, leading to her misconception of pH, which was confused with the acid-base indicator concept. During the following class period, care was taken in verifying what the students' understanding of these concepts was and in providing her with the resources that enabled her to improve her knowledge in this area. Similar techniques were used regarding misconceptions of other students evidenced in the maps that they created.

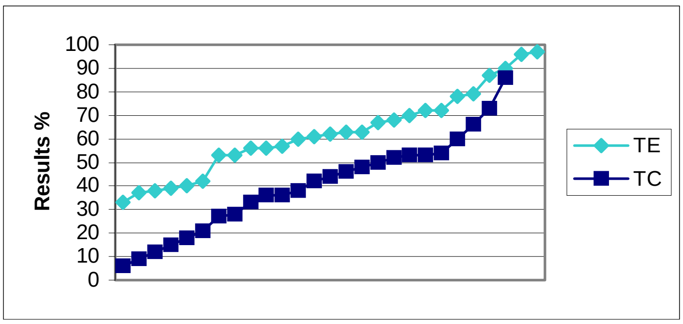
The following map was subsequently created by the student that created the map above. One can easily recognize that there is a broader differentiation progressive from the way the student expressed how she now perceives concepts to be connected.



The student also demonstrates an understanding of the acid and base idea according to Bronsted's theory, not just exclusively related to aqueous solutions. As new material on the subject was presented, the student gained broader knowledge, and was able to relate new concepts to more general ones.

For the most part, students that worked with concept maps developed a more significant and correct knowledge of the acid-base concept than the average student in the control group (TC), showing more in-depth understanding of the subject matter.

The superior performance of the experimental group (TE) was evidenced by the results of a post test based on an answering model and grading guide. Test results are shown in the following table.



5.3 Concept maps and the improvement of personal interaction in the classroom

Besides the aspects related to progress of a cognitive nature, one must also note the improvement in the students' personal interaction and the reinforcement of their self esteem and motivation for further learning. Debate within the experimental class, generated by the construction of maps in a team environment, or a discussion about a specific map, provided each student with a platform for expressing his or her point of view and for communicating to other students at an understandable level, even assuming the role of tutor.

This aspect proved to be very important. Record of observations in the classroom showed that in attempting to verbalize his or her own idea on a specific subject with the intent of communicating this idea to others, students were forced to re-think and analyze what they wanted to verbalize, and, in doing so, were able to find further discrepancies and mistakes in their idea; that is, the student was forced to search for an alternate formulation for the same idea which, in turn, helped to broaden the student's point of view. The verbal interaction among students helped to keep them focused and, in some instances, to pay more attention to a classmate than to the teacher.

During the creation of concept maps by a group of students, special attention was given to promote coordination and assignment of tasks within the group to enable students to continually provide and receive assistance among themselves. This way, before starting the proposed task, the team elements established who the moderator would be, who the spokesperson would be, and who would be responsible for drafting the maps.

Another aspect that should be emphasized is the fact that students gradually showed more interest in debate, as they gained more emotional control to face the "conflicts" generated by the difference of ideas on the same subject and that, in turn, translated into accomplishing the construction of the maps.

Comments such as "You are really stupid!", "You don't get any of this….", and "You were better off saying nothing." were slowly replaced with "Maybe you're right…", "And what do you think?" or "How do you explain that?"

Gradually, several students demonstrated their ability to draw parallels among their points of view without attributing their differences to incompetence or lack of information. We feel that debating was also crucial in allowing to show the importance of communication and interchange of ideas, establishing a need for a climate of acceptance and mutual respect.

Conclusion

Concept maps, created by our students either individually or in group work, have shown to be useful in many ways. They have allowed us to collect data on the meanings that students attribute to certain concepts, particularly regarding misconceptions that they may have. Their use, as an analytical instrument of conceptual knowledge and metacognitive knowledge, awareness and control was useful in obtaining a preliminary and overall idea of the types of representations that the students have and the way that these representations could evolve. We have successfully used them in the assessment of students' prior knowledge, and they have allowed us to plan our teaching in accordance with this knowledge. Since the maps provide an immediate assessment of achieved results and allow for an adopted strategy to be molded to the desired objectives, this formative assessment enabled adjustments in the course of teaching to be made.

In creating the maps, students clarified concepts and became gradually aware of the changes that occurred within their thought processes. This awareness helped them, in some cases, to learn how to learn and to ponder on the nature of acquiring knowledge. In some instances, this was stimulating in the sense that it instilled in the student the notion of being "able" and, in turn, this feeling of personal accomplishment became a driving force in the learning process and a reinforcement of the student's motivation to learn. Another relevant aspect is that diverging opinions among students while working on concept maps helped them to realize the importance of exchanging ideas, achieve personal growth and team knowledge, and also developed positive attitudes towards respecting diverse points of view, tolerance, and understanding the importance of dialogue.

In short, concept maps have proven useful for the purposes reported in numerous research works, specifically in Martinez and Moreira (1997), Novak, Gowin and Johansen (1983) and Boton (1995).

Bibliography

ABRECHT, R. (1994). *A Avaliação Formativa*. Rio Tinto: Eduções Asa

AL-KUNIFED e WANDERSEE, J. (1990). "One Hundred References Related to Concept Mapping" in *Journal of Research in Science Teaching*, 27(10), 1069-1075.

AUSUBEL, D., NOVAK, J. e HANESIAN, H. (1980). *Psicologia Educacional*. Rio de Janeiro: Editora Interamericana.

BEEBY, C. E. (1977). **“**The Meaning of Evaluation” in *Current Issues in Education*, Nº 4. Willington: Dep. of Education.

BONNIOL, J. (1986). “Recherche et formations. Pour une problématique de l’évaluation formative » in De Ketele J. (Éd.) : *L’évaluation ; Approche descriptive ou prescriptive ?* Bruxelles: de Boek.

BOTTON, C. (1995). “Collaborative concept mapping and formative assessment key stage 3: Understandings of acids and bases” in *School Science Review*, 77 (279), 124-130.

DRIVER, R. (1986). “Psicologia Cognoscitiva y Esquemas Conceptuales de los Alumnos” in *Enseñanza de las Ciencias*, 4(1), 3-15.

MOREIRA, M. (1999). *La Teoria del Aprendizaje Significativo*. Burgos: Departamento de Didácticas Específicas da Universidade de Burgos.

MOREIRA, M. (1997). “Aprendizagem Significativa: um Conceito Subjacente” in Moreira, M., Caballero, C. e Rodriguez, M. (Orgs) *Actas Encuentro Internacional sobre Aprendizaje Significativo*. Universidade de Burgos.

MOREIRA, M. e BUCHWEITZ, B. (1993). *Novas Estratégias de Ensino e Aprendizagem*. Lisboa: Plátano Edições Técnicas.

NOVAK, J. (1988b). “Constructivismo Humano: un Consenso Emergente” in *Enseñanza de las Ciencias*, 6(3), 213-223.

NOVAK, J. (1990a). “Concept Mapping: a Useful Tool for Science Education” in *Journal of Research in Science Teaching*, 27(10), 937-949.

NOVAK, J. (1990b). “Human Constructivism: a Unification of Psychological and Epistemological Phenomena in Meaning Making”. Paper presented at the *Fourth North American Conference on Personal Construct Psychology*, San Antonio, Texas.

NOVAK, J. (1991). “Ayudar a los Alumnos a Aprender cómo Aprender” in *Enseñanza de las Ciencias*, 9(3), 215-228.

NOVAK, J. (1997). “Clarify with Concept Maps Revisited” in Moreira, M., Caballero, C. e Rodriguez, M. (Orgs) *Actas Encuentro Internacional sobre Aprendizaje Significativo*. Universidade de Burgos.

NOVAK, J. e GOWIN, B. (1999). *Aprender a Aprender*. Lisboa: Plátano Edições Técnicas.

NOVAK, J., GOWIN, B. e JOHANSEN, G. (1983). “The Use of Concept Mapping and Knowledge Vee Mapping with Junior High School Science Education” in *Science Education*, 67(5), 625-645.

TENBRINK, T.(1981). *Evaluation: A Practical Guide for Teachers*, New York: McGraw-Hill Book Company

VALADARES, J. e GRAÇA, M. (1998). *Avaliando Para Melhorar a Aprendizagem*. Lisboa: Plátano Edições Técnicas.