THE USE OF CONCEPT MAPS IN THE TEACHING OF INTRODUCTORY CHEMISTRY IN ENGINEERING SCHOOLS

José Antonio Cascales[1], Enrique Solano[2] and Gerardo León[3]

Abstract *¾ Engineering can be considered as a broad discipline that embraces knowledge and training in science, mathematics, business and management, social science and computer technology. A wide range of skills can be defined as necessary to an actual engineer. Among them, technical knowledge skills and intellectual skills play a very important role. The teaching of science subjects must contribute to develop both, knowledge skills, including basic concepts, laws, theories and principles of the science, and intellectual skills, such as logical thinking, problem solving and design. A good understanding of a technical subject need not only the knowledge of the different concepts, but also the relation among them as a way to obtain a suitable meaning of those concepts. In this way, concept maps, as knowledge representation schemes in which the concepts that form the body of the thematic unit are organised in a structure according to different levels of abstraction an inclusion, can play a very important role. In this paper we described the use of concept maps as a tool for enhance the learning of basin principles of chemistry and the acquisition of some intellectual skills.*

Index Terms ¾ Concept maps, Introductory Chemistry, instructional tool, constructivist approach.

INTRODUCTION

Engineering is a profession directed towards the application and advancement of skills based upon a body of distinctive knowledge in mathematics, science and technology, integrated with business and management and acquired through education and professional formation in an engineering discipline. Engineering is directed to developing and providing infrastructure, goods and service for industry and the community.

Consequently, Engineering can be considered as a broad discipline that embraces knowledge and training in science and mathematics, business and management, social sciences and computer technology. A wide range of skills has to be considered as necessary to the actual engineer. Among them, technical knowledge skills and intellectual skills play a very important role.

Teaching of science subjects must contribute to develop both, knowledge skills, including basic concepts, laws, theories and principles of the different specific sciences, and intellectual skills, among them, logical thinking (the ability to make logical decisions), problem solving (the ability to resolve issues, problems and tasks), design (the ability to sketch, plan and work out designs creatively) and communication (the ability to exchange information with other people).

The good learning of a specific scientific subject requires not only the knowledge of the different concepts that the subject contains, but also the adequate relation among such concepts, in order to obtain a satisfactory meaning of them. In this sense, it makes necessary look for didactic methodologies to achieve an effective instruction, that is, a teaching that conduces to the desired learning.

Any instructive process is developed, implicitly or explicitly, inside a theoretic setting provided by the educational psychology.

The first half of the last century was dominated by the behaviourism. Passivity of mind was emphasised, with the environment providing an input whose information is directly transmitted to, an accumulated by, the learner, the resulting behaviour being the output. This "black box" approach to human functioning led to an experimental approach initially closely paralleling empirical-inductivism in science.

At the beginning of the second half of that century, behaviourism was essentially finished as a theory that could adequate explain the more complex aspects of human mental activity, and the influence of cognitive theorists increased. They argued that the process of development is neither direct biological motivation nor direct environmental pressure, but a reorganisation of psychological structures resulting from learner-environmental interactions. They advocated a psychology which monitored such interactions by establishing the personal meanings attached to experience.

Among those cognitive approaches, the cognitive developmental theory [1], which emphasises the importance of the cognitive developmental levels in the learning of scientific and technical concepts, and the constructivist theory [2], which emphasises the importance of the ideas that the student has and takes them in consideration in order

[1] Jose Antonio Cascales, Universidad Politécnica de Cartagena. Deparatamento de Ingeniería Química y Ambiental.. Paseo Alfonso XIII, nº 44. Cartagena 30203. Spain. Tel.: (34) 968 32 55 52. Fax: (34) 968 32 55 55. e.mail: josea.cascales@upct.es
[2] Enrique Solano, Universidad Politécnica de Cartagena. Deparatamento de Ingeniería Química y Ambiental. Tel: (34) 968 32 55 47. Fax: (34) 968 32 55 55. e.mail: enrique.solano@upct.es
[3] Gerardo León, Universidad Politécnica de Cartagena. Deparatamento de Ingeniería Química y Ambiental. Tel: (34) 968 32 56 69. Fax: (34) 968 32 55 55. e.mail: gerardo.leon@upct.es

to design the instructional process, have been the most studied during the last years.

The constructivist model has been used, in the last years, as a theoretical framework for a lot of researches about the instruction of science and technical subjects. Though the basic ideas of that model can be traced to the Greeks, is in the middle of last century when the denominated "theory of personal construction" is elaborated [3]. Attending to that theory, each person elaborates a model of reality that is continuously subjected to revision and to be replaced. These ideas were after developed and extended by the Ausubel's meaningful learning theory [2], which has been object of a lot of attention by researches on the learning of scientific disciplines [4]-[5]. The most important idea in the Ausubel´s theory appears in the preface of his book: "the most important single factor influencing learning is what the learners already know; ascertain this and teach accordingly".

Ausubel distinguishes between "meaningful" and "rote learning". Meaningful learning involves a conscious effort on the part of the learner to relate new knowledge in a substantive, non-arbitrary way to relevant existing concepts or prepositions in the learner cognitive structure. Cognitive structure is the framework of knowledge stored in our minds that grows and develops from childhood to senescence.

In contrast, rote learning results in arbitrary incorporation of new knowledge into cognitive structure. Rote learning most occurs when no relevant concepts are available in the learner's cognitive structure.

Ausubel emphasised that the meaningful learning does not result as a kind of accretion with new knowledge added to concepts. Instead, the new knowledge interacts with existing relevant concepts and is assimilated into these concepts, thus altering the form of both the ancient concept and the new knowledge assimilated.

According to that, in order to obtain a successful learning, student must acquires the knowledge actively, that is establishing relations between the new concepts to be learned and the ones he owned. That process of elaboration of a personal meaningful learning occurs through the re-structuring of the conceptual structure existing in the student.

It is a contrasted fact that many of the students of the first courses of the Engineering Schools obtain unsuccessful learning when they study basic scientific and technical subjects. One possible cause of that problem is that those students are not constructing appropriate understanding of fundamental scientific concepts from the very beginning of their studies and therefore they cannot fully understand the more advanced concepts that build upon the fundamentals.

Concept maps are a simple technique that can be very useful to detecting possible shortage of understanding and learning of basic concepts. Developed by NovaK [6], as a part of the meaningful learning theory, concept maps are a convenient and concise representation that make possible visualize the structure of concepts, and their relations, that the students own in a specific domain of knowledge. Therefore, they can be an effective instrument for both, knowing the start point of the instructive process, in relation to the initial conceptual structure of the students, and evaluating their evolution through the instructive process, knowing in each moment how new information is related with the existing information. Concept maps could so reveal the concepts already present in student's mind, the conceptual linkages between the concepts and the evolution that takes place as a consequence of teaching/learning activities.

Concept maps have the object of represent, in a hierarchical way, meaningful relations between concepts in the form of prepositions. A proposition consists in two or more concepts related by words in order to form a semantic unit. The representation includes a series of nodes and labelled lines. The nodes correspond to important terms in the domain (concepts). The lines denote a relation between a pair of concept (nodes), and the label on the line tells how the two concepts are related. The combination of two nodes and a labelled line form a proposition. A proposition is the basic unit of meaning in a concept map and the smallest unit that can be used to judge the validity of the relation drawn between two concepts.

Previously to the elaboration of a concept map, the more relevant concept related to the domain must be selected. Several techniques to carry out this selection has been described, varying from the most simple, in which all the concepts and labels to be used are supplied to the students, to the most complex, in which the students must select themselves the concepts and the labels [7].

Other aspect of importance in the concept maps is their hierarchical structure. Concept maps must be organised in a way that the more general and inclusive concepts appear in the top of the map. As we go down in the map, the specificity grade of the represented concepts increases. Concepts with the same specificity grade must appear at the same level in the map. The hierarchic structure of the concepts included in the map normally change with learning, as a result of the introduction of new concepts and of the new relations that learning produces. In fact, the new established hierarchical structure produces changes on the propositional relationships between concepts and the multidimensionality of organisation of the cognitive structure of the learner is schematically made clear.

METHOD

Subjects for this study (90) were randomly chosen from two groups of students enrolled in the Introductory Chemistry courses of the first year of Industrial Engineering and the first year of Mine Engineering.

The training in the elaboration of concept maps included a presentation of the concept map technique followed by three practical sessions. We have used seven steps in these training sessions [8].

1. Explain to students what is a concept map and what element it includes.
2. Select one subject, or one specific part of a subject, that students have studied yet. Ask students to select the fundamental concepts of the subject.
3. Arrange the selected concepts from high to low generality level, taking into account that several different concepts can be of the same generality level. Make a discussion with the whole class about the different arranges made for the students and agree about the best arrangement.
4. Elaborate individual concept maps using as conceptual hierarchy the agreed arrangement and adding the appropriate labels.
5. Make a new general discussion about the maps that students have elaborated trying to unify the different individuals contributions. Basically correct individual contributions that show differences in the way of interpret the relationship between concepts must be highly valued.
6. Present to students the criteria used to score the concept maps and apply them to some of the individual concept maps elaborated before.
7. Select another subject, or specific part of a subject, that students have studied yet. Ask the students to elaborate individual concept maps about that subject. These concepts maps are scored and commented individually with each student.

Then we ask students for elaborate different types of concept maps about different parts of the Introductory Chemistry course. Four ways of use of concept maps has been carried out.

In the first one, a fixed number of concepts related to the subject are given to the students and they must construct his own map by using only the terms given and choosing the structure, the linking relations and the labels.

In the second one, a number of concepts greater than what is requested to construct the map is given to students. A fixed number of concepts related to the subject is given and each student must choose only a fixed part of these concepts to construct his own map using the structure, the linking relations and the labels that he considers most suitable.

In the third one, we ask the students to identify the most important concepts of a subject and to construct a concept map. Only one concept is given (a very general concept), the number of concept the students can add is not limited, and each student must elaborate his own concept map using the added concepts (not limited), the structure, the linking relations and the labels that he considers most suitable.

The assessment of the concept maps has been carried out both in a qualitative and in a quantitative way. For the quantitative assessment of the maps two methods has been used [9], the structural scoring method and the relational scoring method.

In the structural scoring method, maps are scored identifying correct propositions, the presence of different level of hierarchy and the presence of cross-links. The scoring protocol assigns different points to the different structural elements of the map, and the final score is the sum of all those scores (Figure 1).

In the relational scoring method, maps are scored by evaluate the separate prepositions identified on the map. Each proposition is scores from zero to three points in accordance with a scoring protocol that considers the correctness of the proposition. The final score for the map is found by summing the scores of all the separates prepositions (Figure 2).

RESULT AND DISCUSSION

Concept maps are a very useful tool on the teaching-learning process of Introductory Chemistry at the first courses of Engineering Schools. Our use of concept maps has made possible several didactic achievements.

Exploration of student's misconceptions

The science and technological education literature of the past two decades contains numerous studies that have revealed that students bring to instruction concepts, ideas and explanations of scientific and technical phenomena that differ from the views held by the scientific community [10]-[12]. In many cases those concepts, ideas and explanations are not isolated but form conceptual structures, which provide a coherent understanding of the phenomena. According to the constructivist perspective, an adequate instructional process requires, necessarily, make explicit those misconceptions and search for the conceptual change, that is the learning abandoning primitive and erroneous conceptions in favour of more sophisticated conceptions closer to the scientific view.

The elaboration of concept maps by the students as a previous step to the instruction have let us visualize the initial conceptual structure of students in a specific subject, detect possible misconceptions and, according to that, design the teaching-learning process in order to obtain the conceptual change.

Advance organizer

Once the initial situation in which the student comes to instruction has been detected, we have used concept maps as a tool for an organised presentation of the concepts and facts to be studied on a specific subject. That presentation plays the role of advance organizer suggested by Ausubel [2], in order to act as a bridge between what the student knows and what he need to know in order to obtain the meaningful learning [13].

Different levels of generality of the subjects can be used. In any case, we have obtain good results presenting to the students a series of successive concept maps, going from the more general aspects of the discipline, including the complete discipline, to the more specifics aspects, directly related with the subject to be studied.

Assessment of learning in Chemistry

Concept maps construction involves organising concepts, linking existing concepts to relevant concepts in student's cognitive structure, arranging these concepts hierarchically and labeling the linkages between concepts. So comparing of successive concept maps of the same student, can be used for determining knowledge acquisition and for exploring conceptual change [14]-[19].

Concept maps has result a valuable source of information about both the content and the organisation of the student knowledge. Therefore, it is necessary time for instruction and practice for student to develop the skills to produce concept maps that accurately represent what they know. By other way, the scoring methods used in this study have result suitable to a general quantitative valuation of the assessment of the students.

Improvement of intellectual skills

Up till now we have referred to the use of concept maps as a tool for assess the instructive process in order to obtain a better learning of the scientific disciplines, Chemistry in our case, that support the formation of the future engineers. But the design and construction of concept maps can also contribute to develop the intellectual skills.

The elaboration of concept maps implies relate and organise the concepts. So it will produce an increase on the logical thinking capacity as a result of a high level of abstraction. This will produce an increase in the academic achievement of the students as have been described in different studies [19]-[20].

The elaboration of concept maps, as a way to a reasoned establishment of meanings systems, let students know how those meanings systems can be applied to solve concrete situations, that is to solve problems. Likewise, the construction of concept maps improves the creativity and the basic ability of design.

Finally, students acquisition of basic skills in the design and elaboration of conceptual maps must contribute to an improve of the ability to extract meanings of books and periodicals, and to prepare written or oral communications.

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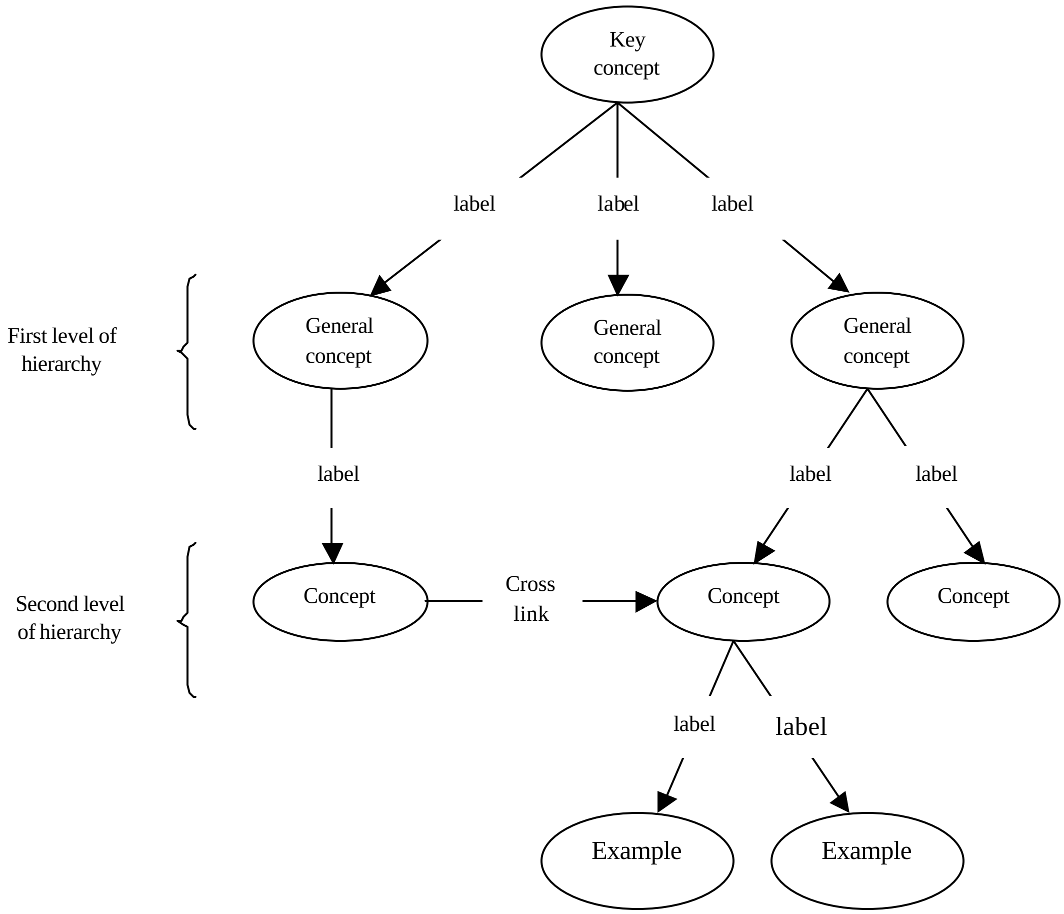

Propositions (if valid)	score	= 1 x 8 =	8
Hierarchies (if valid)	score	= 5 x 2 =	10
Cross-links (if valid)	score	= 10 x 1 =	10
Examples (if valid)	score	= 1 x 2 =	2
		Total	30

FIGURE. 1

VALUATION OF CONCEPT MAPS BY THE STRUCTURAL SCORING METHOD

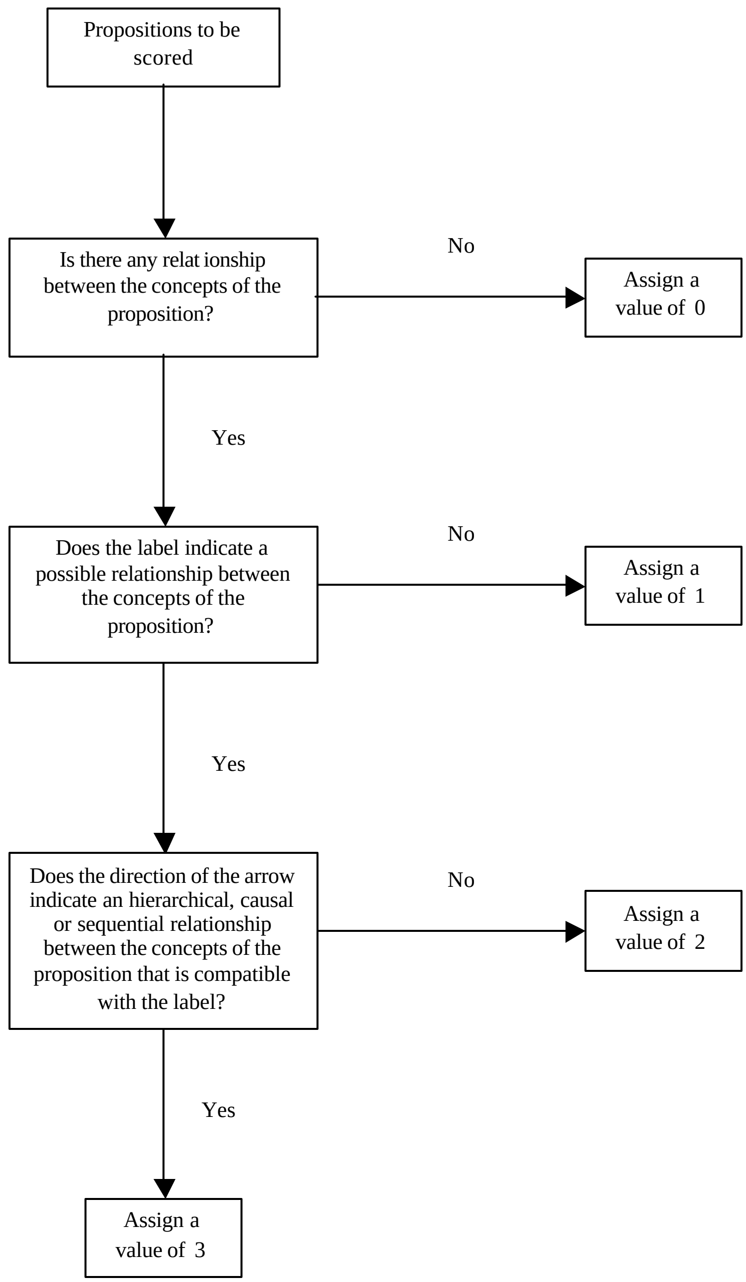

FIGURE. 2

VALUATION OF CONCEPT MAPS BY THE RELATIONAL SCORING METHOD