Conceptual maps in engineering education: a case study[1]

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ABSTRACT: *Conceptual maps are knowledge representation schemes in which concepts that form a body of a thematic unit are organized in a structure according to the different levels of abstraction and inclusion. Conceptual maps arise from Novak's theory on meaningful learning. This approach has been applied to other disciplines and at other educational levels. In these approaches, conceptual maps closely resemble a one-to-one mapping from sentences in a text to a graphical representation. This approach may simplify their elaboration at the expense of clarity and cumbersome knowledge retrieval. We have used conceptual maps for an undergraduate engineering course on Neural Networks using an object-oriented approach. This approach allows the definition of three types of concept relations: structural, functional and combinatorial. Reducing the number of relations between concepts and constraining their construction by a specific and limited set of rules lead the students to carefully analyze the study material. Besides, classroom activities are oriented to reinforcement of concept learning by discussion. A further advantage is that the conceptual maps or networks can be directly translated into a computer language to build a knowledge base.*

INTRODUCTION

This paper presents a case study on the use of conceptual maps or networks as a classroom strategy in an undergraduate Engineering course on Neural Networks. The objective of this approach is to help the students integrate the concepts in a new material with their cognitive structures from other subjects and previous knowledge, thus leading to a meaningful learning of the new concepts. They also promote a systemic view of knowledge as a result of this integration process.

Day by day, the need for new approaches to education become more critical as the world context changes from one paradigm where most emphasis

1 Esta ponencia fue presentada en el First Asia - Pacific Forum on Engineering Education efectuada entre el 6 y el 9 de julio de 1997 en Monash University de Melbourne, Australia. La ponencia se hizo acreedora al premio al tercer lugar entre las ponencias presentadas en el evento. La misma se publica con la autorización del First Asia-Pacific Forum on Engineering Education y de la UNESCO International Center on Engineering Education (UICEE).

was placed on the information possessed by one person to one where abilities are critical to his professional success. This change is forced by the rapid transformations in each discipline and the need for an interdisciplinary approach to problems. Thus, it is speculated that although new professionals will need a high degree of specialization to tackle the ever more rapid technological and scientific advancement, a systemic view of problems and methodologies forces the development of abilities to foster interdisciplinary work and communication.

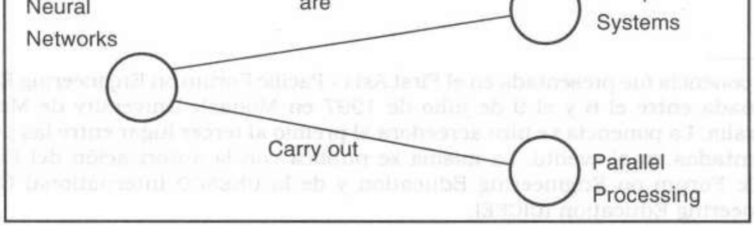
Our classroom approach with conceptual maps provides several ingredients towards achieving this goal. First, the construction of the map by each student help to integrate new to previous knowledge. The reflection process involved in their construction may show knowledge weaknesses and misunderstanding. Additionally, the establishment of connections in the map lead to integrate concepts of different subjects. Discussion in the classroom promote the development of communication abilities and the construction of sound arguments in an logical sequence.

We have used conceptual maps for two academic terms at Javeriana University and, to analyze our case study, we will initially present the theoretical background of conceptual maps. An explanation of our object-oriented approach will be presented next. This will be followed by the presentation of the classroom activities. After this, the results from a qualitative evaluation will be discussed and finally conclusions and suggestions for further refinement of the method will be pointed out.

CONCEPTUAL MAPS

This approach to education was initially proposed by Novak [1] as part of the theory on *meaningful learning*, where new concepts acquire meaning as they are integrated into the existing cognitive structures. Conceptual maps are a graphical representation of concepts and their relations and in the approach shown in [2], concepts are represented by nodes and connective words by branches in a graph. These branches represent relations between close concepts. A small example is shown in Figure 1.

Figure 1. Conceptual maps structure



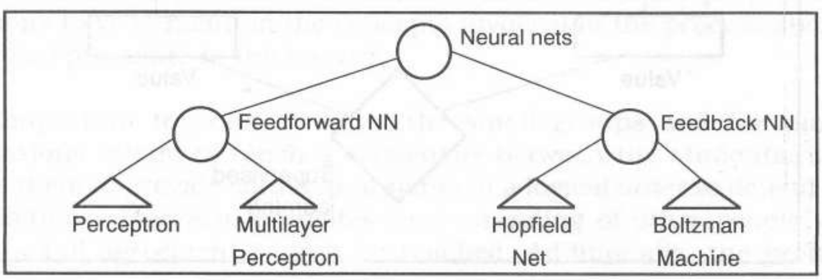
The map in this figure can be read as follows: *Neural Networks are complex systems that carry out parallel processing.*

As can be seen, in this figure there are three concepts, neural networks, parallel processing and complex system. They are connected by connective words which in most cases are verbs. Notice that in this representation, there is a structural resemblance to the sentences that gave origin to the map and this similarity presents three drawbacks: first, the construction can become a routine work where the student simply converts each sentence in the text into branches and nodes in the graph; second, the simplicity of the process does not promote insightful thinking or reflection; and third, the conceptual maps can become so entangled that knowledge retrieval can become extremely cumbersome. Additionally, any verb can become a connective word and thus any type of relation can be defined.

We propose the use of an object-oriented approach where we have two types of concepts, classes and objects. Also, only three types of relations can be obtained, structural, functional and combinatorial. In addition to that, we have property and method inheritance that complement the definition of concepts as we move down the hierarchy.

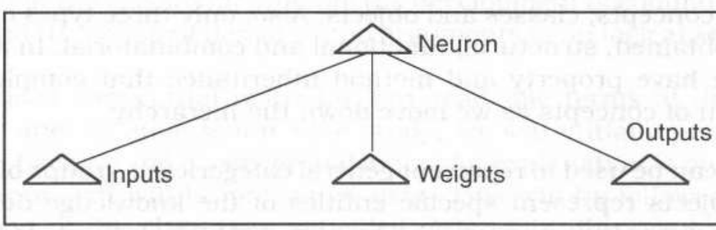
Classes can be used to represent general categories or groups of concepts, while objects represent specific entities of the knowledge domain. For example, *neural networks* can be represented by a class, since there exist different types of them. In contrast, a *multilayer perceptron* can be viewed as specific object which can be directly implemented. Properties characterize classes and objects, and are inherited down from classes to subclasses and from classes to objects. For example in Figure 2 the *multilayer perceptron* inherits the properties of *neural networks* in general, and of *feedforward neural networks* in particular, since this last subclass is the parent of the *multilayer perceptron* and by being a child of the more general category of *neural networks*, it provides a path for inheritance. In this paradigm, objects do not inherit properties from other objects higher in the structure. In all the figures in the paper, circles represent classes, triangles represent objects, diamonds represent methods and rectangles represent properties.

Figure 2. Structural relations in conceptual maps



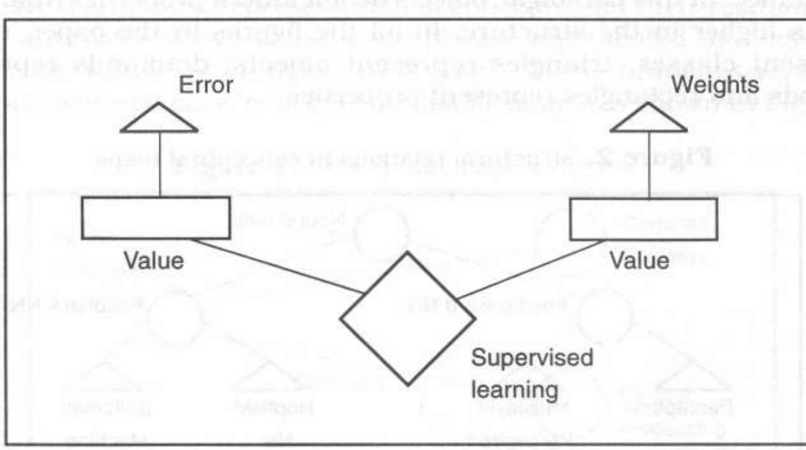
This hierarchical arrangement allows the representation of *structural* relations that can be interpreted as *is_a_type_of* when dealing with class-subclass and class-object connections. In Figure 2, for example, feedforward neural networks *is_a_type_of* neural networks. Similarly, multilayer perceptron *is_a_type_of* feedforward neural networks. Relations subobject-object are interpreted as *is_a_component_of*. This type or relation exists, for instance between the inputs, the weights, the outputs and the neurons which are all objects as shown in Figure 3. For example, neuron is the parent object of the other three and their relations are given by: inputs *is_a_component_of* neuron; weights *is_a_component_of* neuron; and outputs *is_a_component_of* neuron, respectively. This last type of relation justifies that no inheritance takes place since a component does not need to have the same properties or attributes of the object it belongs to.

Figure 3. Subobject-object relations



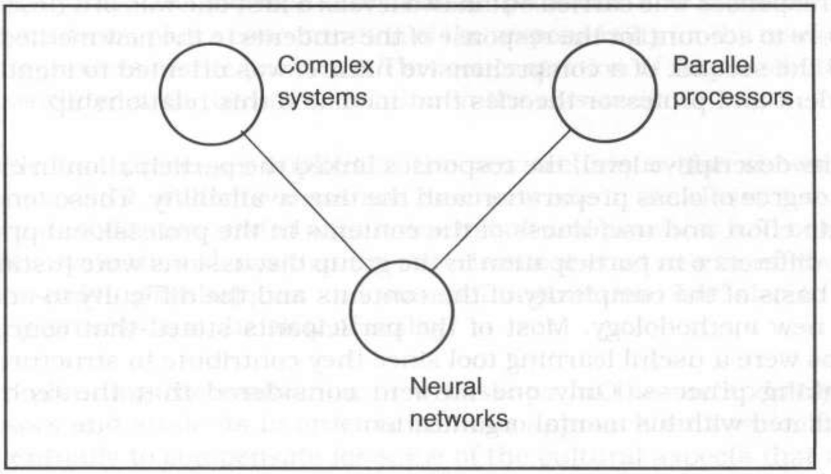
A second type of relation uses the methods in the object-oriented sense and we refer to them as functional relations. Thus a method relates a source to a destination object according to the function performed. Thus in Figure 4, the method *supervised learning* takes the *error* value to modify the *weights*.

Figure 4. Functional relations



A third type of relation is the combinatorial one which refers to substructures that possess similar topologies and share common parents. For instance, the nervous system and neural networks have this type of relation. To contrast the conceptual maps proposed by Ontoria et-al with ours, the map in Figure 1 is shown again in Figure 5. Although these maps share the same concepts, the connections between them imply categorization tasks which combined with the inheritance mechanisms promote reflection processes in the students.

Figure 5. Combinatorial relations



2. CLASSROOM ACTIVITIES

Our case study included, in addition to building conceptual maps, different activities in the classroom. First, an introduction to a thematic unit is presented by the professor. For the next class session, each student constructs his/her personal conceptual map which is discussed in small groups in the classroom. In the following class, all groups discuss their maps to reach an agreement on a classroom map. When finished, a review of the material is presented. Problems and exercises are proposed and solutions have to mention the concepts involved in the process and how this concepts relate to the answer.

It is important to point out that the small groups and the plenary discussions intend to reach a consensus between the students, which forces them to provide sound arguments in a logical order to defend their propositions. This also promotes understanding of other people views when a full agreement cannot be reached. Additionally, the professor views are also part of the discussion thus intending to place the class participants at the same level.

EVALUATION OF THE METHOD

Three categories of analysis were covered by a questionnaire used in the evaluation. The first category refers to the individual behavior of the participants, the group activities and the learning process. The objective of the questionnaire was to describe and evaluate the experiment from the double perspective of the students and the professor. The analysis of the responses was carried out in two levels: a first one was of a descriptive nature to account for the response of the students to the new methodology; and the second, of a comprehensive nature, was oriented to identify the student and professor theories that mediated this relationship.

At the descriptive level, the responses linked the participation in class to the degree of class preparation and the time availability. These tended to relate effort and usefulness of the contents in the professional practice. The difference in participation in the group discussions were justified on the basis of the complexity of the contents and the difficulty to adapt to the new methodology. Most of the participants stated that conceptual maps were a useful learning tool since they contribute to structure their thinking process. Only one student considered that the technique conflicted with his mental organization.

At the comprehensive level, and taking into consideration the three categories of analysis mentioned at the beginning of this section, it was found that:

- at an individual level, it is important to note the observed tendency of the students to assume responsibility for the contents understanding prior to the class, which in our student culture is unusual since the professor, in addition to possess the power of knowledge, has the responsibility for the student learning.
- at the group level a change in the distribution of power was observed which was difficult to assume, since the construction of conceptual maps propose a concerted work. Such situation causes a power dilution and the students culturally continue to expect that the professor exercise this power.
- at a learning process level, the resistance to change was observed which is originated, in part, in the difficulty to recognize the validity of other statements to search for the integration of views and the negotiation of differences. On the other hand, the resistance to change

is also related to making evident the inconsistencies and voids in knowledge in the students, the professor and the textbooks. All these factors generate uncertainty and fear.

CONCLUSIONS

This case study has revealed several important aspects in the teaching-learning process. First, the segmentation of subjects has led to a fragmented view of reality based on the emphasis placed on just contents and not in abilities. The experiment has also made evident cultural aspects that tacitly mediate the relations between professor and students and among students, plus a concentration of the responsibility for the teaching-learning process on the professor. This concentration of responsibility is also associated with the power relation in the classroom.

The reflection processes implicit in the new technique also shows the resistance of the students to assume their new role in the classroom and the responsibility associated with it due to cultural practices and beliefs. However, evaluation shows that the experiment opened new frontiers not only in studying techniques and material organization but also in the thinking process and the view of reality.

We are planning the realization of workshops on the methodology to professors and students in order to test our approach on a wider scale and eventually to compensate for some of the cultural aspects that may limit the reach of this approach and the responsibility assumed by the student for his/her education process.

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