CONCEPT MAPS AS A STRATEGY TO ASSESS LEARNING IN BIOCHEMISTRY USING VIRTUAL DYNAMIC METABOLIC DIAGRAMS (DMDV)

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Abstract . This study reports the application of concept maps to follow the Krebs cycle and carbohydrates metabolism apprenticeship using educational software called Virtual Dynamic Metabolic Diagram (Diagrama Metabólico Dinâmico Virtual, or DMDV). Two experiments were performed with undergraduate students of the medicine course while the software was being developed. The first composed by 24 students used DMDV preliminary version of the software containing Krebs Cycle, and the second composed by 36 students used the new version the DMDV program, containing contents of additional metabolic pathways. All students could access the system at anytime through an intranet. Concept maps were used in this study assessing learning and identifying misunderstood concepts by the students after the used DMDV. Concept maps permit the representation of new knowledge in the course of study, perceived as the processes of assimilation and adaptation of new mental schemes, in terms of reflective abstraction (Piaget, 1995). The evaluation was made by analyzing three concept maps made by each student at a different time: (a) one map before initiating the study with DMDV; (b) the second just after the study; and (c) the third two months later. Criteria for the analysis were: predominance of associative over classificatory character; correct concepts and relationships; coherence; number of relationships; creativity and logic. The initial maps showed that all students had some previous mental scheme about the proposed concept. All final concept maps showed an expansion of the concepts as compared to the initial maps, something which can be seen even by a mere glance at the size of the maps. A purely visual comparison between the maps indicated that new elements had been added. The associative character has been shown to predominate over the classificatory one. The results obtained suggest the validity of using concept maps as a strategy to monitor the cognitive process, both by the teacher and by the student him/herself and apprenticeship using educational software DMDV

1   Introduction

This study reports the application of concept maps to follow the Krebs cycle and carbohydrates metabolism apprenticeship using an educational software called Virtual Dynamic Metabolic Diagram (Diagrama Metabólico Dinâmico Virtual, or DMDV). The learning subjects were undergraduate students of the medicine course of the Federal Foundation School of Medical Sciences of Porto Alegre (FFFCMPA), Brazil.

Concept maps, founded in meaningful learning according to Ausubel theory and the Novak (1998) proposals are used as tools to organize and present knowledge. They are an important teaching and learning support for use by teachers and students. Concept maps are graphical representations of related concept systems in any domain, disposed to show the relationships among them and the whole system, allowing the perception of each connection (Moreira & Buchweitz, 1987).

The process of producing a concept map affords the development of a cognitive learning process in which the student organizes his/her knowledge autonomously, identifying in an oriented way the acquisition of new pieces of information, which will be integrated into his/her previous knowledge. As a learning tool, it can be used by the student to, e.g., making notes, solving problems, planning the study and/or writing of long reports, preparing for examinations, and identifing the connection of topics.

For the teachers, concept maps can help:

- making difficult concepts clear, organized in a systematic order;
- keeping focus on key concepts and their interconnections;
- conveying a clear general picture of the topics and their relationships to the students;
- offering a reflection support of the student about their own representation;
- allowing the visualization of key concepts and summarizing their interconnections;
- assessing learning and identifying misunderstood concepts by the students;

- evaluating the teaching process;
- evaluating the attainment of goals by the students through the identification of misunderstood and missing concepts.

An example of the use of concept maps in Biochemistry can be found in Campbell (2000). At the beginning of each chapter, the author presents a concept map of the topics that will be dealt with therein, characterizing an important reading support tool. Another example in Biochemistry it is in a book by Richard Harvey and Pamela Champe (2005). Since students often view Biochemistry as a pile of facts or equations to be memorized rather than as concepts to be understood, these authors created a series of concept maps about the biochemical contents to illustrate graphically the relationships between the ideas presented in a given chapter, as well as to show how information can be grouped or organized. For these authors a concept map can be used as a tool by a student him/herself to visualize the connections between the concepts. Differently from the educators who define concepts as perceived consistencies in events or objects, these authors understand concepts in biochemical concept maps as abstractions (e.g. free energy), processes (e.g. oxidative phosphorylation), and compounds (e.g. glucose-6-phosphate).

According to Jean Piaget the development of the human cognitive process, the building of concepts is a system in which their elements are necessarily supported on one another, while at the same time being open to multiple exchanges with the outside. It is thus assumed that it is impossible to build a single concept A as a starting point in a classification without using other domain-related concepts, which characterizes a non-hierarchical, dynamic process of interconnected variables. According to Dutra, Fagundes and Cañas (2004)[1]: "(...) in the dynamic of making a concept map one can follow the representation of a system of meanings activated in an individual so that in it we also recognize subsystems that relate to one another by mutual support in the building of such meanings".

In the present work, concept maps have been used as tools to represent knowledge, from an instrumental point of view, i.e., as a tool to support students' and even teachers' expression. From the conceptual point of view, they were used according to the Piagetian view of concepts formation, described by Dutra, Fagundes and Cañas (2004). This means that these instruments have been given the ability to represent systems of preexisting meanings in students, as well as activation of later constructions, and possible subsystems of signification associated with the concepts of the content at issue. By the analysis of concepts and linking sentences made by the student, we aimed to ascertain (1) the student's knowledge of the studied topic, (2) the influence of the use of the educational software, and (3) how the student would represent his knowledge two months after completion of the study.

Concept maps focus on aspects relating to the conceptual structure of content, and therefore they were considered as instrumental for evaluation purposes, so as to add conceptual and pedagogical value to the traditional forms of evaluation, i.e. through tests. This stance is supported by various authors who have done research on concepts maps as a support of teaching activities. According to Farias (1995, p. 23), "(...) for a student to elaborate a correct concept map, he/she must have a wide understanding of the studied material, differentiating between more general concepts and the various levels of subordinate concepts". This view had been previously presented by Stewart, Van Kirk and Rowel (1979 apud Farias, 1995), who think that concept maps appear to evaluate student's knowledge more effectively than other evaluation tools, because they depict the structure of the studied content.

In order to facilitate the student's understanding of the metabolic pathways and provide greater interaction with the contents and thus better learning an software, called Virtual Dynamic Metabolic Diagram, was developed which allows the user to learn, study, and review contents concerning Krebs Cycle and carbohydrate metabolism through:

a. interactive games with a string of substrates and enzymes of the metabolic pathways, their control, inhibition, role of vitamins in their correct functioning, and their connection with other systems;

b. readings on the functions and characteristics of metabolic pathways, as well as historical milestones along their development;

c. solving of essay and multiple-choice questions.

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[1] Electronic document, referenced at the end of this paper.

2   Methods

After the pilot trials in using the preliminary version of the software containing Krebs Cycle, reported in Azevedo, (2003; 2003a and 2004), a second trial with a new version of the software containing contents of other metabolic pathways. The software was evaluated by two groups of undergraduate students regularly enrolled in the discipline of biochemistry. All students could use the software for studing during two classes in a computer room. In the following week, before the evaluation of the discipline concerning this topic, the software was made available again through the intranet of the institution. All students were registered on the system, and their access, through use of a personal password, allowed the recording of activities on an individual basis.

Two groups of students were tested on the application of concept maps as a tool to assess learning after the use of the DMDV software educational for the Krebs cycle and carbohydrates metabolism. While the first group used concept maps to depict their knowledge of the Krebs Cycle, the second group worked with a wider content, including the Krebs Cycle as well as Carbohydrates Metabolism. The content didn't work in the expositive class, only in the software that make possible a comprehensive student interaction, making possible the initiative and autonomy of the student during the activity. The software makes possible the student action with the logic sequence game, to do the metabolic route, and with the classmates, to access new information through the hypertexts, available in the virtual environment or in the internet, or still to consult texts or printed books. This experience was realized with the target that the students did a activity of concept' contrution and no to repeat the expositives class informations. The construction of a concept map permits the representation of knowledge during the study, perceived as the processes of assimilation and adaptation of new mental schemes, in terms of reflective abstraction (Piaget, 1995). The evaluation was made by analyzing three conceptual maps made by each student: (a) one map before initiating the study with the DMDV; (b) the second just after the study and; (c) the third two months later. This analysis used the following criteria: predominance of associative over classificatory character; correct concepts and relationships; coherence; number of relationships; creativity and logic.

3   Analysis of Concept Maps

Some general observations about the concept maps of all participants can be made from an analysis of the whole. The initial maps indicate that all students had some previous knowledge of the proposed concept. All final concept maps showed an expansion of the concepts as compared to the initial maps, something which can be seen even by a mere glance at the size of the maps. A purely visual comparison between the maps indicated that new elements had been added. Some initial maps presented few concepts and relations. A purely visual comparison between the maps indicated that new elements had been added, reinforcing the opportunity of using concept maps in the learning process.

Students with less previous knowledge (fewer representations in the initial map) presented more expansion on the final map (showing changes that occurred in the students' previous ability to represent).

With rare exceptions, both the initial and the final map of all participants were coherent, cohesive, expressive and logic.

The maps also showed another characteristic that is desirable for the teaching-learning process: the interrelation of concepts, so that they are not characterized as fragments but as parts of a whole, whose interconnections are crucial for understanding the content in its more complex sense, which includes generalizations, abstractions and content disposition by order of relevance and meaning. For example, on the third concept map, the concepts of relations with the synthesis of urea, function of the cycle, and control were more associated, which gives a perfect idea of the insertion of the concept in a contextual whole show examples of these relations in the maps of two students). On the second map, in addition to function, location and characteristics, there appeared the list of names of substrates, concepts that are related to structured memory. An analysis of the relations between the concepts depicted on students' concept maps shows that these concepts were better understood. Interestingly, the first maps often presented the word "is" to indicate a relation, while the two later maps indicated relations using words like "oxidizes", "yields", and "synthesizes", etc..

All maps included concepts related to function, location and characteristics of the metabolic cycle. The second map also showed the names of the substrates and enzymes of the cycles, which seems to suggest enhancement of memorization soon after using the computer program.

Besides representing the student's previous and learned knowledge, supporting the applicability of the tool as a strategy to monitor the cognitive process by the teacher, concept maps also became an important tool for student self-evaluation. Oral evaluations made by the students were determinant for this observation. Some students reported that the first map was difficult to draw and after the game, it was easy to draw the second. Such stance refers to students' awareness of their the learning process, whose indicator is the map itself.

Due to the limitation ot pages in this article, we selected randomly concept maps from one stundent of each group to illustrate our analysis.

Figures one to six show examples of the first, second and third concept maps drawn by the same student, in the two tested groups, whose result of map analysis was similar.
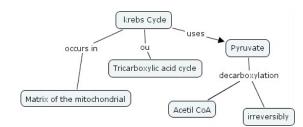
3.1 First examples of Concept Maps by the same student

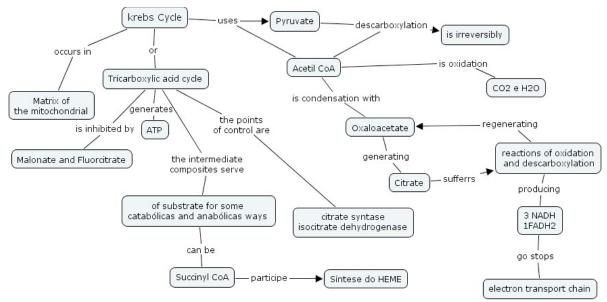**Figure 1**. First Map presents some previous knowledge

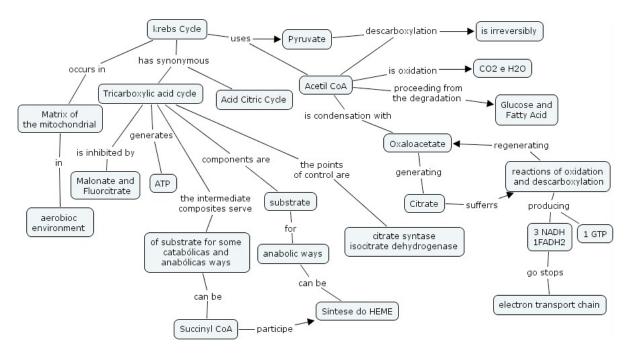

Figure 2. Second map presents expanded knowledge

Figure 3. Third map presents more general concepts and interrelations with other metabolic routes
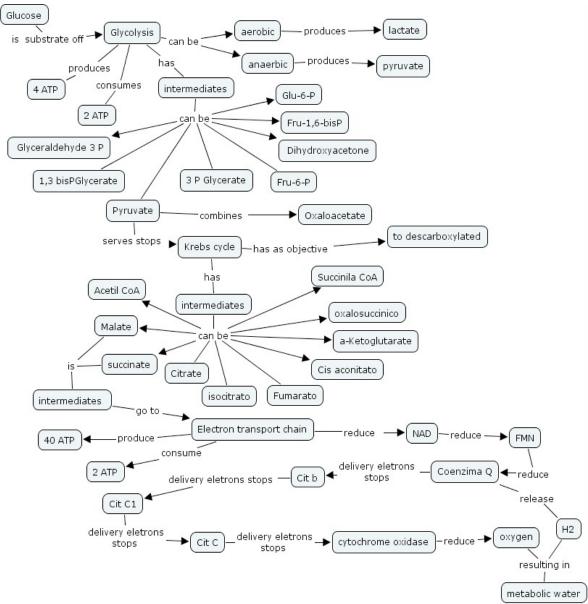
3.2 Second examples of Concept Maps by the same student

Glucose

is substrate off → Glycolysis — can be → aerobic — produces → lactate

anaerbic — produces → pyruvate

produces → 4 ATP

consumes → 2 ATP

has → intermediates — can be →

Glu-6-P

Fru-1,6-bisP

Dihydroxyacetone

Glyceraldehyde 3 P

1,3 bisPGlycerate

3 P Glycerate

Fru-6-P

Pyruvate — combines → Oxaloacetate

serves stops → Krebs cycle — has as objective → to descarboxylated

has → intermediates — can be →

Acetil CoA

Malate

succinate

Citrate

isocitrato

Fumarato

Cis aconitato

a-Ketoglutarate

oxalosuccinico

Succinila CoA

is → intermediates — go to → Electron transport chain — reduce → NAD — reduce → FMN

produce → 40 ATP

consume → 2 ATP

Electron transport chain — delivery eletrons stops → Cit b

Coenzima Q — delivery eletrons stops → Cit b

Coenzima Q — reduce → FMN

Coenzima Q — release → H2

Cit b — delivery eletrons stops → Cit C1

Cit C1 — delivery eletrons stops → Cit C — delivery eletrons stops → cytochrome oxidase — reduce → oxygen

H2

oxygen — resulting in → metabolic water

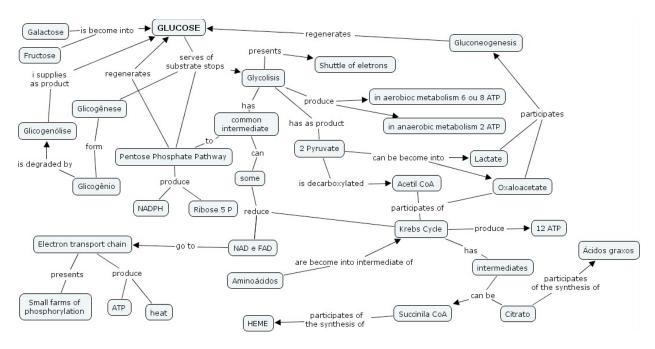**Figure 4**. First Map presents much previous knowledge

Figure 5. Second Map concept map drawn after the game presents progress concerning the interrelation of concepts
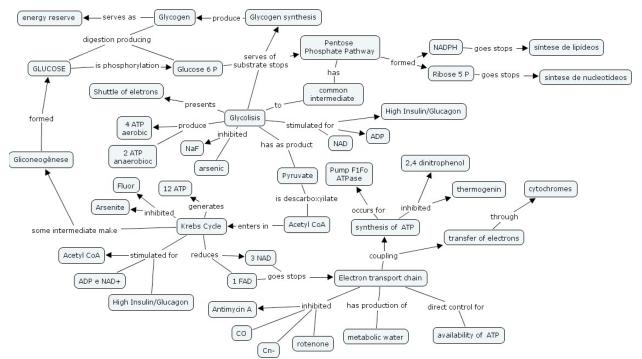
Figure 6. Third map maintained the expanded knowledge, presented more general concepts organized in a coherent way and associated with the studied content.

4   **Conclusions**

More than reporting the use of concept maps with medical students of the FFFCMPA, this work intended to call the attention of professors and researchers in the field of Biochemistry to the potentiality of this teaching/learning resource, in terms of content organization, self-learning and follow-up of the activities of each student, from the perspective of increasing their knowledge of the subject. The concepts maps construction activity provoked a permanent quest activity of new information and offering feedback making possible asked about representations constructs in the conceptl maps. We thus have briefly presented this potentiality and, through the case presented – which originated the author's doctoral dissertation in the Postgraduate Program of Computer Science in Education of the Universidade Federal do Rio Grande do Sul – we have tried to illustrate the outcomes of its utilization. Although in one of the experiments a more comprehensive concept was requested (Carbohydrates metabolism) in addition to the Krebs cycle, the analysis of the three concept maps drawn by the students in both experiments showed similar results.

The efficiency of the tool could be ascertained by comparing the three concept maps of each student, which allowed the teacher to follow up the building of knowledge by the student, according to the idea of conceptual development, proposed by Piaget, of concept formation from previous mental structures in the learner (Piaget, 1978). The initial maps showed that all students had some previous knowledge of the proposed concept; there was an aggregation of new elements on all later maps of all students. Both the students with less previous knowledge (fewer representations in the initial map) and those with greater previous knowledge presented expansion on the final concept map as well as progress concerning the interrelation of concepts, indicating a more complex level of conceptualization. Differences can be seen between the relations between the concepts placed on the three maps, suggesting that there was a deeper understanding of these relations and of the sense of the concepts. In the dissertation, these results were associated with other evaluation tools (tests), indicating that concept maps can be characterized as effective tools to follow up the process of conceptual development in each student. Future research point to the advantages of their systematic use in educational activities in such areas as Biochemistry.

5   **References**

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