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CONCEPTUAL CHARACTERIZACIÓN IN CALCULUS WITH TECHNOLOGICAL MEDIATION USING CONCEPT MAPS AS FOLLOW-UP STRATEGY

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Abstract. Calculus is the language to express basic concepts of various scientific fields. A solid understanding of Calculus by students should be a key process in the learning process of students of diverse fields, it allows for a better performance in various knowledge areas. The use of specialized mathematical software empowers the student to visualize and integrate the concepts at hand and allows for the simulation and modeling of phenomena that the student finds in his/her environment. This way, concepts gain a particular importance for each student, furthermore, its integration the integration and understanding are reflected by the construction of concept maps both inside and outside the classroom.

1 Introduction

The learning process is the result of interation and intervention activities, where the learning subects get support from other subjects and from technology in order to build conections with their environments. These connections become the place for the projects the subjects undertake as social individuals.

Starting in 2005, Eafit University (Medellín, Colombia) has undertaken a long-term research project aiming at observing the learning process that takes place when ITCs are introduced to the classroom.

The integration between technology and the learning process made us think of an "Ecology for Cognition". We built indicators to measure the impact of the use of technology on the didactical practices in the university, both in the short and in the long term. In the project we have observed the communication between students and instructors, as well as the intaractions among (i) students (ii) contents and (iii) context.

The transmission process was analized from the point of view of the transmitted values, cognitive strategies and the context (Debray, 2000). Concept maps were one of the used tools in order to discover the structure of the concepts at hand.

2 Elements for the intervention and development of strategies inside the classroom

In the traditional teaching and learning of calculus, very few collaborative spaces are created by the instructor or by the curriculum. These spaces should allow students to collaborate among them and use their insights in order to solve practical problems. Georg Cantor (cited by Davis & Hersh, 1998), states that "The essence of Mathematics is their freedom. Freedom to build, freedom to propose hypothesis". Based on this statement, we proposed to develop a mathematical thinking on the students based on their environments, as well as practical problems related to their professional lives.

During the experience, students had to undertake activities in which they could develop collective and multidisciplinary projects related to multi-variate calculus. In parallel, they had to formalize and sinthesize mathematical explanations of real-life objects. This process allowed them to exchange questions and answers, compare ideas, regulate and validate the knowledge, all of this guided by the instructor. The process, in turn, allows students to understand how to create and validate mathematical statements.

Students were introduced to specifical situations by the use of Pocket PCs running 3D-Universal[1]. The software allows students and the instructor to visualize and manipulate surfaces and their corresponding equations. The instructor led the students in the process of detecting real-life objects that looked like the mathematical surfaces. They recognized external information from a process involving analysis, processing, deduction, building of feasible solutions; thereby allowing them to understand multi-variate calculus as a powerful language to create (or re-create).

Formulation of questions allowed students to reach conclusions or open new paths to explore (Elder & Richard, 2002). Some questions were used to emphasize concepts. Other questions were used to lead students to

[1] A sofware we designed for the project.

a cognitive “conflict”, allowing them to build their own arguments and connect the new concepts with older ones in a non-straightforward manner. A two-way communication was established between the instructor and the students. The process of formulation of questions, proposition of hypothesis and possible solutions, improved the understaning of the various processes. The use of technology fostered the creation of meaningful concepts on the subject at hand.

2.1 Use of collaborative tools in the construction of solutions to calculus problems

Collaborative work for problem solving is important to collect information from the participants during the experience. The analysis of the anwers is important for the student to expand their networks of concepts. During the Multi-Variate Calculus course, the *Forum* allowed students to collaborate in an asynchronous manner for solving typical problems.

Students had access to the following resources: The text book, a computer with Internet Connection, Eafit Interactiva[2], links to applets related to the subject at hand, Pocket PCs running 3D-Universal, Cmap Tools, basic Office software and math software, such as Derive and MatLab. They could also get support from the instructor.

Students were asked to share ideas, formulas, graphs with their peers using Eafit-Interactiva. We observed three aspects when reviewing the use of the *Forum*: (i) It is not easy to communicate, with words, what students think, therefore, (ii) students use graphs, equations, sketches, etc. to communicate, which, in turn, allows them to (iii) reach a collective agreement on the various forms to approach the problem. This shows a process of meta-learning (or learning to learn). Students identify the ways to construct hypothesis and how these are accepted or rejected according to the problem (meta-thinking).

The analysis of problem-solving by the students allows them to approach knowledge from a personal-meaning point of view. This allows them to start cognitive and meta-cognitive processes based on perception, understanding and modelling (Chavez, 2006). The first step is perception, induction and valuation. Connections are created. The second step is understanding (explanations), where thought is re-accommodated and he mind searches concepts in familiar stimula. The last step involves the creation of a representation (modelling), semantics and language. This is where the student enjoys generating ideas, understanding and abstract reasoning, thereby improving autonomous learning.

In the learning process, spaces have to be created to allow students to freely express their ideas and to explore different forms to solve problems. Students should also be given a number of tools to build their solutions.

2.2 Concept maps in the synthesis process of calculus concepts

Concept maps are a tool to explore and evaluate the relations that a subject has in relation to a concept, subject or topic in his/her mental structure (Novak, 1999), and are a powerful tool to observe the relations that a student or group of students create in relation to a concept or subject.

With the use of concept maps to represent Multi-Variate Calculus concepts, the following cognitive processes are fostered: (a) Ability for induction, deduction and abduction, considered as competences for logical reasoning (Pérez Flores, 2006). (b) Ability for structuring, in a graphical manner, information. This ability is a competence of spacial orientation (Barra, Ramírez y Díaz, 2006).

During the process of research, the experimental group was asked to use concept maps in order to characterized the concepts, integrate and evaluate the processes. The students did use concept maps in order to synthesize a unit of study and at the end of the course, they were asked to use concept maps to summarize their experience. The following questions were proposed:

- What basic concepts of Calculus have I studied?
- How to these concepts relate to each-other?
- What real-life applications does Calculus have?
- How can I connect the concepts to the applications?

[2] http://isis.eafit.edu.co/ei/

One of our objectives was to observe the relations and contrasts of students in the control and in the experimental group. (Students in the control group did not had technological support and did not use concept maps during the course). In order to compare, the control group was taken to the computer room, and were asked to create concept maps to answer the same questions as the experimetal group. There were clear differences between the maps build by students in the exerimental and the control groups.

Students in the experimental group, quickly created connections between the concepts they have previously learned and the applications. The concept map in Figure 1 is a representative example. There is an outstanding number of cross-links, and the language is used in an appropriate way. On the other hand, a student in the control group created the concept map described in Figure 2, with few concepts and limited connections. At the end, we talked openly to each group.

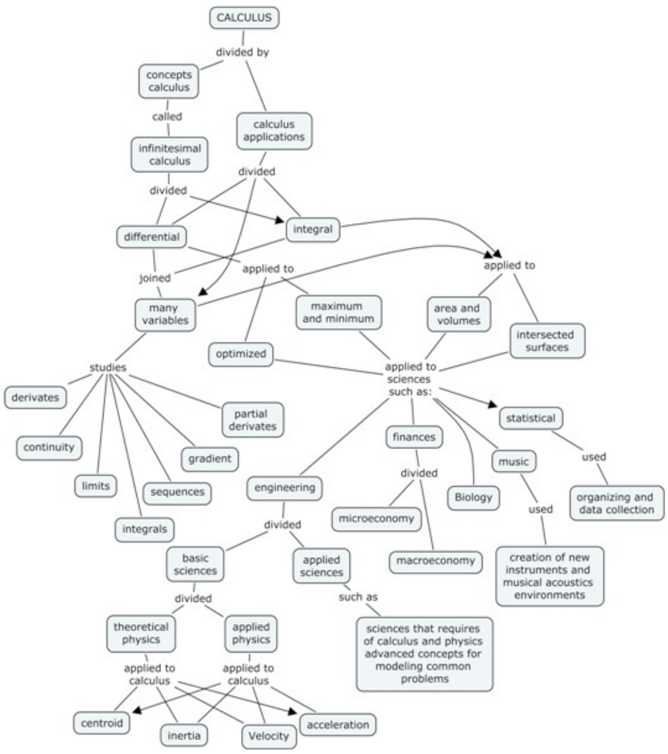

Figure 1. Concept map designed by a student in the experimental group.

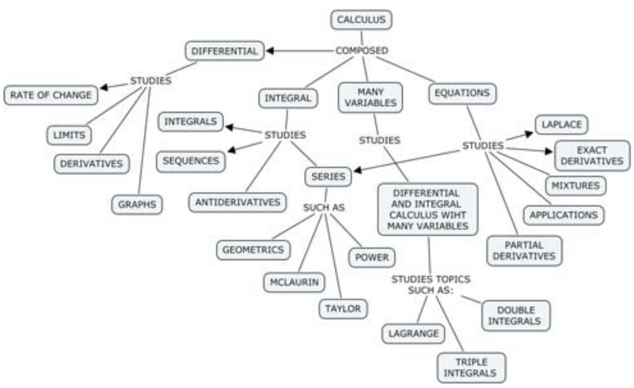

Figure 2. Concept map designed by a student in the control group.

The construction of concept maps allows both the student and the instructor to evaluate the regulate the understanding of the concepts that students have been exposed to during the semester. The observed difference between the concept maps elaborated by the two groups (differences in conceptualization, assimilation, appropriation and use of the course topics) was basically due to the use of technology mediators by the experimental group.

3 Conclusions and future work

An active relationship of the instructor with technology is fundamental for the transmission of concepts in the process of building mathematical knowledge by the students, both on an individual and collective manner. In our experience, technology mediators were were used to foster conversations in which students expressed their reasonings freely, both about their own solutions as well as their peers', thereby creating a process of mutual respect and confidence. This framework was described th the instructor as follows: "This type of course forsters participation of the students with the contents, the quality of formation and processes of interaction. It added a new dynamism to various processes, among them the exchange of ideas. At the same time, it allowed for the evaluation of the individual and group evolution, through the implementation of individual and group assignments."

Based on the supplementary activities proposed by the instructor (real-life objects, virtual forums, concept maps and identification of objects in their environment), students had the opportunity to approach learning from different perspectives. Each activity had different technological support. Since students were comfortable with technology, they could easily use the PocketPCs, even for the first time in their academic contexts.

The instructor considers that the use of technology allowed him to approach learning from the processes of induction, deduction and abduction reasoning. The graphical support of the technological tools also allowed students to understand several concepts easily. Concept maps fostered the creation of connections among the concepts. Technology also allowed students to foster the understanding of relations between the mathematical concepts and real-life applications.

The use of technology in various activities in the classroom, allowed students to recognize other communication and evaluation strategies, permitting the construction of knowledge and self-regulation of learining. The use of technology also motivated students to the use of other information sources and created new ways of student-instructor, student-student and student-context interation, starting from a collaborative work methodology.

Thanks.

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