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# **Virtual collaborative learning environments with the Telepresence Platform supported by the Teaching for Understanding pedagogical framework: experiences in Higher Educational process in Colombia**

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## **1. Introduction**

Currently, most distance-education processes are mostly based on web-published contents. Interaction among the instructor and the students happens in an asynchronous manner, using forums, e-mail or http contents like Moodle. We claim that this interaction is not appropriate to explain complex concepts. Experiences reported within our team in Colombia show that the use of shared virtual environments with a Telepresence tool has fostered interesting interactions among the instructor and the students that would be difficult to attain even in face-to-face education. Additionally, when students interact with virtual objects, the abstraction effort is reduced, thereby fostering the acquisition of knowledge and skills.

In a similar manner, designing courses following Teaching for Understanding pedagogical framework, allows the instructor to focus on the development of competences and skills in students, and this is a fundamental objective of current education systems. The pedagogical models used in distance-education are mostly based on traditional approaches. In other cases, the pedagogical approach is reduced to the interaction with a technological tool.

The Telepresence tool, developed by EAFIT University and University of Quindío in Colombia, permits sharing of courses among the institutions. Instructors from one institution can teach students of the other one, thereby sharing the positive features of each course. The Telepresence tool enables that courses and talks are shared among Higher Education Institutions and individuals who are located in different places. When using our Telepresence tool, instructors create a shared virtual collaborative environment that allows

the instructor and the students to interact from remote places. The tool allows users to load graphic files to support teaching, and, more interestingly, to load a 3D interactive simulation of the concept at hand. Learning Objects supported by the Telepresence platform, with 3D content, are built under the SCORM 1.3 – 2004 standard.

The use of Teaching for Understanding allows the instructor to keep a log of each and every student's progress, and to focus on the development of competences and skills of the course at hand. These types of experiences that involve pedagogy and technology allow for a rapid incorporation of novel technologies, such as Virtual Reality and high-speed networks. Our experience with this project has been that successful practices can be shared between institutions when using the Telepresence tool. The ultimate goal of the project is to create and maintain a repository for creating and sharing learning objects among institutions.

We want to propose the creation of virtual collaborative learning environments to support courses in Higher Education, designed it under the approach of the Teaching for Understanding. The use of new computational collaborative technologies should be complemented with a pedagogical framework, so that both ensure the development of skills and abilities in the students

## 2. Presentation

During the years 2003 and 2004, the laboratory of Virtual Reality of EAFIT University developed the project "Telepresence Applied to Higher Education". This project was supported by Colciencias (Colombian Administrative Department for the Development of Science and Technology) and by EAFIT university. As part of the project, it was constructed a prototype of Telepresence System that combines virtual reality, audio and video on Internet to form a collaborative virtual world. This system allows the instructor and his students to interact synchronously, in spite of physically being in different places. The results of the first stage, using the prototype, allowed to conclude that the use of the system with an associated pedagogical approach (in our case, Teaching for Understanding), allows the students of distance education to obtain equal or superior levels of understanding to those that are offered by physical on-site presence courses. During the years 2005 and 2006 the platform of Telepresence was used by EAFIT University and the University of Quindio in courses of Physics applied to the construction. Excellent results in courses of distance higher education were obtained. Between the years 2008 and 2009, the universities previously mentioned develop the research project called "Evolution of the Telepresence tool and its application in distance education in regions of the country by using RENATA". It is supported by the Ministry of Education of Colombia and Colciencias. The aim of this project is to improve and to implant the Telepresence tool in a mass manner (open). In such a way, the universities impart courses in which the professors are in their campuses while the students are in the regions under the influence of the participant universities. In order to get a mass use of the platform of Telepresence, the Academic National Network of High Speed of Colombia - RENATA is used. This network is administered by the Corporation RENATA, of which the Regional Academic Networks of Colombia, the Ministry of Communications, the Ministry of Education, and Colciencias are member. The Academic Networks of Advanced Technology facilitate the collaborative academic work. They allow to have access to laboratory equipment, to transfer high volumes of data, to develop applications with distributed processing and to support complex and crucial experiments

for the research. Similarly, they facilitate the communication and the teamwork among researchers who are geographically dispersed in different regions or countries; and the development of academic, scientific and technological joint projects. The series of interconnected Advanced Academic Networks conforms what could be called the World-Wide Network of Investigation and Development (ReD+I). From Colombia, we can only have access to this Network through RENATA.

The objective of our research, in the long term, is to contribute to the improvement of the coverage and the quality of the education in Colombia. In our country, like in many developing countries, the most qualified instructors and the educational institutions having the highest quality are concentrated in the great large cities and what is more, in its privileged sectors. Therefore, there is a large number of Colombians who do not have access to an education of high quality, because they live far away from the privileged zones and/or because they are not able to pay the costs associated to their education. To implement projects like the one we present in this proposal, would allow the high quality educational institutions to extend its coverage and to reach the groups of people who cannot accede to this type of education.

Two fundamental aspects are aimed with the development of this project: (i) To turn the Telepresence platform into a huge product that can be used in the real conditions of the technological infrastructure of our country. It can operate on common lines of communications on Internet, or on Academic Networks of High Speed. (ii) To allow that other Colombian universities use the product and develop new modules, under the only condition that these ones can be reached by other universities of the country. In this way, a bank of experiences in the use of the Telepresence tool, regarding different fields of the knowledge, is built. The achievement of this objective depends on the commitment of the universities that are a pilot in the development of the project. In this way, it is expected that the new developments benefit the educational community of the country.

The Virtual Reality is a tool widely used for training and education. The Collaborative Virtual Reality allows that several users interact in virtual surroundings. There are some projects that have explored the combination of audio and video with Collaborative Virtual Reality but, as far as we know, there are no applications to the education, as in our project. The proposed project consists of two stages. In the first one, a technical work is carried out to produce a stable platform that creates a collaborative virtual atmosphere with transmission of audio, video, and objects of 3D learning. In the stage of extension and completion the two universities worked with a pilot test to use the platform in real environments of distance education. It was used a pedagogical approach based on the pedagogical framework Teaching for Understanding. Simultaneously, the professors of the universities received instruction about the educative model Teaching for Understanding and about the use of the tool. In this second stage, the new developments carried out by the pilot universities were used. At the end, the experiences of both the developers of the project and the professors were gathered. With the results of these tests, it is expected to advance in the development of the product and its corresponding documentation. Then, it will be put at the disposal of other educational institutions within the country.

### 3. The Telepresence Platform

The Telepresence tool is an application developed in Java language. It is composed by four environments or modules: an environment of teleconference (audio and video), an environment of virtual reality, a module to run learning objects and an environment for the presentation of slides. They have the following general characteristics:

#### 3.1 Virtual Reality Environment (VR)

This module consists of a collaborative virtual environment in which the professor and the students can interact with 3D shared objects. These objects depend on the specific contents they are used. The participants know, in the virtual environment, the location and/or attention of their counterpart due to the telepointer objects (3D arrows). The professor can interact with the virtual environment through an electromagnetic sensor of position (Polhemus), if it is available. In this case, its telepointer can be used analogously to the mouse pointer, in a 3D space. Otherwise, or in the student's normal case, the telepointer indicates the position of the counterpart's point of view and the interaction is made through the mouse. Only the professor can load and change the contents. The content that is loaded in a VR atmosphere consists of two parts: a panel where the 3D objects are displayed (virtual reality panel) and another panel that displays formal information or specific control of the content; it is called Control Panel. The possible interactions within the virtual environment and the interaction with the objects of the contents correspond to the selection and drag of the virtual objects, the change of the point of view within the three-dimensional scene, and the direct interaction with the information panel. All these interactions can be replied in both views, in such a way that the state of the shared environment always is consistent. Members of another Project at Eafit University have developed a 3D calculator. The calculator allows users to write the equation of a function involving X, Y and Z variables, and plots the corresponding surface. This software is written in C++. In order to add the functionality of the 3D calculator to our Project (written in Java), we are making use of JNI, a software tool that allows a Java program to call functions written in C. This allows the Java program to retrieve a mesh of points in space that will be later plotted in the Telepresence tool using Java and Java3D. Cartesian, polar, spherical and cylindrical coordinate systems can be used. This functionality was requested back in 2005, when the Telepresence tool was used in a course on Physics for Civil Construction professionals.

#### 3.2 Environment for the Slides

This environment allows using visual aids (slides type) to support the development of the session. The controls to handle the slides are only present in the application that the professor runs. The environment for the slides and the Virtual Reality Environment share the same panel being mutually excluding; when the environment for the slides is active, the Virtual Reality Environment is not, and vice versa. Only the professor can change from a panel to another one.

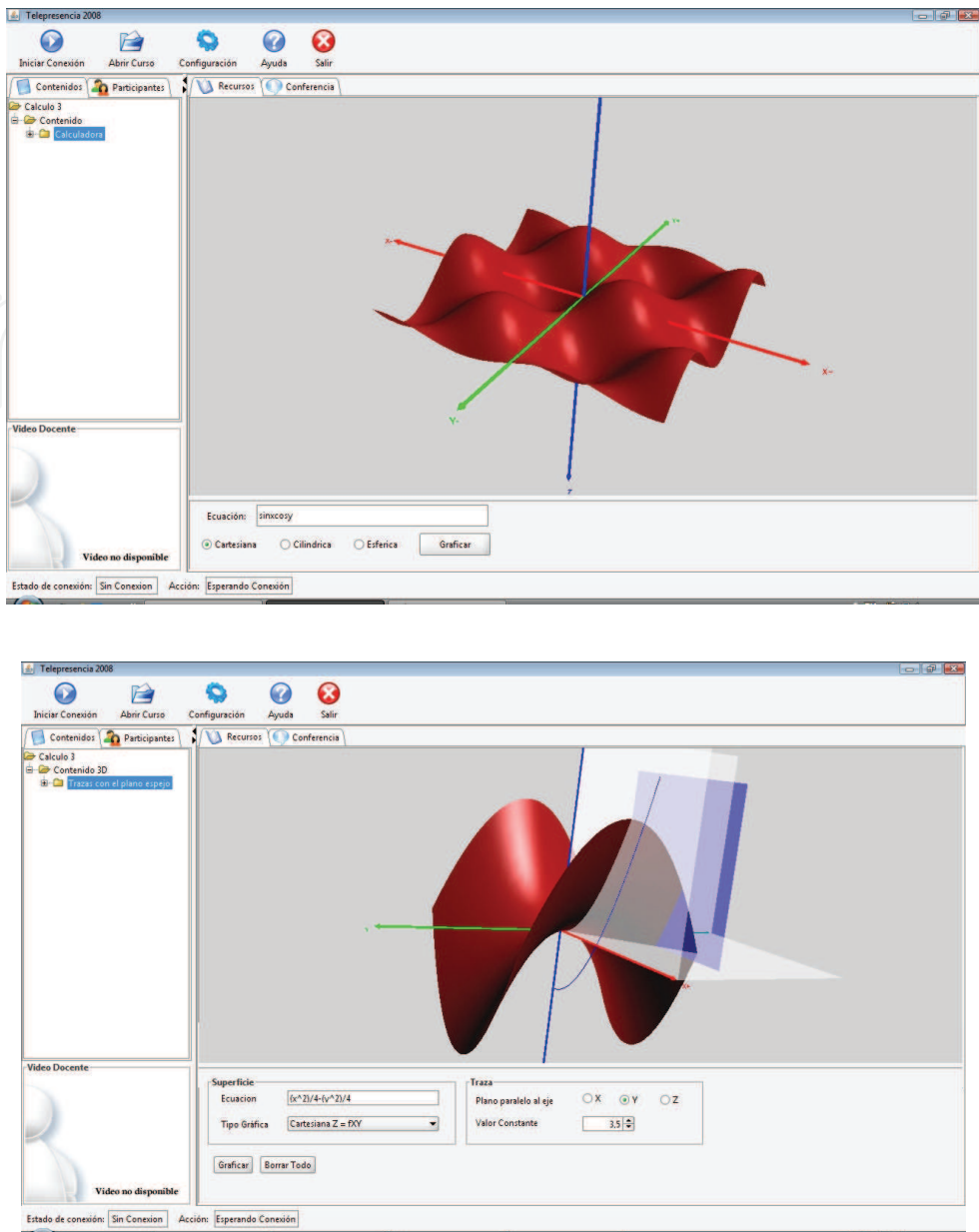


Fig. 1. Examples of 3D shared objects in Telepresence Platform.

3.3 Teleconference Environment

The current teleconferencing system is based on the “Java Media Framework” (JMF), which has not been updated since 2003. Since we are not aware of other java based applications for handling voice and video, we are considering the use of external tools. We are currently evaluating several platforms, including: jffmpeg, jvlc and FMJ. The first tool to evaluate will be JVLC, based on VLC. JVLC provide by developers from Universidad del Quindío have implemented a multi-point communications protocol that allows one instructor to communicate with several groups located in different places. These changes were done by extending the previous network protocol. A new message server was added creating a local cache of the remote users an API that can be used directly from the Telepresence application. VLC is, by itself, a video-stream server.



3.4 Learning Objects Module

We have also implemented a program that packs each content as a SCORM learning object, based on the RELOAD Editor (<http://www.reload.ac.uk/new/editor.html>). These contents can be sent to remote users, when the content is not stored locally. After the content is sent, the tool will allow users to interact over the 3D scene.

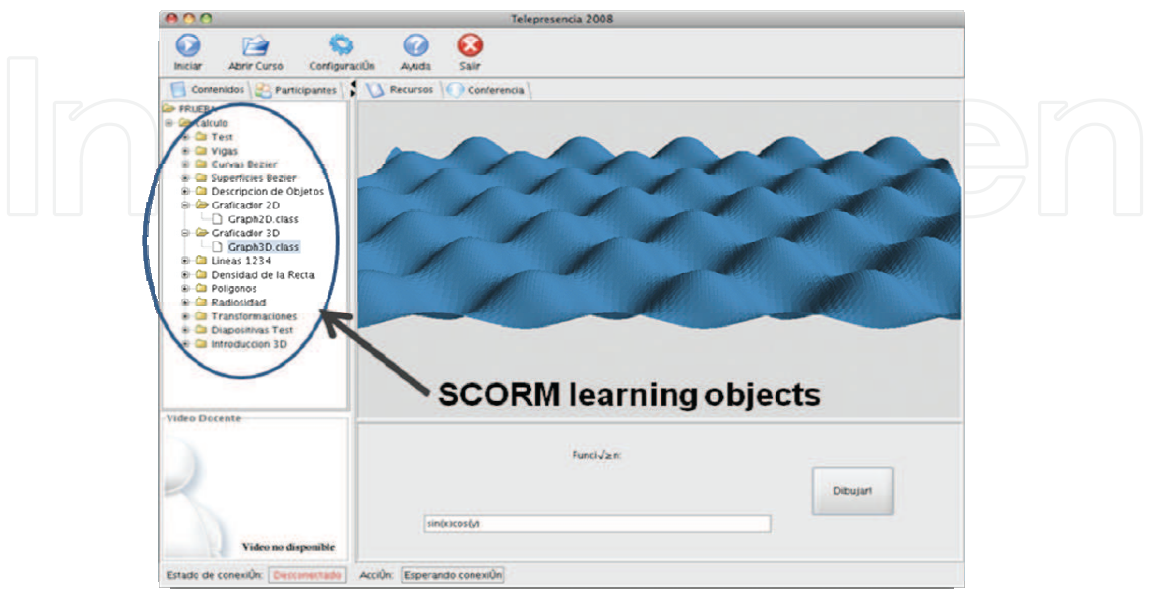


Fig. 2. Example of a SCORM-packaged content loaded in Telepresencia tool.

3.2 General Architecture of the system

Here we summarize the general architecture of the Telepresence platform. The main characteristics of this architecture are the following:

- Model of session client/server. Transmission of point-to-point messages (only between a professor and a client student, who represents a group of students in a same location).
- Contents completely replied (there is a copy of the virtual environments models for each content in each participant machine), and transmission for changes of state (not changes of models).
- Transmission of audio and video in real time between the parts. Different ways of interaction.

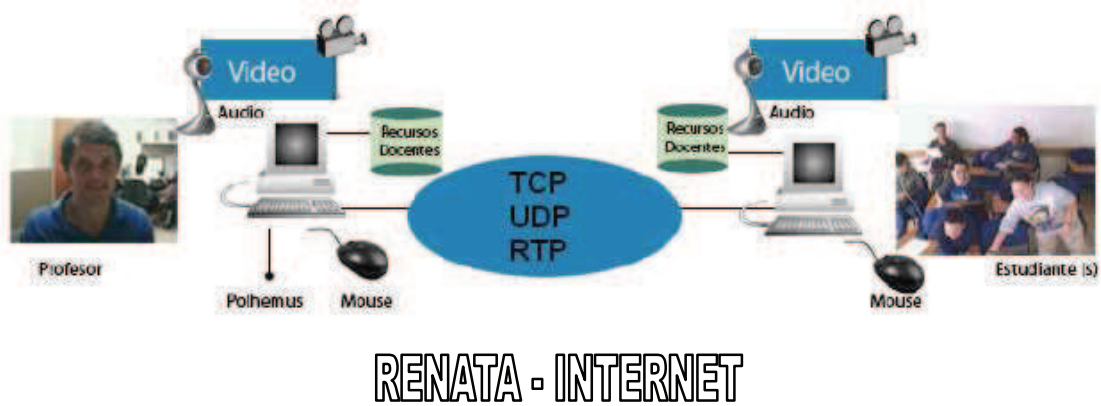


Fig. 3. General Architecture of Telepresence.

Our research project aims to promote the interinstitutional collaboration for the development of proposals in distance higher education. This proposals must integrate the Telepresence tool and the Teaching for the Understanding” to the design of instruction modules to be imparted at distance. The project looks for the integration of the technology and the pedagogy as tools that allow the students to acquire the knowledge, being motivated to understand and transform it according to their personal and social needs. For this reason, we elicited technical and pedagogical questions during the development of the project:

- How to combine messages of audio, video and virtual reality in the proposed system, getting an adequate interaction between the instructor and the students?
- Which logistic and pedagogical factors allow that an education institution, different from the original creator of the prototype, implement the product of Telepresence in a real environment of teaching successfully?
- How to spread the results of the research in institutions that need logistical and technical support to extend the coverage in higher education, and to contribute to the improvement of the pedagogical quality within the country?

#### **4. The pedagogical Framework of Teaching for Understanding**

The understanding, the assimilation and the suitable use of the knowledge are the three fundamental purposes of the Educative System. The understanding has a central function due to the following aspects. First of all, the things we can do to understand better a concept are the most useful to remember it. Thus, to understand and to keep information in the memory is useful to look for rules in the ideas, to find examples, and to relate the new concepts with the previous knowledge. Secondly, the knowledge cannot be used actively if there is not understanding. The assimilation is related to our brain capacity to remember a long term concept or event, therefore if we do not have an adequate understanding we will forget in short time. On the other hand, if the concepts are not understood and assimilate suitably, they cannot be used and transformed by the learner.

Several pedagogical studies have explored methodologies to teach instructors adopt strategies that allow students to attain a better and more profound learning. One of these studies is the one led by researchers of Project Zero, at the Graduate School of Education at Harvard University, who have formulated the Teaching for Understanding (TFU) pedagogical framework. TFU proposes both instructors and students to participate actively in building and acquiring knowledge. Ausubel, when creating the meaningful learning approach, suggests that learning implies a restructuring of ideas and concepts within the student’s cognitive structure. Ausubel also proposes the use of Conceptual Maps as a strategy to acquire new concepts. Concept Maps serves as organizers of previous knowledge and as a strategy to approach new concepts. Concept Maps can increase meaningful learning, helping the student to discover new relationships between the new concepts and those existing in his/her cognitive structure.

When a student is exposed to learning new concepts, knowledge has to be presented in a way that captures his/her attention. In this sense, Ausubel provides the following criteria to structure teaching: (i) Knowledge to be learned has to be clear and explicit, presented in a language according to the student’s previous level, (ii) The student has to have the previous relevant knowledge, (iii) the student has to choose to learn meaningfully, in other words,



he/she has to be motivated towards learning. When a student learns, he/she builds meanings, i.e., organized cognitive structures that are related to current knowledge, thereby producing meaningful learning. When relationships are established in an arbitrary form, or are not generated at all, memorization learning takes place. Memorization learning is easily forgotten.

One of the strongest motivations that human beings have in order to attain a concept, is the possibility of applying it in the solution of existing problems. In order to attain desired goals, the student must have an appropriate set of pedagogical tools. In TFU, the "portfolio" is used. The portfolio is a collection of activities and tangible resources that the student uses and builds during his/her learning process; it is the student's learning log.

The construction of a portfolio can be divided in three phases: (i) Concept Exploration (ii) Guided Research and (iii) Final Performance. In each of them, students show their work to their peers, the instructor and experts. The different phases are described next:

- a) Concept Exploration. The student's environment is explored in relation with the topic at hand. In these phases the individual or group's interests become evident.
- b) Guided Research: Each student or group, with the help of the instructor, selects a Project in which to apply the concepts of the concept at hand.
- c) Final performance: Students present their findings and the solution they have implemented. They present the performances they have done during the project.

The portfolio is built by students and they use it either to revise concepts or cognitive relationships, or to create new ones.

The instructor's relationship with the student plays a very important role in the learning process. He/she has to favor the presentation of new knowledge in an orderly and appealing fashion, and should try to foster the student's interest on learning by applying teaching strategies that encourage learning.

TFU integrates various pedagogical theories in order to foster the students deep understanding of the proposed contents, particularly those that are fundamental when building the knowledge of the subject. For this purpose, it is important to link the students' interests with meaningful real-life situations. TFU does not propose a unique way to be applied, and for this reason the way how knowledge is presented to the student and the instructor's own understanding play a key role in the process.

#### **4.1 The understanding in the Colombian school curriculum**

Although the understanding is a goal in the school curriculum, it is not clearly defined by the Colombian Ministry of Education and the professors have not a clear idea about the matter. What issues must the learners understand? What is the meaning of understanding a concept? How can an educator know when a student has understood a concept? In the curricular designs of the institutions we can find phrases like this one: "The student understands this or that thing..." However, the understanding cannot be measured by a thermometer or by multiple choice tests. The understanding is not a state of possession but a state of capacity that the student can demonstrate when solving diverse kinds of problems. When something is understood, the individual is able to transform the information into something productive. The activities that can be developed from a concept reveal understanding. These processes are called understanding activities. For example, we suppose that we understand the Pythagorean Theorem "The Square of the hypotenuse of a right triangle is equal to the sum of the squares on the other two sides". When exposing this

concept, the professor must reflect about what type of understanding activities the students should develop to understand this geometry theorem. The explanation, the exemplification, the application, the comparison and contrast, and the generalization are some of them. Some of these activities are simple; for example, it is easy to find examples of the Pythagorean Theorem by measuring a soccer field, a classroom or a house. However, other activities are more demanding, for example, the generalization. This variety of activities reveals some important characteristics of the understanding. The understanding is identified through the creative activities in which the students “go beyond the provided information”. The understanding consists of a qualification state to exercise such activities of understanding. The different understanding activities require different types of thought: analogical, metaphorical, logical, and creative; consequently, it is required the application of different intelligences types.

The understanding is not something that is “acquired or not acquired”. For this reason, it is quite important that the professors devote enough time and efforts to prepare the understanding activities they will present to the students. On the other hand, the understanding is open and gradual. With respect to a determined subject, an individual can understand little (the development of few understanding activities) or understand a lot (to develop many understanding activities), but s/he cannot understand everything because there are new extrapolations that have not been explored, therefore it does not exist the ability to do them.

The understanding is a complex mental process that requires the intervention of the memory and thought systems, the codification and perception, and the inferential operators based on previous behaviours and contextual factors. The Understanding becomes a constructive process, in which the information of a stimulus or event interrelates with previous information registered in the human being memory.

## 5. Course design under the TFU - Overview

The way how we relate to our environment and the capacity to extract various properties from the objects in it, are key issues in the teaching-learning process. Based on these ideas, the course on Multi-Variable calculus was chosen, since it allows students create relationships between the environment and the mathematical concepts, as well as the concepts covered in other courses in the same semester. For this reason, the instruction modules to be used with the Telepresence tool were designed based on the syllabus of the Multi-Variable Calculus subject. Figure 4 presents the training process of TFU for teachers of Calculus in University of Quindío.



Fig. 4. Training on TFU for the whole research team – June 2008. Copyright® University of Quindío, 2008.

The Multi-Variable calculus course is part of the Engineering Curriculum at the universities that take part of the Project. The design of the course was built around the question “*How can I to apply Calculus in my field of study?*”. With this question we try to encourage students to relate the course with other subjects in their curricula, and also with concrete objects in their environments. As part of the course, the students look for real-life objects that can be modeled with the equations covered in the course.

Calculus-related concepts that are particularly important are: vectors on the plane and vectors in space, partial and directional derivatives, multiple- and line-integrals. These concepts lead to the concept of “surface”, therefore, students appreciate how the surface's concept is key for understand the Multi-Variable calculus course. In this course, students are asked to establish relationships between real-life objects and the concepts of the course. For this reason the concept of surface was defined as one of the key concepts.

For each concept in the course, several ways were proposed for students to demonstrate their deep understanding:

- a) *Concept Exploration*. Students created an idea network, in which students put together the ideas they have about calculus and how it's related to their life. Concrete applications of calculus in various engineering fields were presented by the instructor. During this exploratory phase, students chose a problem to be solved by them. The problem was supposed to be related to their field of study.
- b) *Guided Research*. Students starting solving the chosen problem, using the course contents and the technological tools to support the process. During this phase, students created a report with the problems they faced and the solutions they found
- c) *Final Performance*. Each student demonstrated his/her understanding in a final Project that was presented to their peers.

### **5.1 Use of the Telepresence tool in the multi-variable calculus course**

One of the main objectives of this Project is to use the Colombian high-speed network (called RENATA). It links the research community in the country with the international research community, as a platform to run our Telepresence tool. The added value of the use of RENATA as communication platform is its power to foster communication and collaboration among the various communities involved.

RENATA is the academic high-speed network in Colombia. It is linked to other academic high-speed networks in the world and allows the Colombian academic community to share data, information, lab equipment and transfer large amounts of data with other communities in our country or abroad. Also, RENATA enables the use distant of lab equipment and access to academic information between Universities at Colombia.

The Telepresence tool, running over RENATA, will allow an instructor from Eafit University to teach a Multi-Variable calculus to students at University of Quindío. It will also allow an instructor from University of Quindío to teach students at EAFIT University. In both cases, the instructor and the students will interact in a shared virtual environment. The 3D content to be used is being built by the development groups.

### **5.2 Applicability of the Teaching for Understanding Pedagogical approach and the Telepresence Platform in a Multivariate and Vector Calculus Course**

In order to start the experience of developing the Multivariate and Vector Calculus course from the Teaching for Understanding pedagogical approach, the professors received instruction about this method. The instruction consisted of two parts, a conceptual and practical foundation about the pedagogical approach and the introduction to the use of the Telepresence platform, executed on RENATA, to teach the Calculus course at distance. Additionally, we questioned the students who had attended the Multivariate and Vector Calculus course about the main difficulties they found, the main contribution of the Vector Calculus to their professional formation, and its applicability to daily life. We also ask for the suggestions and recommendations they had to improve the development of the course. The students agreed that it was necessary to modify the methodology used to teach the academic subject. They considered that it was important to identify clearly the applicability of the Multivariate and Vector Calculus course in daily life. Taking into account this information, it was possible to have a preliminary view about the pedagogical approaches and the methodologies used in the development of the subject. It was evidenced a very low level of motivation, apathy and little applicability. The students considered that this course is too complex and consequently, it is necessary to take it several times. Besides, they maintained that the course is quite important for the Civil Engineering students, but not for the Electronic and Computer Systems students.

To develop this experience, we took three groups of students who attended third semester of the Engineering school. These groups were heterogeneous since they were students from Computer Systems, Electronic, and Civil Engineering. The average number of students per group was 45; some of them attended this subject for second or third time (situation that generates low motivation). The students were between 18 and 25 years and the courses were daytime demanding the students' presence in the classroom.



### 5.3 Expectations in the development of the subject

The three groups of students attending the Multivariate and Vector Calculus course were asked to answer a previous knowledge test to identify the specific concepts related to the subject. This pretest included several concepts (i) the daily life situations where some concepts of the Vector Calculus were observed (ii) the mathematical concepts that were used in the Calculus learning (iii) the real situations where the students had used the Vector Calculus.

The first aim when applying the pretest was to identify the student's previous concepts and the relations they established with some specific concepts of the Multivariate and Vector Calculus course. The pretest included fifteen (15) general knowledge questions about the subject. The second aim was to allow the students to express freely their thinking about the subject, the applicability they had learned in previous subjects and the intuitive relations between the Multivariate and Vector Calculus and its applicability to the students' professional formation. It was an open test that did not allow closed answers; the students were asked to respond all of them. When analyzing the answers given by the students, we evidenced the following aspects.

- Most of the students affirmed that the Calculus is evidenced in daily life when developing Civil Engineering projects like bridges, buildings and other constructions. Some students mentioned the elaboration of advanced computing programs and the analysis of budgets. It is important to highlight that it is not evidenced a students' high level of argumentation when describing real and specific situations for the applicability of the Calculus. Since there were students from different programs, we expected diverse applicability and contexts.
- Most of the students consider that they have not used the Calculus on their lives. Some other students related the Calculus to the speed or they were not sure if they have used it or not.

Generally, the students perceived the Multivariate and Vector Calculus like an important element in their academic activity, but they could not explain clearly how they could apply it to their professional performance and their daily life. Most of the students related the Multivariate Vector Calculus course to diverse applicabilities like automobiles route; measurement of distances, speeds, and lands; and the construction of bridges and buildings. Nevertheless, they did not support clearly the applicability of the Calculus to their professional formation as futures Electronic, Computer Systems and Civil engineers.

## 6. Pedagogical Approach: the Multivariate and Vector Calculus from *Teaching for Understanding*

Our main purpose when designing the course from the Teaching for Understanding pedagogical approach and the use of the Telepresence platform is to develop and to strengthen the students' understanding, the flexible thought and the processes of action-reflection taking into account the meaningful experiences they found in their daily life.

In order to determine these components we invited the professors who teach the academic subject to participate in several meetings. Initially, we questioned the professors to explore the concepts and issues they considered relevant for the development of the Multivariate



and Vector Calculus course. Then, we gathered and grouped the information to design a conceptual map containing the issues to consider in the development of the course. Then, we developed an instrument to know the perception that each professor had about the applicability of the Calculus to daily life, the main contribution of this subject and the difficulties found in its development. Later, we distribute this information to the professors who finally agreed to implement the Teaching for Understanding pedagogical approach. We defined the pedagogical guidelines to follow, the methodology to use, the type of activities the students would develop, the way of assessment, and the appropriate moments to use the Telepresence tool. Taking into account these meetings and agreements, we designed the following pedagogical proposal.

### 6.1 Conductive Wires for the Multivariate and Vector Calculus Course

The concepts related to the Calculus through which diverse situations of the plane are expressed, are the vectors in the plane and the space representing them in the diverse surfaces, the directional and partial derivatives, and the lineal multiple integrals. These terms lead towards the concept of Surface. In some variables of the Calculus course, the students were questioned because they established relations between objects of the real life and the different concepts studied through the course. For this reason, the Surface was one of the key aspects to be understood.

To present the concepts to the students, it was found that the best way was to formulate an affirmation encouraging them to think and reflect about the importance of the Multivariate Vector Calculus. With this strategy, it was expected that the students were motivated to give the answers and to research about the concepts they intend to learn. Thus, the conductive wire used is *"the students would appreciate how the concept of surface is a key for the understanding of the Calculus"*

### 6.2 Generative Topics for the Multivariate and Vector Calculus Course

After analyzing the thematic axes of the subject and their relations with other disciplines, the topic defined was the Calculus itself. Thus, it was made a reflection about these relations, the professors' and student's interests and the context. Accordingly, the generative topic was denominated *"How can I apply the Calculus course to my career in a comprehensible way?"*

### 6.3 Goals of Understanding for the Multivariate and Vector Calculus course

- The student will develop understanding by determining and relating the fundamental concepts of the Multivariate and Vector Calculus course in a daily context.

To achieve the previous goal the students will understand:

- The vectors in the plane and the space representing them geometrically in the daily situations they face.
- The concepts of the partial and directional derivative.
- Multiple and lineal integrals through its applicability in the surroundings.

#### 6.4 Phases of the understanding performances

In order to define the activities proposed for the understanding performances, three phases were proposed. They must be accomplished in different moments of the class. The Understanding performances defined are the preliminary performances, the guided investigation and the final performance of synthesis.

##### Preliminary Performances

The aim of the Preliminary Performances is to allow the students relating the Multivariate Vector Calculus to their surroundings, and its applicability to their professional formation. The activities proposed are the following ones.

##### Exploration of the topic (Phase I)

- Through the elaboration of a network of ideas, the students stated all their doubts and preconceptions about the Calculus concepts and about the objects and phenomena they related it to their daily life.
- The professor exposed concrete examples to evidence the applicability of the Calculus to the students' careers (Civil, Computer Systems and Electronic Engineering).
- Later, the exploration of the topic (phase I) is started through the open question "How can I apply the Calculus subject to my career and what important issues I can solve by using the Calculus subject in my career? The students were asked to investigate on this question.
- The students conformed work groups and researched about the Calculus subject. They consulted about the Calculus applicability to daily life and interviewed diverse professionals who spoke about its usefulness. They also read about the history of the Calculus and explored constructions and objects that allowed them to perceive it in their real and daily life.

When finishing this exploration phase, the students chose a problem or project to be solved through the Vector Calculus. Each group described in detail the kind of problem they wanted to solve and the ideas they have to solve it.

##### Guided Research (Phase II)

The guided research allowed the students choose a structural element with which several concepts of the Multivariate and Vector Calculus could be explained and its relation between their professional role and daily life.

These are the activities that were developed.

- The students analyzed and solved the proposal they chose by using the contents of the course and the technological tools to support the development of the project. During this phase they were asked to report the advances of the proposal, the solutions that were proposed, the definitive design, and the contents to approach. All these elements had to be registered in the portfolio.
- In this phase the proposals began to develop conceptually the contents of the Vector Calculus. In addition, the students had to analyze how to transform them into a real and viable design in our context. The expected result was that they could visualize themselves performing their profession.
- Here is the description of some of the projects or proposals developed

- Construction of a cylindrical or circular building, The group described the physical parts that composed the building, its principal and secondary members, its shape, the different classifications according to its use, the property, the structural system, the disposition, and the general environmental, cultural and social impact. Additionally, the research that began in phase I, about the cylindrical buildings construction was retaken and improved. Later, the students selected the application to work with, the dimensions of the model on scale, and the calculations of the superficial area of the structure by using integrals. They calculated the volume of the building by using double integrals, outline the graphic structure in a three dimensional system, deduced the mathematical model that relates the structure with the mathematics (Calculus), and began the elaboration of the scale model of the building.
- Design of two Towers in hyperboloid of a leaf shape united by a horizontal straight cylinder in the middle of the height with spiral stairs employing the concept of the movement direction. To develop this project the students retook the information of the portfolio and improve it. The necessary concepts were the squared surfaces, hyperboloid of a leaf, cylinders and their classification, direction of movement, shapes of the buildings, classifications, and the exploration of the Quindío region in terms of general information, history, earthquake, representative places, Shopping centers, developing projects and needs of the region.



Fig. 5. Towers in hyperboloid of a leaf shape united by a horizontal straight cylinder proposed by students.

- Construction of a scale model concerning a pedestrian bridge based on the concepts of the Multivariate Vector Calculus which allow joining two buildings separated by an avenue. To develop the proposal, the students looked for the bridges history, classification, efficiency, and the urban situations of Armenia city. They retook and improved the information of the portfolio about Hyperboloid of a leaf and analyzed the benefits and advantages of the project in Colombian regions.

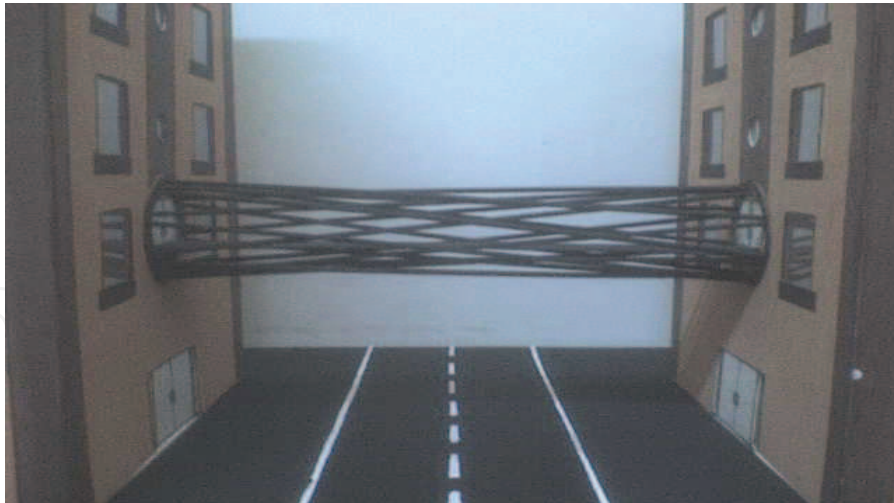


Fig. 6. Proposal for pedestrian bridge that allow joining two buildings separated by an avenue

### Final Project of Synthesis (Phase III)

The main objective of this phase is the socialization of the construction design or created solid. Each group of students described the processes they implemented for the design of the concrete object. They were listened to by their classmates, the professor of the course, a professor from the Computer Systems Engineering department, and a professor from the Pedagogical department. The activities proposed to guide this phase were the following ones.

- The students had to design a scale model of the construction or selected solid.
- The students identified the fundamental concepts of the Multivariate Vector Calculus subject according to the construction or the constructed solid.
- The students presented the constructed solid and supported the elements of the Multivariate Vector Calculus in the objects and structures of the building.
- The students presented a report where they summarized the diverse applications and manifestations of the Calculus in the construction or selected solid.
- The report also contained the analysis of each concept, the conclusions and recommendations, and the students' opinion about the work they carried out.
- This socialization of the final project was filmed and photographed. (we attached the filming, 2 CD)
- Interesting and new projects were developed:
  - Shopping center in the form of a coffee grain
  - Hyperbolic towers
  - Parabolic antenna
  - Hyperelipsoidal building
  - Water source
  - Water dam arc type
  - Bus stop
  - Ecological washbasin
  - Elliptical Sofa

6.5 Continuous Valuation

To fulfil the fundamental objective of the valuation, it is necessary to demonstrate to the students the progresses of the understanding of the Multivariate and Vector Calculus concepts in the execution of the projects. These are the criterions for a continuous valuation.

- The students consigned the advances of their proposal in the portfolio where the understanding performances were evidenced taking into account the preliminary performances, the performances related to the guided investigation and the final performances of synthesis.
- The advances achieved in each understanding performance were discussed in group.
- The exercises proposed by the professors were developed and the reports of the workshops were presented.
- The final project of synthesis was socialized. The team works exposed the result of the project to their classmates and expert people.
- The performances made in the development of the of Generative Topic were valued from the levels of the understanding (see the tables)
- The final project of synthesis evidenced the conceptual and practical competence about the contents of Multivariate and Vector Calculus. Additionally, It was evidenced the applicability of the Calculus to the formation of three kind of professionals (Civil, Computer Systems, and Electronic Engineers)

The results of this experience allow deriving the matrices of continuous valuation that appears bellow.

	INGENUOUS	NOVICE	APPRENTICE	EXPERT
<b>Oral Presentation</b>	Very low tone of voice. His/her presentation is not clear.	S/he is not clear in the explanation of the project. S/he reads the script or the written work exactly	S/he is able to separate from the script when it is necessary and S/he can explain and support the project His/her presentation is clear and coherent.	Suitable tone of voice. S/he demonstrates confidence. Coherent Presentation that invites to other analyses.
<b>Handling of the technical language</b>	S/he does not use technical language	S/he uses technical terms, but not always correctly.	S/he appropriates the technical terms	S/he uses the symbolic systems of the subject effectively.
<b>Handling of the questions</b>	S/he does not answer the questions or answer them erroneously.	S/he does not support the answers	His/her answers demonstrate support and discernment.	With her/his answers s/he demonstrates to master the subject.



<b>Interaction with the audience</b>	S/he does not consider the audience.	S/he rarely looks at the audience.	It maintains contact with the audience.	She/he adapts his presentation to cover all the audience and perceives people’s mood getting adapted to the situation.
<b>Performances of Understanding (Abilities)</b>	S/he uses a single way to explain the solid or the project of synthesis	S/he uses some different ways to explain the project but s/he does not relate them.	S/he uses diverse ways to explain the project and relates them.	The diverse forms to explain the project allow him/her to generate new knowledge and new applicability.

Table 1. Matrix of continuous valuation.

	INGENUOUS	NOVICE	APPRENTICE	EXPERT
<b>Applicability of the concepts of Multivariate and Vector Calculus in the elaboration of the project or solid.</b>	S/he does not identify the concepts of the subject to construct the project or solid	S/he mentions some concepts, but s/he does not explain clearly how they were applied.	S/he mentions the concepts and describes how they were applied.	S/he explains which concepts were used and argues why they were used and not others.
<b>Mastery of the concepts</b>	The knowledge that the student demonstrates is intuitive, but not formal The concepts s/he takes are not related to the solid.	The student begins to generate connections, but it is evident that they are tried previously.	The student demonstrates a flexible use of the subject. S/he demonstrates creativity when selecting the concepts to use.	The student masters the formal concepts to validate and create new knowledge. S/he demonstrates the way s/he used creatively the concepts and its applicability.

<b>Understanding of the relation between the concepts learned in the subject and its possible uses</b>	S/he does not find the relation. S/he does not consider the purposes and the uses of what it was learned	S/he understands the relation between the concepts and the project developed, but s/he does not extrapolate these uses in her/his professional life.	S/he demonstrates to understand how to use what it was learned in her/his professional life	S/he demonstrates her/his ability to generate creative uses of what it was learned generating new knowledge or new applicability.
<b>Mastery of the generalization of the Multivariate Vector Calculus concepts.</b>	S/he does not understand that the concepts used can be applied to solve similar or even different problems.	S/he understands that the concepts used can be applied to other situations but s/he does not explain how.	S/he explains how the solution of the problem can be applied to other situations of the daily life.	The explanations given about the applicability of the solution of the problem are creative and generate new knowledge.

Table 2.Matrix of continuous valuation from the understanding levels - socialization of final project *“How can I comprehensively apply the Calculus in my career?”*

**7. Results of the use of the Teaching For Understanding pedagogical approach with the mediation of Telepresence tool in the multivariate Vector Calculus subject**

At the end of the current course of Multi-Variable calculus course, students submitted a final project or portfolio where they demonstrated how to apply the concepts seen in class on real scenarios and situations. For this purpose, students at the University EAFIT and Quindío University made a socialization of projects, with the presence of students and teachers of the course. Some of the most remarkable projects are:

- **Hyperbolic Towers**  
This project has two towers in form of hyperbolic of a leaf, joined by a straight horizontal cylinder at half the height of the towers, and ladders in form of spiral. The purpose of this project is that the proposal are used by the governor's department of Quindío and the mayor

of the city of Armenia, capital city of department of Quindío - Colombia . It also intends to use the project as an initiative to consolidate tourism in the city of Armenia.

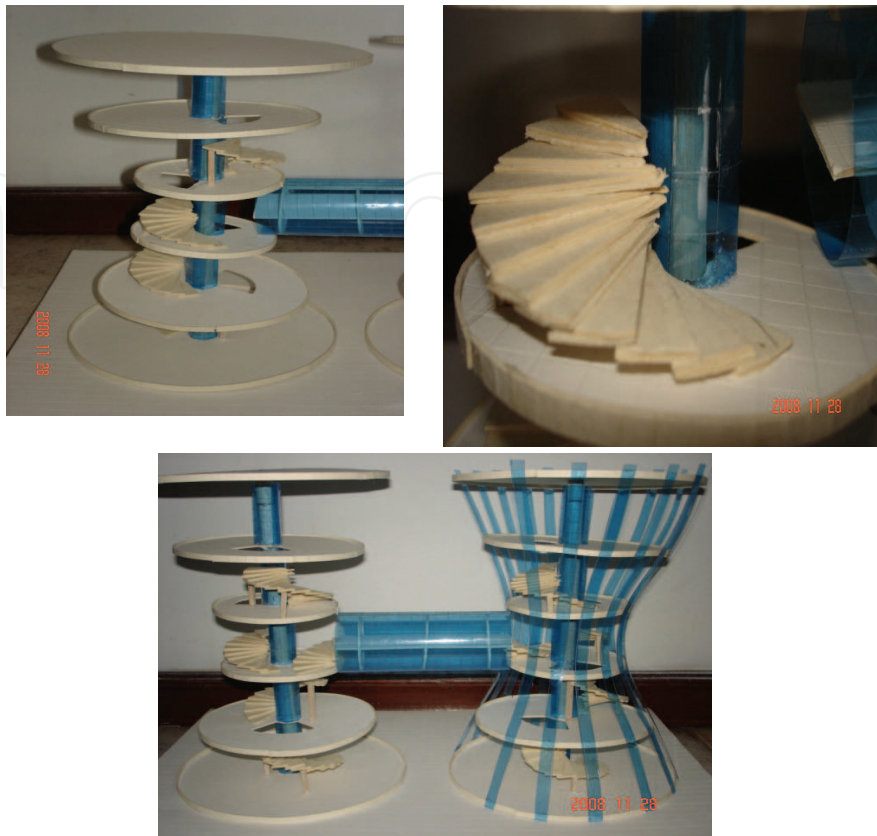


Fig. 7. Hyperbolic Towers's process of building.

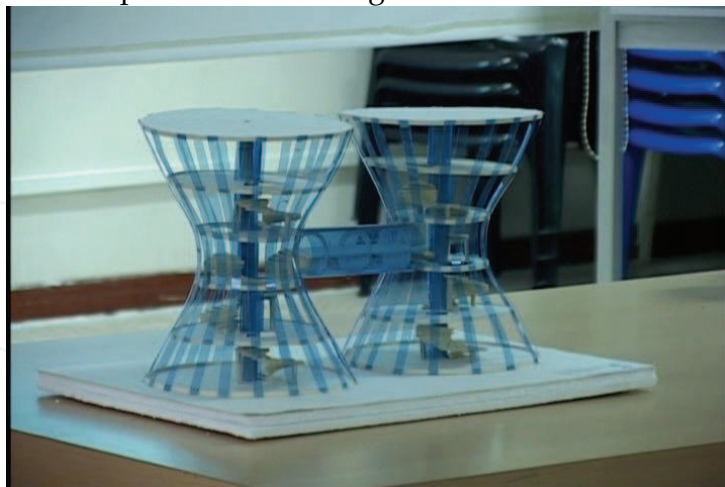


Fig. 8. Hyperbolic Towers (1:50 scale).

- **Mall of Coffee**

Due to the culture and tourism potential at the department of Quindío, and taking into account the low commercial potential of the city of Armenia respect to other Colombian cities, a group of students proposed the project as a shopping center in the form of Parabolic

elliptical, which represents Outside the building, with a hole at the top to make visible a small park in the form of coffee beans consisting of several ellipses.

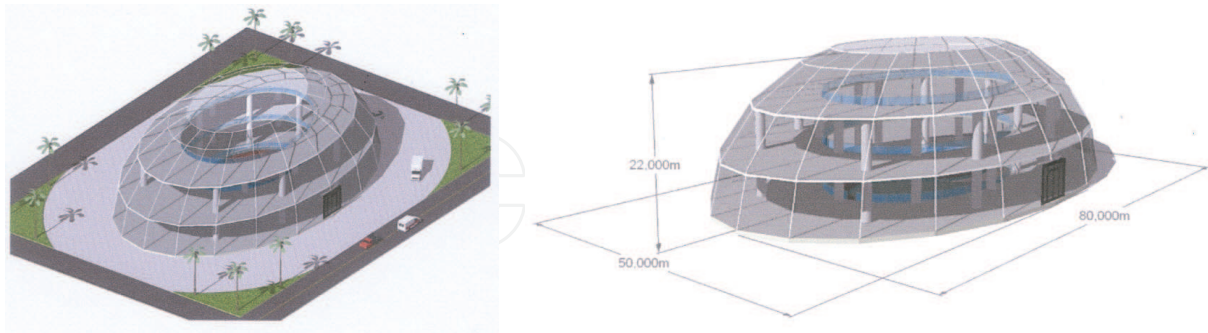


Fig. 9. Front view of Mall of Coffee.

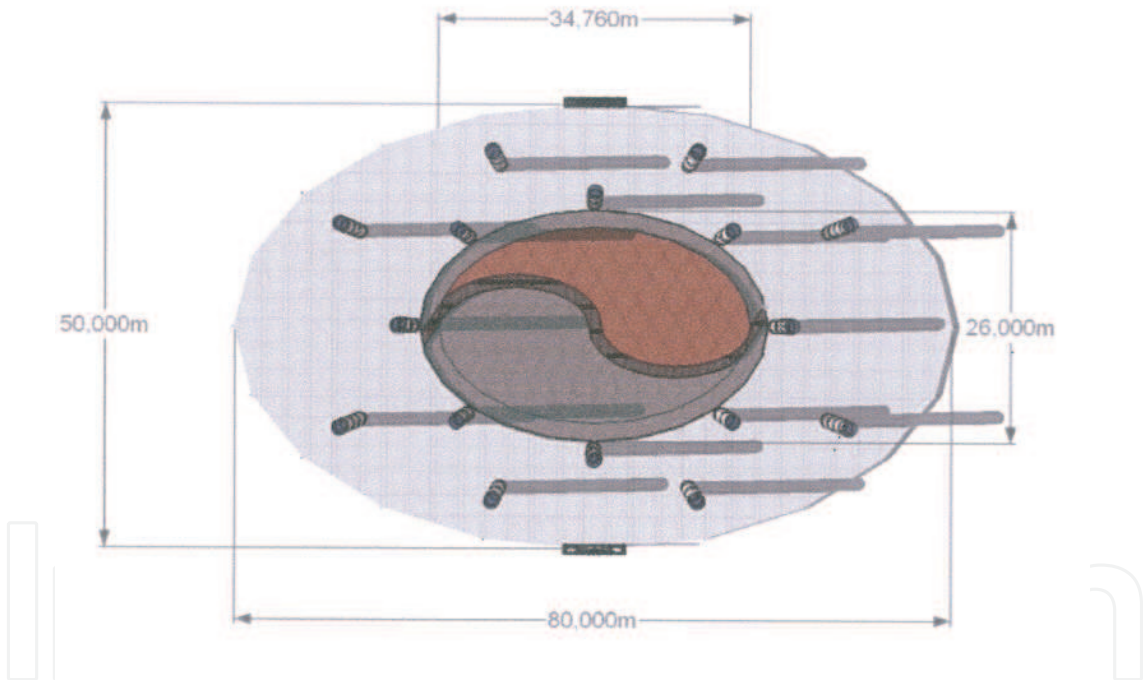


Fig. 10. Top view of Mall of Coffee.

- **Elliptical Sofa - Elipsofa**  
Another group of students decided to design a sofa primarily formed by an ellipsoid which would be the seat of it. Two cylinders that form the arms of the sofa, and four hyperbolics of a leaf that would fulfill the function of supporting the sofa. Although the design of the sofa is a complex for students, it reflects how the Calculus is an important part of the everyday objects that look the students.



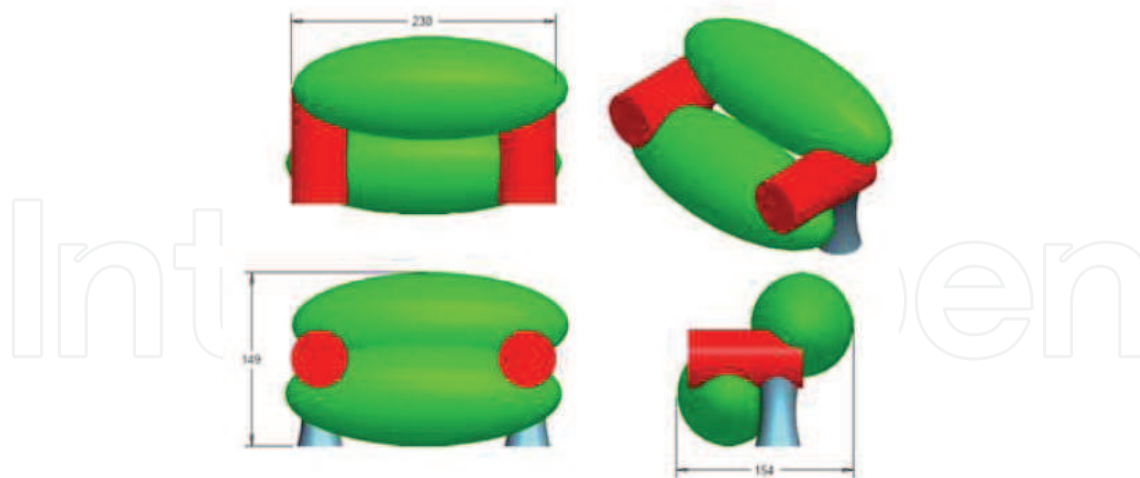


Fig. 11. Plane assembly of ElipSofa

- **Ecological washbasin**

Concerned about the excessive costs of water daily presented in using the toilet, estimating that a person spends approximately 96 liters of water daily just to go to the bathroom, considerable bearing in mind that the liquid is potable, a group of students designed a project which they expose the storage of non-potable water previously used in the process of cleanliness, for reuse in cases that not require potable water like the toilet. The project is to design a sink which stores used water and sends the water to the tank of the toilet when is required. The design is comprised of three quadratic surfaces, the main surface is the base consisting of a hyperbolic of a leaf, which gives the general shape of the sink; within the hyperbolic of a leaf there are a cone that serves as the storage tank, at the same time the hyperbolic holds a container in the form of parabolic elliptical. With the various applications of the multi-variable Calculus, students estimated the size of the solid to design and volume of each of its elements.

### 7.1 Post-Test

Researchers who worked in the experience designed a post-test that contained eleven questions about the applicability of the Multivariate Vector Calculus to the Civil, Computer Systems and Electronic engineering careers. It was a post-test composed by open questions to allow the students to express freely what they thought about Multivariate Vector Calculus, the applicability they found and the kind of relation they established with the daily life.

The aim of applying the Post- Test was to evidence the level of the student's understanding. The questions formulated had the purpose of confronting the student with their previous concepts and the ones learned through the academic subject using the Telepresence tool and the Teaching for Understanding pedagogical approach. It is important to remark that besides the understanding of the Multivariate Vectors Calculus concepts, we also expect that



they apply the knowledge of the Calculus in the daily situations they could find when exerting their professions.

When analyzing the given answers, it is evidenced a great level of conceptual appropriation and a deeper argumentation of each concept. These aspects lead us to conclude that the understanding level was strengthened. Finally, we concluded that the students’ perception about the concepts of the Multivariate and Vector Calculus modified the cognitive schemes they had about them. The students also modified their perception and attitude toward the academic subject. In this way, the students reached the assimilation and a complex cognitive accommodation that allow them to have a significant cognitive balance.

7.2 Results of the Experience from the Teaching For Understanding pedagogical approach

The experience obtained in the development of the academic subject Multivariate Vector Calculus from the Teaching for Understanding pedagogical approach was quite satisfactory. It was possible to evidence the improvement of the understanding in the students belonging to different careers. The learning environment was receptive, participating and very dynamic allowing the students to develop the understanding performances not only inside the classroom but also outside. In addition, the support of the Telepresence tool in the process of each performance was fundamental for the final result, since it allowed the students to project themselves in the real life and to extend the concepts of the Calculus. Similarly, it is fundamental to highlight the interest and commitment that the professors of the subject devoted to implement and develop the project from this pedagogical approach. This experience contributes to modify the cognitive schemes from the education focused in teaching to the education focused in learning. In this case, the professor is a mediator of the process and not just a transmitter of knowledge helping the students to strengthen their understanding.

The following table presents the difference between the Traditional Pedagogical approach and the Teaching for Understanding approach.

	Tradicional Teaching Approach	Teaching for Understanding Pedagogical Approach
Purpose	To transmit knowledge to the students	To encourage students to discover and to construct their knowledge.
Evaluative Process	<p>To produce repetitive, fragmented and theoretical knowledge.</p> <p>The learning process is determined when finishing the transmission of the knowledge by means of examinations, tests and final assignments.</p>	<p>To produce demonstrable, meaningful learning.</p> <p>It evaluates the learning process of the learning at every stage of its development by applying diverse formal and informal methods.</p> <p>It emphasizes the productive work having applicability in the daily life situations.</p>

	It emphasizes the individual work and evidences the students' results by the amount of their academic work.	
<i>Curricular Contents</i>	To develop the academic subject through a fixed program that is predetermined by the amount of contents and methodologies previously established.	The development of an academic subject generates flexible and motivating environments.  The curriculum is considered as a whole and not as a list of fragmented contents.
<i>Teacher-Student relation</i>	The teacher is who imparts the knowledge and delimit it.	The teacher is a mediator who generates flexible uses of the knowledge and invites the students to confront them.
<i>Goal</i>	Search of the acquisition of a particular discipline knowledge.	Search of the strengthening of the understanding levels.
<i>Methodology</i>	The teacher approaches the learning process from diverse methodological principles according to his/her own experiences and interests.	The teacher guides the learning process by means of the conceptual framework of the <i>Teaching for the understanding</i> approach

Table 3. Differences between the Traditional Pedagogical approach and the TFU approach.

We evidenced in the students a collaborative work, the relation they establish with other subjects, the integration of the conceptual framework of the Multivariate and Vector Calculus with the contents of the previous Calculus courses and the conceptual bases achieved to continue strengthening the understanding through posterior conceptual developments. It is important to highlight the contextualization of the final projects of synthesis evidencing how the students analyze the characteristics and needs of the region. We found projects to promote the tourism in the region, to benefit the coffee culture, to improve and to give greater identity to the infrastructure and to approach the regional policies to promote the environmental and economic development of the region



Fig. 12. Students presenting pedestrian bridge's portfolio

## 8. Conclusions

The opportunity to integrate academic and technical groups from different universities, each with different perspective on the education process makes the collaborative work more enriching and interesting. Some of the highlights of the current collaborative work are:

- a) Pedagogical training on TFU of the math instructors involved with the experience.
- b) Training on the use of virtual resources by the instructors that take part of the design of the Multi-Variable Calculus course at both institutions.
- c) Collaboration and integration of the two development groups in creating a stable single code base.

This integration will result on an improvement of the teaching process of the Multi-Variable Course at both universities, as well as a better utilization of the available technological resources by the students at both universities.

This project will foster the use of new technologies in the teaching-learning processes that are built on top of high-speed networks like RENATA. Our goal is to continue improving the Telepresence tool in order to make possible new and novel ways of interaction between the instructor and the students. High-speed networks should allow the academic communities to share learning objects and promote the integration and collaboration of academic communities in our country and abroad.

The pedagogical model used, allowed to develop the subject in a novel, interesting and exciting way not only for the students but also for the professors who worked in the project. This approach allowed developing the students' understanding since a flexible bridge was created between the concepts related to the Calculus and their applicability,

modifying the memory theoretical concepts and the complex and incomprehensible academic processes. The students confronted their knowledge by applying them to their future professional roles. Additionally, the students obtained new perspectives about the applicability of the Multivariate Vector Calculus to the daily life.

The work climate was interesting and motivating, since it was allowed to interact in different ways with the knowledge, for example, with the Telepresence platform. Also, the interaction was made by observing the context, analyzing the surroundings and integrating the knowledge. The Teaching for Understanding pedagogical approach activated the students' understanding and stimulated their capacity to relate the concepts, to extrapolate, and to associate them with objects or situations of their daily life.

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E-Learning is a vast and complex research topic that poses many challenges in every aspect: educational and pedagogical strategies and techniques and the tools for achieving them; usability, accessibility and user interface design; knowledge sharing and collaborative environments; technologies, architectures, and protocols; user activity monitoring, assessment and evaluation; experiences, case studies and more. This book's authors come from all over the world; their ideas, studies, findings and experiences are a valuable contribution to enriching our knowledge in the field of eLearning. The book is divided into three sections. The first covers architectures and environments for eLearning, while the second part presents research on user interaction and technologies for building usable eLearning environments, which are the basis for realizing educational and pedagogical aims, and the final last part illustrates applications, laboratories, and experiences.

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