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PRINCIPIA PROGRAM: TEACHING MATHEMATICS TO ENGINEERS WITH INTEGRATED CURRICULUM, TEAMWORK ENVIRONMENT AND USE OF TECHNOLOGY.

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Abstract: The ITESM's teaching model has evolved in the last years. Nowadays, several abilities, attitudes and values (AAV's) are taken into account without forgetting the development of knowledge in students, including teamwork, use of technology, self-learning, problem solving among others. Principia is an engineering academic program for the four first semesters of engineering school which arise to develop this kind of education.

The main purpose of Principia is to develop a mathematical, physical and technological culture in students that will make them able to analyze and solve complex problems. This is achieved with the integration of different subjects in one unique program where the classroom and learning environment are considered. The two principles in Principia are the Integration of curriculum for mathematics, physics, and computer sciences and the use of technology to solve problems (in agreement with problem solving). With these elements, Principia has evolved as an integrated program that considers objectives, knowledge, methodology and an evaluation system which develops in the students the AAV´s of our new teaching-learning model. In this work, we present our experiences in Principia over five generations of students and some statistical and comparative results.

I.- BACKGROUND

In the last years, it has been observed a change in the ITESM's teaching method. Nowadays other abilities, attitudes and values (AAV's) are being taken into account without forgetting that knowledge is very important too. In the past five years, the Math Department, which belongs to the Engineering and Computer Science School of ITESM-CEM, has developed different projects and pilot courses in which AAV's are trying to be emphasized. Some problems in math teaching and learning in teachers and students have been identified thanks to these projects.

Principia comes out from the idea of overcoming these problems. Principia wants to support the development of a mathematic, physics, technologic and dynamic culture in students, which will make them able to face different problems that might need a physical and mathematical raising. Principia is looking forward to teaching the best possible way and to enlarging the learning specter in students on different areas. Besides, it considers the room and the environment where this learning process takes place. Some of the most important characteristics of the project and the educational methodology used in it are included in this document.

II. – PROGRAM PRINCIPIA

The program Principia is a teaching-learning model of Basic Sciences helped by technology. This technology develops in engineering students the ability for teamwork, self-learning, creativity, analysis and synthesis of information, which is in agreement with the objectives of ITESM's mission. This mission is based upon the following fundamental principles:

Integration of the curriculum of courses of Mathematics, Physics, and Computer Science.
Collaborative learning.
Teamwork.
Emphasis in mathematical modeling as a fundamental tool for Sciences and Engineering.
Use of technology in the learning process.

To follow these principles we use several activities that constitute the operative and methodological section of it. The most recurrent activities within the program are:

Field of study	Lectures

Problems resolutions	Learning based in problems solving
Laboratory	Learning based in projects
Presentations	Learning based in the use of technology
Subject Evaluation	Integrating Evaluations

From these activities, the first six correspond to the classic activities in the classroom. The last three have been introduced in Principia taking up to 50% of the effective time of the program as basic elements in the structure of it.

III.- CURRICULAR INTEGRATION

Curricular integration is, from the five principles, the moving axis of the activities of the program while the four others are the means to reach the objective. To achieve a curricular integration in Principia implied introducing additional activities that required more time. This had to be reduced as much as possible to achieve a balance with its traditional antecessor scheme. Therefore, it was very important that the activities of the second column of the list above would allow:

Consider the contents of all the integrated areas and the objectives of long term (field of specialty of the student).

Semester	Mathematics	Physics	Computer Science
First	Differential Calculus of functions of one variable. Vector functions, basic elements of calculus and differential equations.	Mechanics	Excel, Mathematica.
Second	Integral Calculus of functions of one and several variables. Vectorial Fields.	Mechanics, elasticity, thermodynamics.	Matlab, C++.
Third	Multiple Integrals and Ordinary Differential Equations. Probability and statistics.	Electromagnetism and Modern Physics.	Numerical Methods.
Fourth	Differential Equations Systems and Modeling.	Study of mechanic and electric systems.	Simulation.

Table 1. The General Curricula of Principia.

Reduce the presentation time of a traditional class to use it in the own integrated activities, which are more extensive and recurrent. This implies that these activities should be clearer in their objectives. Besides they should be rich in the self-discovery of the student.

Take advantage from the recurrence of the activities contents to achieve significant long-term learning.

Table 1 shows the basic different topics per semester of program Principia, under the schema of integrated curricula.

IV.- COLLABORATIVE ENVIRONMENT AND USE OF TECHNOLOGY

The use of collaborative techniques and technology in learning and the classroom.

Technology is used in several ways. Table 2 shows some aspects and the desired objectives. We must point out the fact that the design of the space (classroom equipped with complementary spaces) comes out in a natural way when considering the processes that occur in our activities. The classroom is a room for 80 persons with movable divisions. It has 20 tables for teamwork that allow connection to Internet. Additionally it counts with reading zones, look up material and basic library. The program is administered in a 100% by the Learning Space platform. The academic part is being worked with the problem based learning and project oriented learning methodologies. In the first one we permit the progress in all areas involved in the objective, working on their specific goals. In the

Fig. 1. Classroom in Principia

second we integrate the areas. In both of them we use collaborative learning.

Technology	Activities	Objectives
Matlab, Mathematica.	Projects, practice and homework assignments. .	That the student applies physics, mathematics and computer knowledge to problems of higher complexity than the ones studied in traditional courses.
Laptop.	Projects, homework and practice assignments.	That the student uses the cutting edge technological elements.
Microsoft Office.	Projects, presentations, homework and practice assignments.	Develop numerical and graphical strategies for the resolutions of problems, such as the written and oral expression skills.
Equipped classroom.	The entire project.	Link the student with the cutting edge technological advancements.

Table 2. Technology, AAV and objectives.

Problem Based Learning (PBL)

Collaborative learning among students is developed in the program in several activities:

Exercise solving, where students leave their basic team to form new heterogeneous teams and solve academic situations of intermediate level. The objective is to develop elemental competitively level in each field. The activity ends with the returning to the original teams to share and enrich the knowledge to their team partners.

PBL that in their design integrate the organization of the exercises to solve a problem with integrated curriculum. This also requires the use of technology for its development.

The development of projects is the open resolution of a complex situation that involves the acquisition of additional knowledge. In these projects, future knowledge is used in the special fields of study.

Since the emergence of PBL as a formal paradigm in medical education at Mc Master University in Canada [1, 2], several other universities have adopted this educational practice in various countries [3] and inclusively in some areas of Engineering [4, 5], as also in levels of Basic Education [6, 7], and Media Superior [8, 9, 10, 11].

In the PBL approach, students are confronted with complex, usually multidisciplinary problems, which must be solved in teams. Generally, the PBL curriculum is organized around general themes, instead of the discipline-based organization that characterizes the more traditional curricula. This kind of organization requires teams of teachers with different disciplinary backgrounds to prepare activities. It is not the intention of this paper to go into an extensive discussion of PBL and its different modalities.

We mentioned that some of the non-traditional activities of Principia are: Problem Based Learning, Project Oriented Learning, Learning with use of Technology and Integrated evaluations. The projects (two or three per semester) belong to a different degree and occasionally they have more similitude with the open-ended problems. For this reason we want to focus on this report to the problem based learning and integrated evaluations activities. Both of them use technology in the learning process.

The creation of a network of problems under these considerations establish a frame of analysis, allows evaluating the recurrence to previous and future subjects. In this way the whole network is more important than the problem because it allows giving constant sense to the activity within the course.

Particularly using PBL activities within the mathematics and physics courses, which include the use of Computers as a tool, have not constituted a distortion to education al least in the students currently in the program. The evaluation of the students has been inside the global evaluation. The consistency of it with the results obtained is high.

In an evaluation study on the effectiveness of problems, the students grade 9.56 (average in a scale 0-10) having 0.4 as standard deviation. Applying this kind of activities is more influenced by the preparation of the teacher for leading an activity than by the one of the student [12].

5.- STUDIES ABOUT THE EFFECTIVENESS OF THE PROGRAM

Since 1998, more than 14 studies have been done about the effects in the learning of the students that participate in the program. These studies are both: qualitative and quantitative. At first, the studies are very local but then they are expanded to a very global one. We present some of the evaluation of effectiveness scheme that show some of the characteristics of the program.

a) Students opinion about the program in the development of AAV
Respecting the evaluation that students made to the project, the following test was applied with the objectives of:
Analyzing the effects of project Principia in the development of AAV's in the students.
Comparing the effects of the project with equivalent courses.
The dimensions of the research were:

Leadership	Quality and Excellence
Analysis, synthesis	Use of technology
Critical thinking	Work capacity
Communication	Self-Learning
Teamwork	Problem Solving
Creativity	Learning
Search and management of information	Motivation
Entrepreneur spirit	

The research asked the student to compare the degree in which the course contributed to develop each ability, attitude or value of the above statements with the average of the rest course. A scale 0 – 10, where 0 is much less, 5 equal and 10 much more was used. Also an adaptation of the instrument "Self-Evaluation of AAV" (ITESM 1996) was used. The quantitative results were put under associative tests. In previous research [13] one of the authors reported some preliminary data on students' self-perception of skill development. In this paper, studies to confirm those previous data, when students were formally assessed on oral and written communication. The test was applied to three students groups as described bellow.

Principia Principia Teachers Program Principia	Witness 1 Principia Teachers Equivalent Course	Witness 2 Non-Principia Teachers Matching Course
Teacher1	Teacher 1	Teacher 6
Teacher 2	Teacher 2	Teacher 7
Teacher 3	Teacher 3	Teacher 8
Teacher 4	Teacher 4	Teacher 9
Teacher 5	Teacher 5	Teacher 10
26 students	154 students	111 students

Figure 2 shows the comparing results for each group and the dimension of the research in which the least and most difference was obtained respectively (for full description of the test see [13]). This difference is with respect to the evaluation given to program Principia.

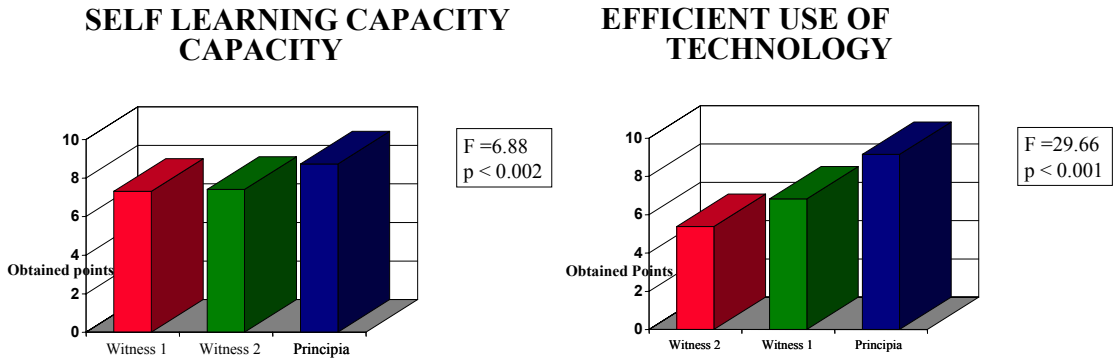
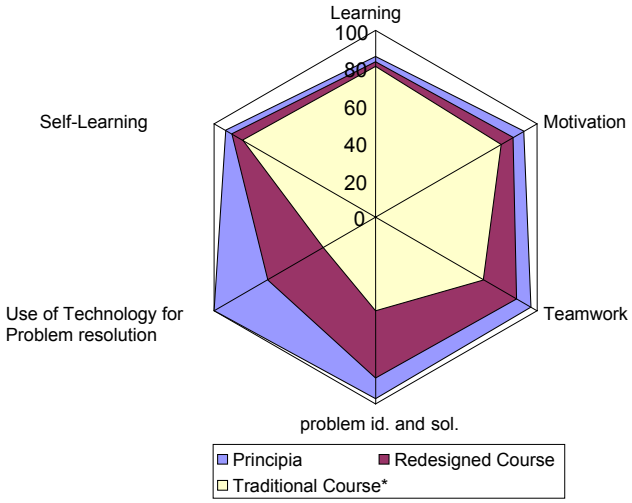


Figure 2: AAV with least and most difference in evaluation with respect to Principia courses in the opinion of students.

Evaluation based upon measurable observation through evaluations

This test compares three different problems in the final course of the program. One of them corresponds to program Principia, another (traditional) to the way it was taught in 1995 and at last (redesigned), to the way it is currently taught under the circumstances of the new educative model of ITESM. Aspects derived from the evaluations of the proposed activities in the course are compared. The evaluations are considered on a 0-100 scale).



*Referring a previous research(1998)

Figure 3: Comparison of the different schemes of teaching-learning at ITESM, in relation with program Principia, based in student's evaluation. These students are coursing one of the final courses of the program.

Nowadays a new test was carried out and results are being processed, based in the criteria that compare, with a witness group, the development of two groups (Principia and traditional) the capability to solve integrated problems. This study finished in 2002. The research is intended to measure the recurrent effect of the execution of collaborative activities, use of technology and those proper of the program Principia.

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