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AUTHOR	Polanco, Rodrigo; Calderon, Patricia; Delgado, Francisco	
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ABSTRACT

A 3-year follow-up evaluation was conducted of an experimental problem-based learning (PBL) integrated curriculum directed to students of the first 2 years of engineering. The PBL curriculum brought together the contents of physics, mathematics, and computer science courses in a single course in which students worked on real-life problems. In order to assess academic achievement, three data sources were used: pretest and posttest scores on physics tests for two samples of students, grade point average of all students enrolled in the curriculum, and students' grades in advanced engineering courses in comparison with the grades of students in the traditional courses. A second source of data came from studies that evaluated the acquisition of professional skills. Test scores on critical thinking skills, as well as self-evaluation and co-evaluation tests were used. The final set of data attempted to assess how the PBL curriculum affected students' attitudes toward mathematics, physics, computer science, and education in general. The PBL curriculum seemed to improve the academic achievements of these students, but student attitudes were very similar to those of students in the traditional courses in spite of their enhanced academic achievement. Additional studies are planned to investigate students attitudes toward the PBL course and continued academic achievement. (Contains 12 figures, 3 tables, and 31 references.) (SLD)

Effects of a Problem-based Learning Program on Engineering Students' Academic Achievements, Skills Development and Attitudes in a Mexican University

Rodrigo Polanco
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Francisco Delgado

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Effects of a Problem-based Learning Program on Engineering Students' Academic Achievements, Skills Development and Attitudes in a Mexican University[1]

Rodrigo Polanco[2], Patricia Calderón[3], Francisco Delgado[4]
Instituto Tecnológico y de Estudios Superiores de Monterrey

Abstract

The aim of this paper is to report on a three-year follow-up evaluation of an experimental PBL integrated curriculum directed to students of the first two years of engineering. The PBL curriculum brought together the contents of physics, math and computer sciences courses in a single course. Instead of the students having to enroll in physics, math and computing courses, they had the opportunity to enroll in a single course in which they learned the contents of those subjects by solving real life engineering problems. In order to assess academic achievement, three data sources were taken: pretest- postest scores on Physics tests, grade point average, and students' grades in advanced engineering courses. A second source of data came from studies that evaluated the acquisition of professional skills. Test scores on critical thinking skills, as well as self-evaluation and co-evaluation tests were used. The final set of data attempted to assess how the PBL curriculum affected student's attitudes toward Mathematics, Physics, Computer Sciences, and education in general.

Everything coincides, is the paranoid's formula. However, as any psychotic formula, it conveys a certain amount of truth. Historians of ideas might, in a better way, provide a description of the turnabout of man. Many of the changes we have coursed as gender coincidently arise from different ambits of human reality. Thus, while present-day Physics runs into the Heisenberg's principle, and Mathematics encounters Göedel's theorem (Hofstadter, 1980), epistemology questions the immobility of scientific knowledge, the great economic models –and of other types- manifest their inconsistency. The proximity to other cultures questions many of our conceptions about the being human, (such as gender differences). Everything coincides. Uncertainty comes to sojourn in our house. Certainty of control abandons us (Anderson, 1990).

Our certainties and longings for absolute control, of reality and of ourselves, have proven ineffective. Perhaps uncertainty was always in the core of humanity. However, the great narratives among which we lived (our conception of science, about accessibility to truth, the firmness we granted to symbolic systems, and above all, the mathematical system), as well as confidence in our small and daily tales about ourselves and about life, had permitted us to elude their persistent encounters.

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[2] Dirección de Efectividad Institucional, Rectoría Zona Sur. E-mail: rpolanco@campus.rzs.itesm.mx
[3] Dirección de Efectividad Institucional, Rectoría Zona Sur. E-mail: pcaldero@campus.rzs.itesm.mx
[4] Departamento de Matemáticas, Campus Estado de México. E-mail: fdelgado@campus.cem.itesm.mx

These changes produce a new reality which we must now struggle with. Living in uncertainty with an education of certainties is a difficult challenge.

Traditional teaching obtains its support from a rationalism that has proven its ineffectiveness in the present complex world where we live. Straight-line cause-effect ratios, our possibility of accessing truth, the pertinence of general models, all what has helped us reach to the point we now are, to develop science, to achieve a certain control over some phenomena, to expand our possibilities in an extraordinary fashion, today seems ineffective to respond to quite a more complex reality (Dreyfuss, 1993), with a demand for adequate answers to each case, with a greater number of interrelations, a communication much more within reach, and consequently, a reality unfolding at a faster pace.

With all this the human being of today cannot continue to function from rationalism, he has outgrown his former birth cradle. The ineffectiveness of traditional education is also a product of the scopes of rationalism. It is their greatest achievement, and their limit.

Most of all, because from there – from rationalism -, uncertainty is but a threat, something undesirable and hard to bear. Without modifying this discourse, we will find it very complicated to face dailiness. We cannot continue educating for the sake of control and certainty. Education must prepare adolescents to become adults who permanently live in an uncertain and changing world. A world of constant renovation, that also demands of them a permanent reinvention of their identity.

How can that education be? An education in favor of flexibility, that will develop the capacity of expanding one's own possibilities of alliance with others, where the only certainty rests in the conviction that nothing guarantees the success of our undertaking, but as far as we are able to see, the best option has been chosen. This education might, for example, give the adolescent another discourse about uncertainty. Propose that he confront uncertainty with the meaning we grant to it in the game, such as that emotion without which there is no entertainment.

Other changes necessary in this education, more than an accumulation of information – as a professor strived for in the past – are meant to offer him certain coordinates that permit him to move about adequately in the sea of information he now has access to. In addition, beyond information, what the future professional requires is the capacity to act in a wide ambit of knowledge. The segmentation given to knowledge by the academy leaves it less functional for its application in real situations. It is quite often that a profession is learned when beginning to exercise it. This leaves the period of professional formation of little use for its purposes.

This is the matter that led the academics of Mc Master in Canada (Barrows and Tamblyn, 1980; Barrows, 1986) to try to modify the pedagogy of teaching Medicine, starting from the knowledge history has revealed to them: that a student really does not learn until he is in the midst of the practical problems of his discipline. The proposal by this Canadian university has now been adopted by other universities in various countries (De Graaff, and Bouhuijs, 1993), and in various areas of Medicine (Maxwell and Wilkerson, 1990; Sobral,

1995; Vernon and Osokawa, 1996), Nursing (Williams, 1995), Odontology (Pereira, 1998; Aldred and Aldred, 1998), Psychology and Occupational Therapy (Reynolds, 1997), Educational Administration (Cordeiro, 1997; Copland, 2000), Engineering (Stevens and Wilkins, 1993; Woods, 1996), as also in levels of Basic Education (Achilles and Hoover, 1996; Williams Hemstreet, Liv and Smith, 1998), and Media Superior (Glasgow, 1997; Jones, Rasmussen, and Moffitt, 1997), Dods, 1997; Milbury, 1997).

Although the original proposal has its origin in the pedagogic and practical exposures referred to in the above paragraph, its repercussions reach beyond them, they touch the history of knowledge. Human understanding developed in this manner. This does not mean that the student be subdued to finding solutions, that scientists of the discipline referred to have solved. It simply points toward the fact of organizing the structure of the student's knowledge in respect to problems, that allow him to find a significance to the already existing scientific explanations. To find the feasibility of a technique in order to solve a problem and also, a much clearer relation between theory and practice, to face the necessary interdisciplinary method (Morin, 1977) demanded by any solution of a real problem.

Thus, knowledge comes as an answer to those questions that arise in the student from the case or practical situation, and not an answer – as it was in the past – to the teacher's questions. By its connection with other disciplines, as well as the cognitive motivation involved in solving mysteries themselves, this learning is more lasting and widens the student's practical capacity (Inhelder, 1975). In addition, the context within which problems are solved forces the student to solve them in a group, and in this form, if work is adequately guided by the facilitator, the means also becomes a space to develop skills in communication, listening, negotiation, collaboration, in building alliances with others, all of which could be comprised in one term, team work.

These three pillars of problem-based learning, interdisciplinary method and team work, in the summer of 1997 gave origin to what was called the "Principia Project", a curricular program consolidated on Problem-based Learning, directed to students of the first two years of Engineering. In this project the students learn the contents of the basic subjects (Physics, Mathematics and Computing) by applying Problem-based Learning (Barrows, and Tamblyn, 1980). The aim of this document is to report results that show the advance achieved by the project in these four years of its existence. The following work section provides a detailed description of the program, and further there is a report of the evaluations it received.

Antecedents and contextual definition of the proposal

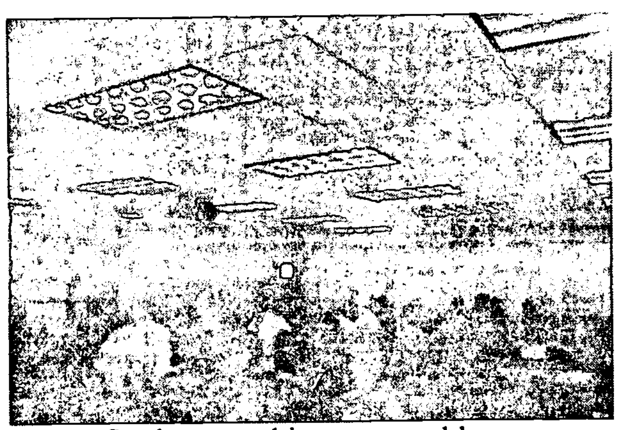
A trend observed in recent years, is to change the teaching-learning model of ITESM, a private institution of Mexican Higher Education recognized for its high standards in the formation of students. Without overlooking the area of knowledge, the new educational model emphasizes on developing various skills, attitudes and values (SAV) in students, such as teamwork, learning on one's own, the use of technology, capacity of analysis, synthesis and evaluation, capacity to identify and solve problems, good oral and written

communication, and others. These SAV's pretend to prepare the student so that he face the future with leadership and participation.

During the last five years, various projects and pilot courses have been instrumented in the area of Engineering, which seek to emphasize on the development of SAV's in the courses that are imparted. As a result of these projects, it was possible to observe problems that exist in teaching and in learning mathematics among our professors and students. For example, we found there is a low retention of knowledge in students; that the courses are exaggeratedly directed and centered in algebra; that there is an abuse in the use of orthodox rules and algorithms, and a complete development of a mathematical reasoning is not achieved. On the other hand, the courses were found to lack applications in the areas that interest students, and that the density of the programs restricts the use of applications. These conditions result in a very low motivation among the students toward mathematics and, in general, toward sciences, as their contents lack significance.

The Principia Project

The **Principia Project** was born as an answer to the above situation, with the idea of surpassing the difficulties mentioned, and to help students in Engineering develop a mathematical and scientific culture that permits them to face various situations where successful proposals for physical and mathematical problems could be required. For such purpose, with Problem-based Learning (PBL) as reference framework, the mathematics, physics and computing program for the first two years of the career was redesigned. Instead of the students having to enroll in the traditional Physics, Mathematics and Computing subjects, they had the option of enrolling voluntarily in the **Principia Project** where, in an integrated subject the student acquired knowledge in those subjects by solving engineering problems.



Students working on a problem

From the beginning of the academic semester the students are assigned to permanent teams where they will remain throughout the entire period. PBL develops under a system of collaboration, mainly through three types of activities:

a) *Solution of exercises*. In this activity the students temporarily leave their basic teams and form transitory teams to solve small-scale problems, where the purpose is to

develop elemental competence in each area. The activity concludes when the students return to their basic teams to transmit, share and enrich the knowledge among the other members.

b) *Solution of complex problems.* In this activity the students work in their permanent groups and confront large-scale problems, where the solution of exercises forms part of the solution of a more complex problem, requiring the integration of knowledge in various disciplines, as well as the use of technology for its development.

c) *Development of projects.* An activity also developed in permanent teams, consists in the open solution of a complex situation. This situation implies acquiring additional knowledge to that contemplated in the curriculum, where future learning in major fields and in sharp problems in these fields is normally exploited.

The elements normally considered when designing the problems are schematized in the following table:

Dimensions of the design

RESOLUTION OF PROBLEMS											
	DIMENSIONS										Elements
	E	**Levels**	*C*	**Levels**	*R*	**Levels**	*T*	**Levels**	*F*	**Levels**	Primary dimensions that define them
PROBLEM	ENVIRONMENT	Possible strategies through which the problem can be solved	CURRICULUM	Mathematics		Previous learnings (Before)	TECHNOLOGY	Significance	OB. F. FORMATIVE	SAV That can be developed: Team work • Collaborative work	Objectives: *C, F* Requirements: *R, T* Material: *C,T*
				Physics				Simplicity			
		Levels as those of the problem can be understood		Computing		Long-term objectives (After)		Means		• Analysis and synthesis of information • Identify and solve problems • Work culture • Efficient use of technology	Instrumentation: *E, C, R, T, F* Script: *E, R, T, F* Evaluation: *E, C, R, T*
				Engineering				Objetive			

- **Environment (E):** refers to real situations that can occur when developing the activity in respect to the level of comprehension reached or used by the student, such as in the classic scheme.
- **Curriculum (C):** the contents on which the activity is centered and for which it is basically created. The curriculum is the traditional nucleus of learning; however, in a problem-solving activity it must be subordinated to other elements. In addition, in the Principia Project, the curriculum of every area must be considered.
- **Analysis point of reference (AV):** also refers to the curriculum of the areas integrated, but implying that previous (retrospective) purposes and future (prospective) objectives are retaken to enrich and enable the problem, foment a long term retention of other fields of knowledge, and detect the need for future knowledge.
- **Use of technology (T):** the technological elements (software, laboratory, means, etc.) which the activity integrates. This dimension must establish an analysis of its plausibility, its significance, and the role it plays in that activity.
- **Development of formative objectives (F):** within the context of ITESM, this dimension takes care of the SAV's mentioned in the Mission of this Institution.

During a typical and complete problems session within the program, three stages are distinguished and are schematized in the table on next page.

The complete stages of a problem-solving activity

STAGES OF A PROBLEM-SOLVING ACTIVITY			
	STAGE I: acquisition of knowledge	**STAGE II: collaborative learning**	**STAGE III: problem**
Instructions and rules	**Professor:** does not provide information, but guides and feedbacks every team in its actions. **Student:** every team,may resort to the necessary sources of information.	**Professor:** does not provide information, guides regarding the performance and participation of every expert. **Student:** cannot interact with other teams, permits every expert to speak in every section of the activity.	**Professor**: does not provide information, tenaciously takes care of the time and guides the team toward the objective. **Student:** cannot interact with other teams, permits every member to participate in the same manner.
Elements of action	• Areas of specialization are defined. • The expert teams are formed based on each student's skills.	• An activity of immediate application is defined that will allow interaction and exchange of experiences of each expert with his team-mates.	• An applied problem is proposed that involves the application of previous stages, • And of other contents within the framework of the analysis proposed.
Work form	Every basic team is divided to form expert teams integrated by elements from different teams.	The basic team meets to solve an intermediate activity where every expert provides his knowledge to the group.	The basic team guides itself as a team to solve the problem.
Evaluation	Every expert team exposes and is evaluated for its fulfillment of the specific activities listed in the script.	This is field evaluation (as to efficiency and work form of the team) and mainly in the scope of the objective proposed in the activity.	The evaluation is centered on the in situ report prepared by the team and the annexed report that the team may hand in the next class.

The idea of these stages is to gradually introduce the student to a subject until he can end up with an applied problem that has its roots in the control of such problem. However, stages I and II may be absent in some activities, and will invariably be absent in any integrating evaluation activity. However, their design is the same, although evidently, the script changes. The fundamental requirement in those "incomplete" activities is that other of the activities has previously covered these elements.

The creation of a problems network under these considerations, where a framework of analysis is established, permits to evaluate the recurrence to previous subjects and the perspective toward future subjects. With this, the entire network results more important than the problem, as it allows to consistently giving a meaning to that activity within the course.

The following work section presents some of the results obtained to date about evaluation of the program in three areas: academic achievements, development of skills, and attitudes of students.

Academic achievement

In order to assess academic achievement, three studies were carried out. Every study will be reported separately.

Math and Physics Concepts

In the first study, a pretest on Physics and Calculus concepts was taken to two samples of students. The first sample was composed y the students enrolled in the PBL curriculum. The rest of the students, who were enrolled in the conventional curriculum, composed the second sample. Two standardized tests on Physics (the *Force Concept Inventory* and *A Mechanics Baseline Test*) were administered to all the students at the beginning of the first semester (pre-test) and at the end the fourth semester (post-test). Those tests were developed and reported by Hestenes, Wells, and Swackhamer (1992) and Hestenes, and Wells (1992) respectively.

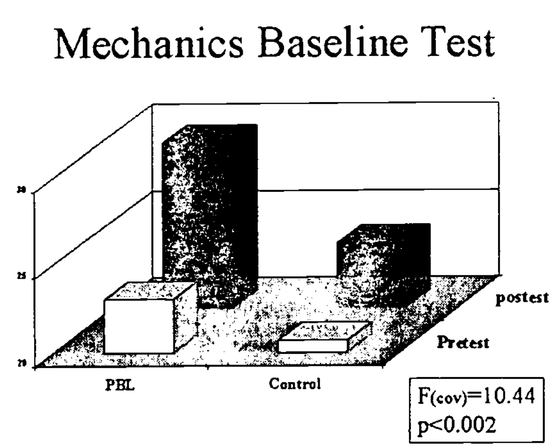


Figure 1.- Comparison of PBL and control students on Mechanics Baseline Test's scores

As can be seen in figure 1, ANCOVA analysis showed a significantly greater change in learning in PBL students in the Mechanics Baseline Test. In other words, although both groups' scores improved from pretest to posttest, PBL students' improvement was greater than control students'. Figure 2, on the other hand, showed that both groups (PBL and control) improved their scores in a similar way, with no differences in improvement between them.

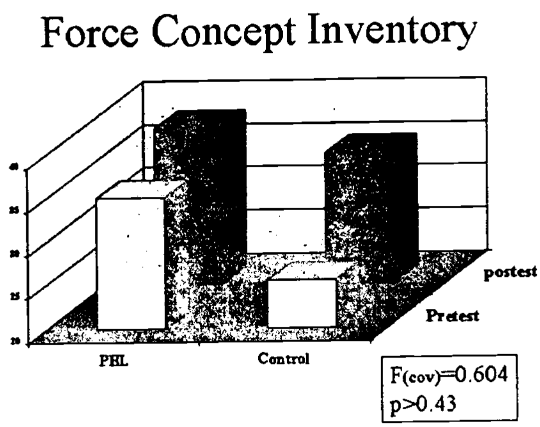


Figure 2.- Comparison of PBL and control students on Force Concept Inventory's' scores

Grade point average

The second study compared the GPA obtained by students enrolled in the PBL curriculum with the GPA of a sample of control students enrolled in the traditional curriculum.

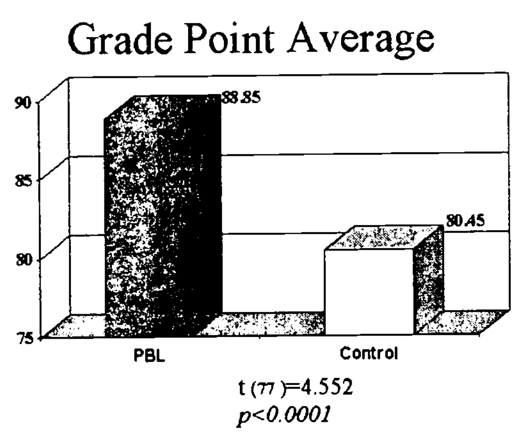


Figure 3.- Comparison of PBL and control students on grade point average means

This study also showed achievements that were significantly more favorable for PBL students. As Can be seen in figure 3, when GPA means were compared for PBL and conventional students, PBL students significantly surmount conventional ones.

Advanced engineering courses performance

Finally, a third study followed up students' grades in advanced engineering courses. The purpose of this study was to test whether PBL built a stronger learning transfer of basic sciences principles to applied fields. If this condition were true, it should be reflected by better achievement of the PBL students in specialized professional subjects, in comparison to the control students.

In order to test this hypothesis, PBL and control students' grades were compared for a sample of advanced courses that were selected by the program chairmen.

As can be seen in figure 4, results showed that although PBL students were superior to control students in *Mechanics, Electrical Circuits I, Digital Systems I*, differences between the two groups were not significant.

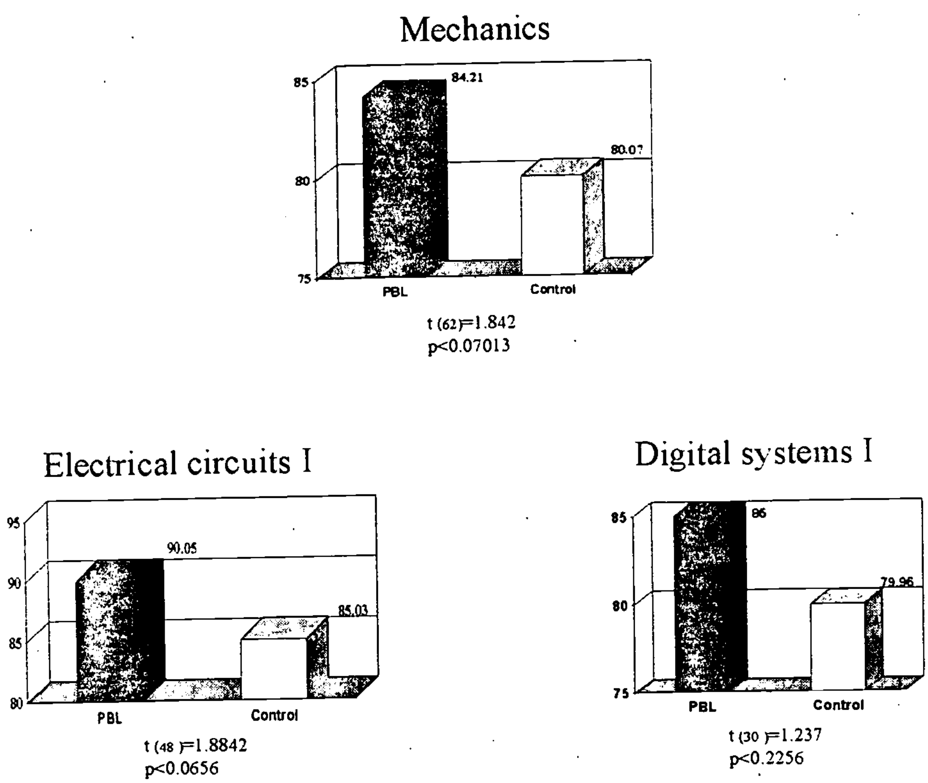


Figure 4.- Comparison of PBL and control students on grade means in Mechanics, Electrical Circuits I and Digital Systems I

However, statistical significance was achieved when PBL and traditional students' grades in *Probability and Statistics* and *Oral Communication* were compared (see figure 5). Oral

communication was chosen because, even though it is not a topic related to engineering, it is very relevant to the PBL project: students work in teams every day, communicate to each other his/her ideas, and make oral presentations at least four times during each semester. So it was expected they would have a good performance in formal oral communication courses. It is also worth noting than in no case were traditional students superior to PBL students.

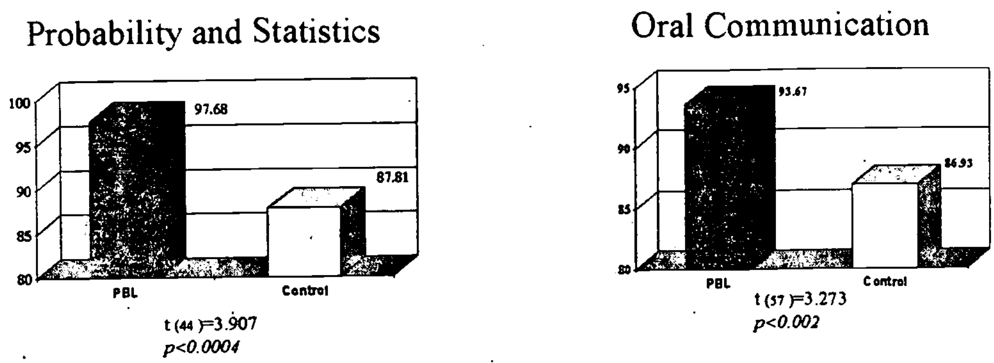


Figure 5.- Comparison of PBL and control students on grade means in Probability and Statistics, and Oral communication

Acquisition of skills and abilities

One of the assumed benefits of problem based learning is the acquisition of generic skills by the students. As was explained before, our PBL curriculum is addressed toward the development of some skills, abilities and attitudes. So the second source of data used to evaluate the benefits of the PBL curriculum was related to the acquisition of professional skills. Three studies were carried out. The first compared students' ratings of the degree in which the PBL/control courses contributed skill acquisition. The second study assessed inter-rater reliability of peer-evaluation and teacher-evaluation of skills and abilities. The third study compared PBL students and control students with regard to their performance on the California Critical Thinking Test.

Students' perceptions of PBL influence on the development of skills and abilities

In the first study, students compared the PBL curriculum to the remaining courses with regard to the development of 15 skills. Students rated on a 10-point scale the degree to which the PBL curriculum contributed to the development of each skill as compared to the remaining courses, so that a rating of 10 meant "much more", a rating of 5 meant "equal", and a rating of 1 meant much less. The skills and abilities involved were Leadership, Analysis-Synthesis, Critical Thinking, Communication, Teamwork, Information Searching and Management, Entrepreneurship, Quality and Excellence, Creativity, Management of Computing and Telecommunication Technologies, Coping with Excessive Work Loads, Autonomous Learning, Problem Solving, Learning, and Motivation.

Two control groups were used for comparison. The first one (CG1) involved students taking equivalent traditional courses (physics, math, computing) which were taught by teachers who also teach in the PBL program. The second control group (CG2) involved students taking equivalent traditional courses that were taught by teachers who do not teach in the PBL program.

Table 1

Students' perceptions of PBL influence on the development of skills and abilities

Skill	CG2	CG1	PBL	F	P<
Leadership	6.19	6.22	8.5	16.66	0.001
Analysis-synthesis	7.23	7.33	9.19	12.66	0.001
Communication	5.79	6.03	7.73	7.48	0.001
Teamwork	6.09	7.02	9.23	22.23	0.001
Information Searching and Management	6.24	6.80	8.88	19.83	0.001
Entrepreneurship	6.68	6.88	8.96	14.65	0.001
Creativity	7.13	7.18	8.92	8.73	0.001
Computing and Telecommunication	5.38	6.83	9.15	29.66	0.001

Skill	CG1	CG2	PBL	F	P<
Critical thinking	6.69	7.35	8.76	14.37	0.001
Quality and Excellence	6.82	7.06	8.44	7.19	0.001
Coping with Excessive Work Loads	6.68	6.76	8.65	9.10	0.001
Autonomous Learning	7.31	7.41	8.73	6.80	0.002
Problem Solving	7.00	7.54	8.73	9.74	0.001
Learning	6.73	6.91	9.23	13.45	0.001
Motivation	6.41	6.59	8.69	10.41	0.001

Results are summarized in table 1. Means are reported, from the lowest to highest, for each skill under each condition (CG1, CG2, and PBL). F and p values are also reported. The upper portion of the table shows those skills whose CG2 means were the lowest. The lower portion of the table shows those skills whose CG1 means were the lowest. In every case PBL scores were the highest. Continuous lines under the means represent no between-group significant statistical difference, according to post-hoc analysis. Therefore, score means in leadership, analysis synthesis, communication, entrepreneurship, creativity, quality and excellence, coping with excessive work loadings, learning and motivation showed no differences between GC1 and GC2.

Discontinuous lines represent significant differences. Hence, CG1 scores on teamwork, information searching and management, and computing and telecommunication abilities surpassed significantly those of CG2, while CG2 overcame CG1 scores with regard to critical thinking, quality and excellence, and problem solving. As can be seen in the table, PBL students' scores surmount significantly both control groups in every skill. The fact that between GC1-GC2 differences were not always in the same direction provides evidence that the gains observed in PBL students were derived from the program itself more than from the teacher's characteristics. In other words, whether the teacher teaches in the PBL program or not didn't seem to contribute to the results.

Inter-rater reliability of peer and teacher evaluation of skills and abilities

The second study involved peer and teacher evaluation of the same 15 skills. Its purpose was to assess the way in which different observers (evaluators) develops similar interpretations and expectancies about skills and abilities in the same process of evaluation. Inter-rater reliability on the judgments of skill acquisition was obtained. As it was pointed out, during the academic semester students worked in teams of four students. At the end of the semester, each student assessed their team partners on every skill so that average ratings were obtained for each student. Two teachers also rated every student independently on the same skills. In order to assess inter-rater reliability, correlation coefficients were obtained between teachers' ratings and between each teacher's ratings and the student average ratings. Between-teacher reliability was consistently high in each skill (average correlation coefficients of 0.81). These results are shown in the second column on table 2.

Table 2
Inter-rater reliability of peer and teacher evaluation of skills and abilities

Skill/ability	Teacher 1 – teacher 2 reliability	Teacher 1 – peer evaluation reliability	Teacher 2 – peer evaluation reliability
Autonomous learning	0.84	0.23	0.39
Coping with Excessive Work Loads	0.86	0.59	0.67
Analysis-synthesis	0.83	0.43	0.41
Information Searching and Management	0.63	0.32	0.40
Learning	0.84	0.59	0.54
Quality and Excellence	0.83	0.51	0.62
Communication	0.79	0.36	0.43
Creativity	0.82	0.35	0.36
Entrepreneurship	0.70	0.50	0.56
Computing and Telecommunication	0.73	0.31	0.36
Leadership	0.91	0.67	0.60
Motivation	0.90	0.41	0.36
Critical thinking	0.79	0.34	0.59
Problem Solving	0.87	0.69	0.76
Teamwork	0.81	0.38	0.29

When average peer ratings were correlated with teachers' ratings, reliability was considerably lower (average of 0.46), although positive correlations were obtained in every skill, as can be observed in the third and fourth columns on table 2. In summary, teachers seem to develop a shared interpretation of the skills they are promoting and evaluating in their students. On the other hand, students' judgments seem to be less "in tune" with teachers' judgments. It is worth noting that when this study was conducted students were in their second academic semester. It could be expected that students will develop a more fine interpretation of the same skills in advanced semesters.

Critical thinking evaluation

The third study involved PBL and traditional students taking the Spanish version of the California Critical Thinking Skills Test, which assesses skills such as analysis, evaluation,

inference, inductive and deductive reasoning, as well as critical thinking skills which are a combination of the previous skills.

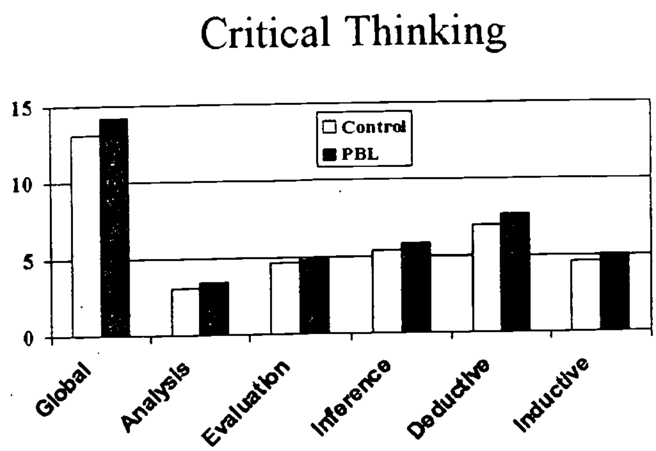


Figure 8.- Comparison of PBL and control students on critical thinking scores

Figure 8 depicts students' scores on each dimension. As can be seen, PBL students scored higher on each skill, as well as in the global score, than control students. However, as can be observed in table 3, between-group differences were non-significant.

Table 3
"t" and p values of the differences between control and PBL students on critical thinking scores

Dimension	Control	PBL	Student "t"	p value
Global	13.07	14.17	1.3	0.20
Analysis	3.07	3.44	0.96	0.30
Evaluation	4.64	4.83	0.35	0.73
Inference	5.35	5.89	1.09	0.20
Deductive	7.00	7.67	1.09	0.20
Inductive	4.62	5.06	0.83	0.41

Attitudes toward math, sciences and education

The final set of data evaluated the attitudinal aspects of the PBL curriculum. PBL, it was hypothesized, should not only produce a better and more meaningful learning, but should also generate a more positive attitude toward the contents to be learned and toward education. Four attitude-rating scales were used for estimating students' attitudes toward Computer Sciences, Physics, Mathematics, and Education.

Attitudes toward mathematics

During the third academic semester, both control and PBL students were administered a Spanish version of the "Revised Math Attitude Scale" (Aiken, 1963) As can be seen in figure 9, PBL students' attitudes toward math were superior, although non-significant, to control students'. It is worth noting, that one of the main problems that gave rise to the PBL curriculum was, precisely, the students' reticence and perceived meaninglessness of mathematics and basic sciences. PBL seems to attenuate this negative attitude toward math.

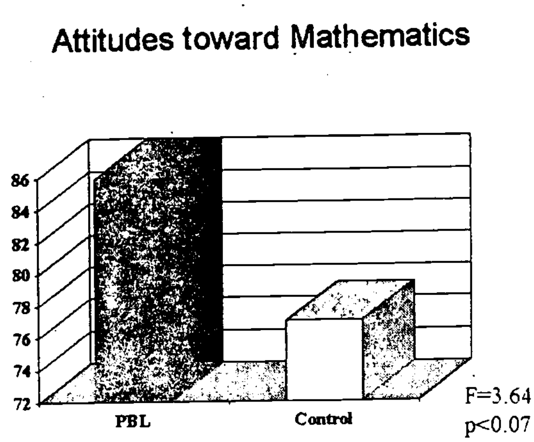


Figure 9.- PBL and control students' attitudes toward Mathematics

Attitudes toward education

Similar results were obtained with regard to students' attitudes toward education in general. The same sample of students answered "The Education Scale" (Rundquist, and Sletto, 1967), and results are reported in figure 10. As in the case of mathematics, PBL students exhibited non-significant better attitudes toward education than control students.

Attitudes toward Education

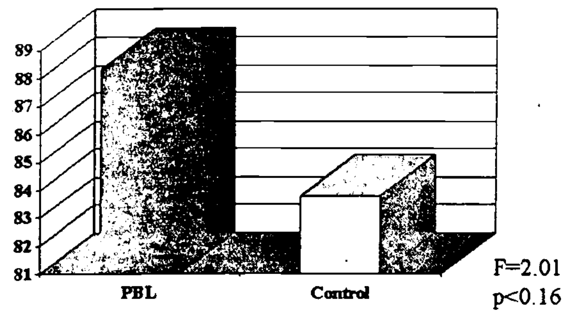


Figure 10.- PBL and control students' attitudes toward Education

Attitudes toward Computer Sciences

The third field in which attitudes was explored was computer sciences. Students were administered an adaptation of the "Attitude Toward Computers" scale (Silance, and Remmers, 1934). As far as one of the program cornerstones was the use of information and telecommunication technologies, it was expected that PBL students would show a better attitude toward computer sciences.

Attitudes toward Computer Sciences

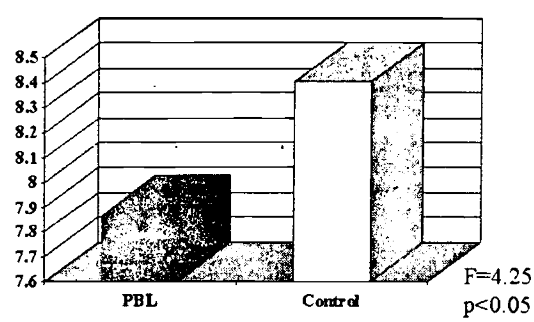


Figure 11.- PBL and control students' attitudes toward Computer Sciences

Nevertheless, as can be observed in figure 11, PBL students' attitude had a more negative trend than control students. Curricular changes are being implemented in order to make computer sciences teaching more meaningful.

Attitudes toward Physics

Finally, Students answered the "Attitude Toward Physics Scale" (Hand, 1953) which evaluates attitudes to Physics. As in the case of computer sciences, PBL students rated more negatively than controls. According to qualitative information, this fact seems to be attributable to teacher's characteristics. However, a follow-up is being made with a different sample of students.

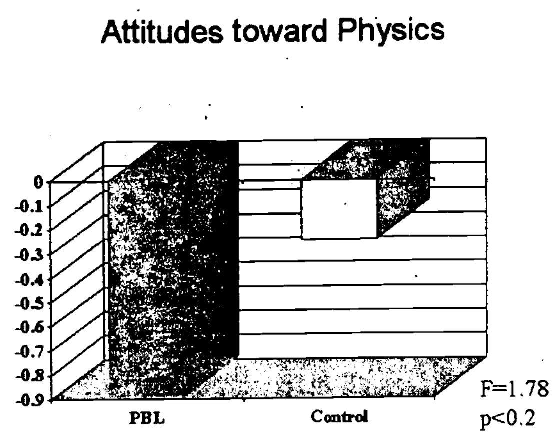


Figure 12.- PBL and control students' attitudes toward Physics

Summary and future perspectives

Although the PBL curriculum seems to improve the academic achievements in basic sciences learning by engineering students, some questions still need to be clarified. The main question that arises has to do with the students' attitudes. Even though PBL students obtained remarkable outcomes in their academic performance, both during the four-semester (sophomore and freshmen) duration of the program, as well as during de higher semesters, their attitude toward the fields being learned did not seem to change accordingly, at least with respect to Physics and Computer Sciences. Some hypotheses may be speculated regarding the role of teacher's attitude, very high requirements and pressure, and to curricular matters. However, additional studies need to be conducted in order to disentangle a satisfactory explanation. In fact, a pre-post attitude evaluation is being performed with a different sample of students.

A second field that needs to be explored in more detail refers to skills and abilities acquisition. The data reported in previous sections of this paper suggests that PBL curriculum promotes some relevant skills. However all the evidence collected to date rests on student's self-perceptions and teachers' judgments. In order to get harder data on this matter, an Assessment Center technique is being planned, in which trained observers assess

student's evident performance under simulated conditions. This way, observers depart from a clear understanding of the skills being appraised, and the simulated conditions provide the circumstances that trigger the behaviors and interactions to be observed.

Currently, a whole replication of the study is being conducted with some new generations of students, in order to assess changes and adjustments to the original program. Also, a follow-up is being planned for the first generation of students during their first years of their professional career.

As a general conclusion it could be said that this project intended to extrapolate the PBL experience from Medical to Engineering Schools, as a vision of future that anticipates an answer to the needs of the current professional. At the academic side, it aims to produce a learning that expands the student's action capability, a more enduring knowledge that does not find sense in information accumulation. Currently, the easiness in data searching leads us to emphasize critical thinking, and the ability to distinguish pertinent from irrelevant information. It is also worth noting that the work market often commits the professional to make changes in the job field. So it is necessary that he/she learn how to learn. In other words, that they develop skills that generate a more effective learning.

In a world in which effectiveness and dignity are struggling against each other, it is important for human beings to learn to give meaning to their actions' effectiveness, not as a solitaire hero's achievement but because their impact in others.

Finally, it is not possible to overlook the fact that the home of the future professional will be the virtual space. He/she will have to walk in the virtual world as he/she does at home. And a personal identity will emerge from that environment. For that to happen, the new citizens need to become acquainted and acquire the necessary skills that allow them to transform this new space in a place for their life-project realization.

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