Experiential Learning Strategies in a Mechanical Engineering Senior Course

R. Pascual
Mechanical Engineering Department, Universidad de Chile, Beauchef 850, Santiago, Chile
rpascual@ing.uchile.cl

R. Uribe
Engineering School, Universidad de Chile, Beauchef 850, Santiago, Chile
rouribe@ing.uchile.cl

Abstract: This article presents an approach to enhance active and collaborative learning spaces in engineering education. The proposed strategy is a result of reflective observation of the stated output competencies and past experience. As a consequence, the course program has been reoriented to achieve the intended outcomes, in a framework of methodological strategies. The proposed methodology is focused on a group-based design project whose goal is, in our case study, to design strategies to manage critical production equipments of actual production plants. This approach includes the blend of several support techniques like: problem-solving centred classroom sessions, cutting edge research homework directly related to the real needs of the visited plants, oral presentations before classmates and external experts, extensive use of information and communication technologies (ICT), and development of concept maps.

The methodology develops skills which are pertinent to new engineers in a professional environment such as: objective decision-making, team working, autonomous learning, conflict handling, and presentation and defence of initiatives. Working with several companies allows students to better understand industrial needs and constraints. The whole learning process effectively supports contextualization of concepts discussed in the classroom and provides an appropriate environment for meaningful learning. The initiatives were assessed through surveys completed by the key players in the process: students, maintenance engineers of the plants under analysis, and external experts. Results show that the application of the approach presented here is successful according to selected criteria.

Keywords: Project oriented learning, meaningful learning, active learning, social-constructivist learning

Introduction
There is now a considerable body of research on innovative learning in engineering education. Considering the program level, Vernon [1] presents an analysis of needs and concludes that an effective learning program in engineering education should: be student-centred and project oriented, include some elements of economics and management. It should be supported by learning with applied problems, industrial visits and industrial training. It must develop communication and interpersonal skills, such as being proficient at team working and mastering a second language. Focusing on change, Andersson and Roxa [2] consider four essential motivation sources for teaching innovation: required skills in the professional market have changed, the amount and complexity of knowledge grows continually, new pedagogical methods appear in time, and current students react and get motivated differently. Likewise, Heitmann [3] emphasizes that programs should be responsive to new demands, and creative to new offers. Among those new demands, we may mention the need to act proactively to face continuous change in knowledge and technology. According to Reich [4], students trained using conventional methods are not well prepared to deal with problems which require them to apply their knowledge to new domains. This affects their capacity to function effectively in current society.

As for learning theories to sustain innovative strategies, several are available. Novak and Gowin [5], based on Ausubel’s learning theory [6], advocate for meaningful and autonomous learning in opposition to learning by memorization and receptive learning. The professor should provide metacognitive spaces, that is, learning to learn and also define and apply a course program providing meaningful spaces for the students. In order to facilitate the process, they promote the use of techniques such as concepts maps. Vygotsky [7], founded on the social constructivist theory, points out that interactive communication among the actors of the learning process develops
superior cognitive and metacognitive processes (see also reference [8] in relation to the use of ICT). In this context, learning must be external and shared, prior to being internalized and made personal. In that sense, activities like: team working, classroom discussions, oral presentations, group-based concept map building, and industrial visits promote communication among peers, with the professor and with other experts. Kolb [9] developed a three-dimensional spiral model of how people learn (figure 1). Each learning cycle includes 4 steps, including active experimentation. For a complete learning process the individual should pass through all steps of the cycle, one or several times depending on the complexity of the subject. Based on the above theories, the use of active learning strategies is clearly encouraged. Active learning strategies also greatly augment the percentage of retention (see Stice [11] and Bales [12]).

Cultural specificity is also an issue when implementing innovative learning strategies. Ratchev [13] points out that studies on the effects of active learning strategies mainly come from Western, Northern-Hemisphere countries. The validity of application of these learning strategies in other cultures is questioned. Weenk, Govers and Vlas [14] observed notorious differences (i.e., professor’s role and peer assessment) when implementing project oriented learning in a Mexican university. Concerning the Chilean environment, we have found that the students have not been exposed to a learning process effectively involving them in a professional environment. In general, students have reduced self-learning skills and do not involve themselves in self-directed information research. We also have observed problems of organization, style, and revision in their academic writing. This situation does not seem to be unique to our culture, as other researchers have described similar situations around the globe (i.e. Peters and Powell [15], or Rahal [16]). With regard to learning in the industrial environment, a study made by the mechanical engineering department to fulfill the national accreditation board criteria revealed that the relationship between the department and industry is perceived by the associated groups (students, professors, graduates, and employers) as weak [17].

Figure 1: Kolb’s learning cycle [9]

Another dimension affecting the choice of experiential learning strategies is the consideration of the different learning styles [18]. It calls for the use of several strategies, in order to accommodate a larger audience and improve students’ learning capabilities as they will see contents in more than one style. Regarding choice, we include: case study, simulation, design projects, and discussion. In all these methods students should work on real-life engineering problems.

The case study method is very effective in the development of skills, approaches and philosophy of decision-making; however, it is not an efficient way of transmitting knowledge according to Shapiro [19]. An example of its use in Mechanical Engineering education is provided in Raju and Sankar [20]. This technique can be considered as an example of problem based learning (PBL).

Summer internships are also interesting, active and meaningful learning experiences. As students make contact with practicing engineers, they gain confidence and professional skills. The level of learning, however, highly depends on the commitment of the industry and the engineer in charge. Control is, generally, low from the academic point of view.
PBL was introduced in Canada in the sixties [21]. Usually, problems in PBL are covered in one or two classes, a few weeks at most. If problems are related to a topic, and are dealt with during one (or more) semester(s) we introduce Project oriented learning (POL). Structured POL is traced back to the seventies, with the Aalborg experiment [22]. Nowadays, many international initiatives advocate project-centred courses. They include: CDIO initiative [23], ABET [24], and the Tuning project [25]. POL is further described in the next section. PBL tends to be more structured than POL, so students can focus more on small scale topics.

In the above framework, we look for an adequate set of strategies to enhance experiential learning in a professional environment. The methodology is focused on the project as it may include the other techniques. Projects provide superior characteristics for meaningful, collaborative, and active learning.

The article is organized from the concept map represented in figure 2. First, we present the logical sequence that allowed us to define the global didactic strategy and the design of its application. Section 2 describes projects as an experiential learning strategy. Section 3 presents a set of complementary learning techniques that contribute to achieve the intended student competencies. Section 4 introduces a case study in a Mechanical Engineering senior course. Finally, we provide some conclusions and further developments.

2. Project oriented learning

POL provides experiential learning opportunities for the students, as previously gained knowledge from current and past courses contributes to the development of professional practice. The process is active and cooperative. This ensures the achievement of the experiential step of Kolb’s learning cycle (figure 1). POL involves the use of situations which are or should be meaningful to the student. These situations are shared and discussed throughout the course, and they should close the gap between theory and professional practice allowing the student to do research by himself, to look for the required information, to write up technical documents, and to make decisions using concepts discussed in the classroom.

Dutson et al. [26] present a survey of courses and methodologies which use projects in engineering programs. A good example is Hanna and Sullivan [27], which describes a situation of experiential learning in a civil engineering capstone course. They propose an open design problem to the students, which is supervised by external experts and by the professor. The course emphasizes the importance of the integration with other branches of engineering (i.e. mechanical, electrical). The project includes a feasibility analysis, cost analysis and task programming. The course proves to be an excellent learning experience, since the interaction with field engineers adds credibility to the learning process. Furthermore, it is a good skill assessment tool (both professional and personal) of the student ready to obtain his degree. In mechanical engineering education, most project oriented courses consider the making of a
prototype [26]. Others, stay at the stage of design drawings or virtual prototypes due to cost and time constraints [28].

POL has also been perceived as a valuable tool for cooperative learning. Hamekink et al. [29] argue that the project process considers team discussion to better learn contents, collect and analyze information, assess and improve the decision support models. Cooperative learning is recognized as a high cognitive learning strategy [30]. For example, POL may include discussion as a learning strategy. Oral presentations allow the students to defend ideas and the professor to act as a facilitator and guide. The discussion has also been referred to as a highly cognitive learning tool [18]. According to McKeachie [31], it greatly improves in the student's ability to solve problems and develop critical thinking, while not requiring a long time.

In relation to learning motivation, Todd [32] reports that students achieve a great level of motivation and sense of responsibility when projects are provided or coordinated to satisfy real needs of companies.

The use of teams in project oriented learning is also an issue. According to Dutson [26], 80% of courses using project oriented learning use teams, a choice supported by Vygotsky's work. Group based projects have been preferred to individual work mainly to develop team working skills and facilitate discussion. In order to form groups it is convenient to look for complimentary learning styles, according to Gabriele [33]. Learning styles can be discriminated using the Kolb test [9]. By doing so, we avoid that students' group themselves, since friendship tends to reduce criticism, negatively affects discussion and facilitates hiding behaviour [33]. According to Dorsey [34], such selection simulates real-life team formation in professional practice. Experience shows that students have little team-working experience, which may strongly affect group dynamics during the semester, due to internal conflicts (see Emanuel [35]). Pournaghshband [36] lists among the causes of group conflicts: poor communication among the members, lack of leadership, low level of commitment, lack of cooperation and trust, personal problems, and clash of schedules.

As for project structuring, it can be guided by the professor, the students or an external expert. According to Bridges and Hallinger [37], project validation can only be done by outside practitioners, defining validation in terms of a project product. Usually, such situations do not occur as they require a significant amount of logistics.

A variety of methods exists to assess projects in relation to the acquisition of the course competencies [38]. Objective assessment is not evident as there are difficulties in judging individual contributions in POL [15]. In order to overcome that, Leung [39] presents a quantitative method to estimate individual contributions. Every student must estimate the percentage contribution of each group member, himself or herself included. Based on them, the professor may obtain an estimate of every person's contribution. An analysis of the deviations will allow the professor to determine which students are suspected of deliberately providing inaccurate estimates. Assessment is also affected by the group size. Perrenet and Adan [40] present a study on group sizing considering dimensions such as personal interaction, hiding behaviour, task division, and creativity.

3. Complementary techniques

Although the project is recognized as a powerful experiential learning technique, it must be supported by others in order to ensure the success of the learning process: attaining the stated output competencies. In this sense, the approach proposed here considers a series of complementary techniques, which provide different learning environments in recognition of different learning styles [9] and also allow for several feedback pathways for the assessment of the learning process [10].

3.1 Individual challenge

As an exclusive alternative to the project, an individual research paper is proposed on a topic of interest to the student, and agreed with the teacher. A recent paper is selected after performing a bibliographical search. The results must be replicated by the student. This kind of individual project is seen as a special case of the reverse engineering strategy (see [41, 42]), since the solution is already known. The solution and the methodology are described, but results should be repeated using available ICT and summarized in a final report.

3.2 Concept maps

A very interesting instrument for assessing the synthesis and integration levels achieved through learning is the concept map [5]. It consists of a diagram in which various types of knowledge, typically concepts, are classified and
their relations are shown (i.e. figure 2). It is helpful to establish students’ preconceptions, to identify misunderstandings, and to find out what they already know and what they have yet to understand [43]. Besterfield-Sacre et al. [44] propose an innovative way of evaluating them. Concept maps are also helpful to promote discussion among peers. They are also used to assess outcomes along the course.

3.3 Information and communication technologies
Gibson et al. [45] argue that project oriented learning also represents a good opportunity to expose the student to innovative information and communication technologies (ICT). They also conclude that projects force the student to take responsibility for his own learning process. In their case study, projects developed by industrial engineering students ended in successful industrial ventures (see also reference [46]). Christodoulou [47] presents a framework for an interdisciplinary course that is fully supported by current ICT in the context of civil engineering education. The authors focus on the interdisciplinarity which is now allowed by the use of ICT. They report very successful results. Based on social constructivist theory, Boyle and Nicol [48] show results when using classroom communication systems to support interaction and discussion. Classroom discussions force students to explain, analyse and defend their answers to concept questions when they face questions and observations by peers with different perspectives [8].

3.4 Student-centred classroom activities
Hansen and Bobbi [49] highlight the importance of questioning techniques for classroom use. The questions must lead the student to make observations on what is being learnt. Concept map building helps students to sum up and explain what has been reviewed in the lesson, while linking them to those of other course or program contents. The professor also benefits from finding out whether the stated outcomes have been achieved. The creation of an open communication environment, where everybody is able to express his or her point of view, such as, conversing on a first name basis, making jokes, making cross-group remarks, and requesting the other’s opinions is important to achieve active learning in the classroom. In this way, a community environment, where the group works as a whole along the learning journey, is achieved. Smith et al. generalize the concept and speak of classroom-based pedagogies of engagement [50].

4. Case study

4.1 Description
The case study described here has been undertaken with the maintenance management course, which is taught during the fifth year of the Mechanical Engineering curriculum at the Universidad de Chile. It can be considered as a
capstone course requiring previous knowledge of statistics, calculus, optimization, solids and fluids mechanics, economics, among others. The focus of the course is the Operate phase in the CDIO initiative [23], although the other system phases are also considered. The stated course goal is that at the end the student should be capable of designing a maintenance strategy for an industrial facility using objective criteria. According to Bloom’s taxonomy [51] this goal considers evaluation, which is coherent at the level of the program where the course is considered. The students are challenged to develop a design project under the following conditions:

- The duration is a full semester (15 academic weeks),
- A group of 3 students,
- It should support maintenance decision-making for equipment (system) with enough complexity to perform analysis. The term sufficient is defined by the professor’s judgement (previous project reports are available on the web as a help). Information on failures and system costs should be available under a maintenance information system. These conditions prevent the failure of the project due to lack of data,
- It considers 3 partial reports and a final report, with an oral presentation each time. Contents and submission dates for each report are given at the beginning of the semester. Each development of the reports should consider a kind of decision, a description of the current situation in terms of costs and necessary information, proposed decision, methodology, expected gains, and conclusions.
- At each oral presentation, the group should defend its proposed decisions before their fellow students, the professor, and at the final presentation, also in the presence of an external maintenance engineer. Each presentation is limited to 30 minutes. Observations made during the oral presentation should be taken into account to update the written report.
- As ICT support, all reports should be written in an adequate word processing environment (i.e. Latex). This constraint helps the students to produce structured texts, with an improved organization of the information. Reports are sent via email 3 days after the oral presentation. Once this is done, each group receives feedback from the other students to help correct mistakes and improve the report; the use of paper is made unnecessary. Other supporting ICT are further described below.

4.1.1 Project planning
At the beginning of the project it is specified that each group represents a maintenance outsourcing office which works for the company. The instructor plays the role of an operations or general manager, who has to be convinced of possibly making some investments or modifying practices in the company’s equipment management. During each presentation, the other students act as engineers of the rest of the company’s departments who also attend the meeting. For the final presentation, an external expert is present as well.

During the first week of the course, the groups are defined, and objectives and scope are stated. Each group selects equipment from an actual facility. Examples of equipments are: a wrapping machine, an industrial printer, and a hydraulic turbine. The selection of the facility and the equipment is the responsibility of each group and is facilitated by the professional contacts made by the students during summer internships. In general, it is guided by the maintenance engineer, who benefits from the results of the project. This method of selection reduces the intervention of the professor and the subsequent coordination load. It increases the sense of responsibility of the students in the project’s success as the group owns the project. In its current state, costs of visits to the plant are covered by the students. Groups are formed according to the procedure described in section 2.

4.1.2 Social and economical implications of the project
Asset management has been recognized as one area whose development is forthcoming or pending, both in developed and in developing countries [52, 53]. It is interesting to explore the social effects of a design project using cutting edge strategies to objectively support decision-making in this field of management. The project, mainly through the final report, represents a vector of technologies towards the company under study. As it includes a study of the economic gains of implementing proposed measures, we also expect an economical impact. Along that line, Buckley [54] affirms that socially-relevant projects have great impact on the motivation of the students.
4.1.3 Project scheduling
The project considers the application of a Reliability-centred-maintenance strategy [55]. As the approach is bottom-up, the students undertake this only during the final weeks of the semester, when this technique is discussed in the classroom. By doing so, learning is inductive, which is recognized as the preferred way to learn [18]. The dates for submission of reports usually coincide with the end of the lessons on the contents required for each report.

4.1.4 Group contest
The final presentation will assess which group achieved greater savings for the company in the maintenance management. For scaling purposes, the savings achieved during a year divided by the equipment replacement costs are taken into account. The prize consists of the publication of the final project report in the course’s web page. It will help future generations.

4.1.5 Information and communication technologies
The support tools (knowledge and associated ICT) the students will require for the project are reviewed during the first 3 weeks: task planning (Project), simulation of queuing processes (Arena), optimization (Excel, What’s best), and concept mapping (Cmaptools). We also program a session where the library staff present available scientific information databases like ISI Web of science, Proquest, or ScienceDirect, just to mention a few. The session is interactive, so students may immediately test the search engines in the context of their projects (figure 4). The course notes are available on the web, and it receives new material each semester from homework, classroom exercises, and individual challenges.

Students are encouraged to use ICT during the whole course. We believe that this is essential for the members of the profession in order to succeed in the technology-based age of information. The project, and the mathematical models that it includes, require the use of several available software packages. Several of these packages are professional, which is very useful for students, who gain some preliminary experience with commercial software and learn how to solve practical problems by using suitable ICT.

![Figure 4: Students receive a training session for bibliographic self-directed search using available databases and search engines](image)

All classroom activities include projector and notebooks for all students. In order to facilitate communication among peers we use a standard communication system, VPN, that allows any student to show his results on the projected screen and discuss them with the rest of the class.
We also have digitalized multiple-choice examinations and the course survey using Acrobat designer. In this way, processing is done very quickly in any spreadsheet software, i.e., Excel.

4.1.6 Visit-oriented homework
As a way of supporting meaningful learning, homework oriented to the needs of the industries visited throughout the semester are used. Each homework consists of the replication of a recent paper or monograph (i.e., during the second semester of 2005 those used were: queuing processes simulation in overhaul workshops [56], preventive maintenance frequency [57]).

An example of cutting edge homework was the first homework of spring semester 2004. It considered spare managements in airlines from that same year [58]. The article was reproduced and presented by a volunteer student at ENAER, the company that maintains the fleet of the Chilean Air Force.

The assignments are presented in every visit by a student volunteer, who is supported by his or her classmates when the discussion with the field engineers takes place. The interaction with engineers helps students improve their inter-personal skills and self-confidence before entering the professional working environment [26].

After the presentation, the engineers complete a survey to evaluate the technical level of the presentation, the applicability of the proposed model to their reality, the level of knowledge of the students, the quality of the audiovisual material, and the way the student took advantage of it. The feedback from the survey redirects the tasks of the next semesters in order to reduce the gap between the contents and our local reality. It is also very gratifying, seeing students teaching in a professional environment.

4.1.7 Individual challenge
To have an idea of the modelling work done by the students we describe some examples. During the second semester of 2005, two students volunteered for the challenge; they worked on the following topics and articles respectively: contract negotiation between maintenance services providers and companies [59], and useful life of equipment fleets [60]. The presentation schedule is similar to that of the Project. The challenge is an open problem, since in the beginning the student has no knowledge of the methodology (selected papers are very recent). When there are elements not included in the course, the student must learn them on his or her own. For instance, the challenges of references [59] and [60] required to master games theory and maximum-likelihood estimation theory respectively. Trying to master very recent articles is actually a mental challenge for the student. If the challenge is deemed unlikely to succeed by halfway through, the student can quit it and carry out a regular project.

4.1.8 Student-centred classroom activities
It is estimated that attendance to classes at the end of the engineering program tends to be in the interval of 30-40%, which is considered low. In our course, students are encouraged to attend classroom activities. At the first class, when the course plan is presented to them, some incentives to attend are offered: (i) creative exercises are proposed (they do not appear in the course notes), (ii) they gain practice in the use of ICT, (iii) grade prizes are offered for special activities, (iv) some evaluations are done at the end of a unit (i.e., the concept map of the unit). Point (iii) is crucial in formal evaluations, as the exams require students to master appropriate ICT. As a result, we have notably increased the average attendance as shown in figure 5. For that semester the average attendance was 61%. It should be noted that at this stage of the program several students are working part-time in engineering consulting and their attendance to classes is more difficult. This kind of student represents 5-15% of the class.

A typical lesson starts with a short review of what was seen during the previous one, and then a connection is made to the topic of the day. A question and answer session is used to let the students to individually identify the relevance of the models they will learn with examples given by them. Usually, the project subjects are used as examples. The above process usually takes about 5 minutes.
Then, the formal presentation of the model is given using PowerPoint, which is available on the web for all students, and an open exercise is proposed. The professor calls for a volunteer who acts as assistant. This student gains control of the projector using VP and starts developing a solution to the problem with the help of his classmates and the professor’s guidance. The professor stands at the back of the classroom in order to facilitate peer group dynamics. All remaining students solve the problem on their notebooks too, and check and comment what is being done in the assistant’s notebook. Once the problem has been solved, some commenting is done and the solution is checked against the professor’s, which is also available. The model presentation-problem solving process takes usually 15-20 minutes. Thus, we have time for 3 sequences in a session. At the end of the session the professor gives an overview of the lesson and makes some final concluding remarks. If it is the end of a unit and half of the semester is over, a concept map is developed in groups of three. The resulting maps are presented to the class and discussed. The concept map is graded on a group-basis. The concept map process lasts an hour in average, but as practice is gained, this becomes faster. For the students, the process helps socializing recently-acquired knowledge (social constructivism). For the professor, it is helpful to assess the achievement of the stated outcomes.

4.2 Assessment

4.2.1 Course grading

Main percentages are: homework, quizzes and classroom activities (20%), project or individual challenge (30%), tests and final exam (50%). There are three tests at each third of the semester. If the test average is above 70%, the student is exempted of the final exam. Tests and final exam consider applied problems to measure the competencies. They require mastery of ICT tools. In order to reduce stress of technology-reluctant students when using the software, the average duration of tests is about 4 hours. Standard examinations provide a good motive for the students to learn as they need an average of 45% to pass the course. Examinations are open book. In Bloom’s taxonomy, all questions look for evaluation level, on account of being a senior capstone course. Figure 6 shows average final grades for several generations. The trend is an increasing one. The second semester of 2004 is considered special as it was a small course with only 10 students, of whom 2 dropped the course and a third one failed it. Two of the successful students are currently enrolled in Ph.D. programs. The group was quite united, and studied together. Notebooks in the classroom and concept maps were implemented at the beginning of 2005. The project strategy has been in place since 2001. Group problem solving in the classroom was implemented at the beginning of 2004.
4.2.2 Project assessment

Individual contributions to the project are assessed through peer evaluation, to be carried out at every mid-project presentation and in the final one [34, 61]. It is worth 10% of the project final grade. The co-assessment has also been useful for the early detection of conflicts between team members.

The engineer in charge (liaison engineer) submits an assessment worth 20% of the written reports grade. Validation of the project results is achieved both in the oral (presentations) and the written (reports) levels. The presentations allow for debates where problems are discussed and solutions are proposed by peers with the professor’s support. Presentations also provide the opportunity to practice particular learned skills, such as analysis, team work and oral presentations. Another validation element is the assessment provided by the maintenance engineer in charge. Some examples are:

... When the study concluded, it proved to be a great contribution by facilitating the conduct and control of maintenance activities for this and the other machines making up the bottling lines. Taking into account the great contribution of Mr. Hidalgo, he should be awarded a 7 mark (in a 1-7 scale)... according to the study, it was necessary to change the design of some shafts and the types of bearings used; the bearing used to be changed every month, but now they have been in use for 4 months and they are still in a very good condition. The efficiency has increased in comparison with the same period of 2004....

...As the project report set out, our management has a great weakness in spares management. This motivates us to further work to improve our system... the work done by your students was quite well developed...

...The final report presents a lot of new analysis to us. We are considering taking measures according to their conclusions.... the work that they have done is very important to us as it show ways to improve. For that reason, we believe that it should be qualified as an excellent job...

The following are some examples drawn from the teaching survey completed by the students:

Very good course, the content is very interesting and useful, but it is time-consuming. Clearly, there is a work overload.

It is always good to use ICT tools in any course; their use, however, is not widespread among many professors. In this course they were highly used. It greatly facilitates learning; however, the professor’s requirements hinder a more thorough study and dedication.
We have learned a lot. In addition, I have learned more about operations research than in the specific course. The visits were interesting and complemented the course well.

The use of innovative learning techniques has added extra difficulty to the course, which is already quite difficult. I don’t understand why these kinds of initiatives start at this level of the program. They should start before (third or fourth year) and with less complex courses.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Autumn</th>
<th>Spring</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>The project is of great help to learning</td>
<td>100</td>
<td>73</td>
<td>87</td>
</tr>
<tr>
<td>There is a high learning/workload ratio in the project</td>
<td>89</td>
<td>64</td>
<td>77</td>
</tr>
<tr>
<td>I learnt more with the project than studying for the tests</td>
<td>73</td>
<td>91</td>
<td>82</td>
</tr>
<tr>
<td>Homework is very useful to follow up the course</td>
<td>100</td>
<td>82</td>
<td>91</td>
</tr>
<tr>
<td>Professor encourages student participation in the classroom</td>
<td>100</td>
<td>83</td>
<td>92</td>
</tr>
<tr>
<td>Exercises satisfactorily contributed to the learning of course contents</td>
<td>100</td>
<td>75</td>
<td>88</td>
</tr>
<tr>
<td>Industrial visits satisfactorily contributed to the learning of course contents</td>
<td>100</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Academic units of this course are inadequate to the workload that it requires</td>
<td>100</td>
<td>83</td>
<td>92</td>
</tr>
<tr>
<td>Course notes constitute an adequate complement for the learning of course contents</td>
<td>86</td>
<td>67</td>
<td>75</td>
</tr>
<tr>
<td>My attendance to classes is above 50%</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>In general terms, I am satisfied with this course</td>
<td>56</td>
<td>83</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 1: Results of the student survey for both semesters of 2005 (% that agree or strongly agree)

5. Conclusion and discussion

The project oriented methodology proposed here provides a good opportunity to experiment with the students both in terms of achievement of the proposed goal and objectives and to put the course contents in a real-life experience context. Students find an excellent opportunity to take a close look to their future work. As implemented, the approach promoted consistent participation of the students and allowed for meaningful and continuous learning.

Evidence supports the hypothesis that introducing active strategies improve learning (and academic performance). From the analysis of grades in time, we observe a positive effect from using active strategies beyond the project. As observed, a small, talented, and motivated group may also greatly enhance the learning process.

The decreasing trend of class attendance over in time is probably explained by the increasing workload imposed by the courses as the semester advances. Besides that, attendance levels are considered very high when compared to other courses at the same level.

Students’ remarks support the hypothesis that during previous courses, teaching tools for the enhancement of learning failed to be used. As for the work overload noted above, homework was reduced by 50%. The students’ perceptions are the natural reactions to a pilot program that has yet to be institutionalized. Once adopted, the different courses should converge in projects that synergize them. This will allow for a greater integration of the course contents.

The implementation of the strategy involves a shift in the professor’s role. He or she assumes the role of a permanent guide and adviser, giving up his or her leading role. The strategy is stimulating for the teacher as it attains the stated outcomes and validates the contents reviewed along the course. The assessment of professionals, as well as the debate brought about during field visits act as feedback to bring the contents closer to the professional practice. The discussion of this methodology among faculty peers has caused a discussion on the use of active learning strategies in the department.
Improvements

Inside the classroom, the use of case studies as a support technique will be reviewed. Available material will be used, i.e., Raju and Sankar [20]. We would also like to explore using an ad-hoc classroom communication system in order to facilitate technology-supported discussion methods and opinion polls. This would enhance and increase active learning in classes. As a complement to concept maps, the assessment process may be improved by implementing the minute paper technique [18]. We have used peer evaluation (within each group) and external evaluation by a practitioner. We would like to try discussion groups, that is, intergroup evaluation. An example of such approach is given in Perrenet and Adan [40]. It would also greatly help the learning process to dispose of online material to: advice on academic writing, develop critical reading, etc., as it exists in other universities.

In the professional environment, these projects could be the basis for business ventures in the growing field of maintenance outsourcing. Elements to support entrepreneurship will be introduced [46]. A different idea would be to organize a meeting between the department and the companies prior to the start of the course, so they can propose the problems they want to be solved, in a similar way to internship programs. Advantages of the project compared to internships: group (v/s individual), 4-month length (v/s a single month); it is also monitored by a professor (v/s the engineer in charge only); it provides several opportunities for peer discussion (unlike internships).

While active strategies appear to be highly motivating for students, it is necessary to further develop objectives in the affective domain [62]. We believe that exploring it with the students could be the next breakthrough in the development of this approach. We are exploring some approaches which will be described in a future article.

Acknowledgements

We would like to thank Project Mecesup UCH-0403 of the Chilean Ministry of Education which provided the setting to develop this article. The first author wishes to extend his warmest thanks to Professor Ventura Cerón (from The Universidad de Concepción) for introducing him to the field about active learning.

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