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Lab Project Management: A Learning Scenario for Experimental Courses

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ABSTRACT: *Experimental work has usually consisted of a series of tasks leading to reproducing and verifying certain already known experiments. Thus, the genuine discovery process that may produce the most significant learning is frustrated by the a priori knowledge of the "correct" result to be obtained, which consequently makes the students drive their (more or less honest) effort to achieve it.*

Certainly, there is a need for the students to undergo a series of lab works in order to experience (or witness) the number of fundamental phenomena required by the curricula. Such quantitative requirement prevents the course supervisors from dedicating the semester to work on a single kind of experiment. Yet, this is just a consequence of the preconception stating that students must work with the limited set of experimental data they personally obtain at the lab, which implicitly means that their task is just measuring instead of carrying out the complete series of tasks that any experiment requires.

However, this should be revised within a cooperative learning environment. Not only "copying" classmates' results should be considered positive, but sharing experimental data forces students to learn better ways of information management, better group self-organization and communication, as well as allows deeper personal interaction and contributes to integrative ways of knowing. Hence, the Lab Project Management (LPM) presented allows maintaining the same course programme of experiments-measurements simultaneously to the introduction of an experiment management at an upper level.

LPM encourages "copying" experimental results with the aim of having more information to be analysed as well as meaning to keep the conclusions open until all the experimental data is gathered. This is put into practice by assigning to each lab team one specific experiment of the course programme for which the team will have to collect, analyse and present at the end of the semester the results obtained by all their classmates. Thus, the experiment is no more just a lab session but a whole-semester experiment: a learning process given by a lab project.

LPM is the additional task assigned to all lab teams. Consequently, students are required to assume the role of Project Managers (they are fond of the title) as well as the associated responsibility: leadership, supervision and control. This new scenario allows learning not just the behaviour of certain phenomena and the measurement procedures related, but provides a deeper insight into the core of experiment design. Regarding social abilities, such a situation permits an implicit learning of the managing game, including producing and solving conflicts.

For the students, this role requires establishing ways for controlling their classmates' experimental work. They have to guarantee that all the data they are supplied is consistent and have been obtained under the same conditions, and consequently they need to exactly explain their "assistants" what they want. Moreover, they may be given a certain freedom for planning and modifying the conditions under which other teams will repeat "their" experiment. Finally, given the larger set of data this way gathered, results analysis is more useful and instructive.

The success of the procedure requires that the course introduction has to be dedicated not only to explain basic lab work but to state the game's rules by making clear that experimenting is not just measuring, but also designing, planning, managing information, communicating results and providing economical evaluation of the experimental project.

This new learning environment has been tested and evaluated during the last three years in the Chemical Engineering Lab courses of the Universitat Politècnica de Catalunya (UPC). Results including the differential perception of the students (at the start and at the end of the semester) are presented and discussed. These results have resulted in the revision of LPM and the inclusion of further supervision, planning meetings, writing of minutes, etc.

1 INTRODUCTION

This paper describes a learning methodology that has been introduced at the lab classes as well as some aspects of the way gone since the course 2001-02 when changes started. The subject is Experimentation in Chemical Engineering (ECE), which includes transport and thermodynamic properties, fluid flow, heat and mass transfer and reaction kinetics.

This course was declared as an independent compulsory course in the new guidelines (Spanish Ministry of Education) for the curricula leading to the Chemical Engineering Degree. This achievement means that students may pass or fail the Chemical Engineering Lab regardless of they passing or failing other compulsory subjects such as Unit Operations or Chemical Reactors. However, despite the news, the fact is that the lab has long been considered not as a subject itself but the complement to the theory lectures. Still it is to some extend and terminology does not help: the ECE is still "the lab" (the Unit Operations lab, the General Chemistry lab, the Control lab).

This scheme is supported on the teaching formula for which theory is first (lecturing) and practice is (should be if we had time enough…) a way to help understanding the theory. Of course, theory is the abstraction that allows gathering and systematising all the trial and error processes undertaken by our ancestors. However, it should be not a way to prevent the students from following (partially) the same processes and committing their own mistakes. Otherwise, students would completely mistake the point of experimenting and modelling.

Natural laws were there to be discovered so that once discovered and the universal constants determined the only point is to study and memorise them, maybe also learn how to use them properly. This leads right to the point that the lab is just to reproduce a well-known experiment for obtaining the well-known universal constant. Students often ask if the value in the handbook is the theoretical value they should obtain. The problem is not only they are seeking for the right value, but also that they call theoretical value the experimental ones. Some effort is required to change part of the terminology to introduce the concepts of modelling, empirical model, empirical parameters, parameter adjustment, etc.

Inertia to changes, however, is not only found in the faculty side but also and a lot on the students'. Due to the limited span of a lab session, students usually go to the lab having read and work (in the best case) some previous materials, take some measurements, verify that they match some law revealed at a theory lecture and produce a written report to be evaluated. Commonly, too few values obtained during the session have to be adjusted to a linear (or linearized) expression and the effort turns to justify why data do not match or, in the worse case, to "force" the data to match. Once this practice is acquired, students feel too comfortable to give it up.

The option of preparing open experiments with indefinite results seems not to fulfil the requirement that a number of practical assignments must be successfully carried out accordingly to the course programme. However, this unfeasibility appears only under the conventional assumption that lab teams must work independently their own experimental data. Regarding a cooperative learning environment, sharing experimental data not only should not be blamed but also encouraged.

On the other hand, why dedicating such a huge worthless effort to keep watch on the students, comparing results reported trying to catch those copying or exchanging their results? Could not be the same students those comparing the results? It is not the essence of the experimental work to gather, compare and analyse data? This proved to be a convincing line of reasoning for dealing with some of the inertia to changes in the faculty side.

The situation at the Chemical Engineering Lab and the main points for starting introducing changes can be summarised:

- Each experiment was assigned to a unique lab session.
- From the experimental point of view it was clear than the set of experimental data obtained by each team during a lab session was too limited for a genuine analysis process.
- This limitation made the sessions be accurately prepared for taking the maximum advantage of time, so that following the lab recipe step by step allowed obtaining more data by avoiding mistakes.
- Faculty and students were mechanically accepting the target was successfully repeating series of known experiments to get the known measurements, thus confirming the theory previously learned.
- Each session students were dedicating their efforts to get the right value (to be forget at the next).
- Faculty devoted a great effort to pursue dishonesty by comparing results reported.

For these reasons the changes started by requiring the students to share their data in order to have a larger set of measurements as well as to leave the result open until the end of the semester when all data has been compared and analysed. Thus, each team is assigned one of the programme experiments and the responsibility to compile all the data obtained by their classmates as they perform this experiment. At the end of the semester they are asked to present orally the data and the conclusions to the faculty and to their classmates, the actual authors of the results presented. Hence, the experiment is no more a lab session but a learning process: an experimental project, which becomes original and unique for each team.

In order not to introduce changes too fast or too drastic that could result in failure, the project was introduced as an additional task, but leaving the traditional scheme: during the lab session each team follows some lab recipe, gets a few measurements and produces a brief report (briefer in this case). The lab recipe is still a useful material for all the teams while is the starting point for the Project Manager Team that has to mid-term plan which is the experiment target, which are the experimental measurements to be required each week to their classmates, which will be the conclusions and which be the best way to present the all the work performed.

Respecting this initial scheme, additional elements have been introduced each new course: standard templates for the reports and presentations, economical evaluation of the project, monitoring meetings and minutes, etc. All these elements have been gradually incorporated to the “culture” transmitted from students in one year to the next, and have finally led to a learning scenario where students get much more involved in their role, their learning is much more internalised and they may build a more significant knowledge.

Regarding the experimental work, not only data analysis is obviously more gratifying and didactical due to the larger data sets obtained but also to the fact that students are forced to learn how to process appropriately the information, by organising data tables using the suitable software, by filtering and presenting this data into clear and understandable graphics, etc.

The way in which the Lab Project Management (LPM) scheme is presently applied at the Experimentation in Chemical Engineering (ECE) course at the Universitat Politècnica de Catalunya (UPC) is next described.

	TEAMS								
SESSION	T10	T11	T12	T13	T14	T15	T16	T17	T18
10-09-03	COURSE PRESENTATION (LECTURE)								
17-09-03	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9
24-09-03	LOCAL HOLIDAY								
01-10-03	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-1
08-10-03	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-1	E-2
15-10-03	Monitoring Meeting								
22-10-03	E-4	E-5	E-6	E-7	E-8	E-9	E-1	E-2	E-3
29-10-03	E-5	E-6	E-7	E-8	E-9	E-1	E-2	E-3	E-4
05-11-03	E-6	E-7	E-8	E-9	E-1	E-2	E-3	E-4	E-5
12-11-03	Monitoring Meeting								
19-11-03	E-7	E-8	E-9	E-1	E-2	E-3	E-4	E-5	E-6
26-11-03	E-8	E-9	E-1	E-2	E-3	E-4	E-5	E-6	E-7
03-12-03	E-9	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8
10-12-03	ORAL PRESENTATION								
17-12-03	ORAL PRESENTATION								

Figure 1 – A course schedule: Assignment of experiments to teams for each session.

2 THE LAB PROJECT MANAGEMENT (LPM) PROPOSAL

Some practical aspects on programme arrangement have to be considered when planning a LPM course. The schedule must be given by a square matrix assigning experiments to teams, so that each team is in charge of an experiment and no experiment is bereft of a supervising team (experience shows that nobody would care much about such an experiment). The first experiment assigned to each team corresponds as well to the assignment of the project. In the example of figure 1, team T12 runs experiment E-3 on the 17th, experiment E-4 on the 1st of October, and so on… while team T12 plays the role of project E-2 manager for the whole course. Clearly, this follows the logic that no team is in a position to lead other teams unless they have the extra knowledge given by the one-session advantage.

Also along with this logic, students internalise the expert role in such a way that they would not like to loose this advantage; they cannot permit other teams to know more than themselves on their own matters. They also are usually angry for wasting this first experiment in solving silly problems, committing practical or conceptual mistakes, etc. Their regrets on the "if we would had known…" is an excellent opportunity for the speech on learning from mistakes and the need for planning their project and taking the necessary steps so that the following teams would not repeat them.

This course schedule also requires all teams running different experiments during each session. The criterion producing this arrangement is opposed to the idea of dedicating each session to an experiment. As much as material resources and lab facilities allow it, this idea seeks having things in the easiest way on the faculty side[1]; but for the student side, this means that all the teams are expected to reproduce (or witness) the same experiment by following the same recipe and obtaining the same result. From a didactical point of view, the out-of-phase approach presents a number of advantages but certainly requires an additional effort and more faculty members.

In addition to fit the course schedule to local holidays and maybe other academic or extra academic events, some days need to be reserved for an introductory session and also the final oral presentations. Including monitoring meetings into the schedule have also shown to be a good idea, for having some feedback from the students and also for interrupting for a while the stressing data overflow they feel they are submitted to.

Kick-off

The first course session is planned as a lecture where the rules of the game must be clearly explained. The original LPM idea has evolved in different formal and practical aspects and no longer consists just of collecting the results of the classmates. From a didactical point of view it is conceived as a project, which must be clear to the faculty and made clear to students. Students are expecting passing through the lab to get some measures and they are faced to a something new and different, and more complex.

It is necessary to show the added value of this extra effort they are faced to. The "culture" transmitted from students in one year to the next is helping, but the faculty speech has also improved during this time. Students self-esteem and responsibility is appealed by reasoning that their professional task is not going to be measuring but engineering: as a matter of fact, measuring is a poorly rewarded task that very soon will let to machines. The task they are expected to carry out is to manage a project, an experimental one in this case, which includes:

- **Planning and Monitoring:** Defining project targets, setting up tasks, responsibilities and due-dates for team members, documenting the project phases and writing minutes, planning revision tasks (thus introducing a quality management scheme)
- **Safety and Environmental assessment:** Linked to their expert role, students are also responsible[2] for managing the safety, health and environment aspects related to their project. Thus, they are asked to search for the necessary information, make their classmates observe the security measures and when incidents/accidents occur they are asked to follow the basics of a safety management scheme: act immediately, analyse causes, revise preventive measures and record the case.
- **Economical evaluation:** Students are asked for an economical evaluation of the whole project including the cost of tubes, flasks, chemicals, utilities and manpower. Even incomplete from a strict economical point of view, the assignment gives the students a very interesting insight into the order of magnitude of the resources they are using[3]. Manpower cost requires the ***experimental measurement*** of their workload in the appropriate ***units of measure*** (person·hour).[4]

1 This was the criterion at the UPC before changes started.

2 A virtual responsibility, as the real one is clearly held by the faculty, who may play the role of the public administration.

3 The usual perception is that they are close to free of charge. Students are very surprised when they discover how expensive lab material is or how much they pay for a kW or m^3 of water at home.

4 Additionally, the workload measurement is also important to the faculty regarding the requirements for establishing the forthcoming European Credit Transfer System (ECTS).

- **Communication:** Results and conclusions, the experiment as a whole, is worthless if it cannot be duly communicated to the people responsible for making decisions upon the information and knowledge the project was expected to arise. Report and oral presentation are thus critical tasks.

Monitoring

Documenting the project is also part of the work. This allows introducing Quality, not in an explicit way since is not the purpose of the course, but as a series of work habits. Every week teams are required to have a technical meeting and to write down the decisions made regarding the planning and the next lab session. Minutes must be emailed each week to the faculty who may use this information to keep record of the progress made and to evaluate the *non-presencial* part of the course[5].

Regarding the schedule, some sessions are dedicated to monitoring meetings with a faculty supervisor instead of the lab work. A meeting at the office allows having a worthy feedback from the students, not only regarding the technical and scientific aspects concerning their experiment and the results they are obtaining, but also on how things are going on: *"do your classmates understand what they are really doing, what they are told? Do they follow your indications? Why not?"*.

Final Meeting

Oral presentations are planned to be 15-20 minutes per team plus questions, thus two sessions are required when considering nine or ten teams/experiments per semester. Attending to oral presentations is considered compulsory for all students. Of course, the talk topic is not a matter having nothing to do with students since they participated in all the experiments and should have some interest in listening, even more when their results are will be publicly presented and compared with those obtained by their classmates. Additionally, some other points are introduced for increasing such interest:

- Any extra interesting point or comment appeared during the team presentation or the questions round may have a chance to be part of the exam.
- Students are required to fill in a nominative questionnaire asking for the quality of the presentation of their classmates (clarity of exposition, of tables and graphics presented, etc.)
- Any presentation so boring and uninteresting that cannot incite the audience to ask at least three appropriate and intelligent questions will get the lowest mark (silly but works! ...once they realize they can agree and arrange the game)

Information Technologies

This LPM scheme increases the need for the use of IT. For one thing, communication is required through the email, and reports, documents and templates should be shared through the intranet.

On the other hand, students are faced for the first time to a large amount of data. They are used to record a few measurements and values on paper, to use the calculator for operating a few values and to use the spreadsheet for plotting the results. However, when collecting series of data week after week, which have to be recorded, processed and plotted, and compared accordingly to the experimental conditions under they where obtained, more systematic approaches and tools are required. Somehow, students need to build and organize a simple database of their own, which forces them to generalise and make an effort to think in more abstract terms.

The tool that more naturally arises for such a task is the spreadsheet, which may be not the most specific and suitable but is the more widespread and general. Students are usually not aware of the possibilities of the tool and use it in a very limited way, just for substituting the calculator and for plotting purposes. This should be also taken into account by the faculty, for being aware of the difficulties students may have and for providing advice and help when required.

Final Exam

Despite the marks obtained at the reports and oral communication, students have to undergo a final exam, since it is the only individualised assessment they have during the course. However, this exam is jointly prepared by the students and the faculty according to the expertise each team it is supposed to have

[5] Non-presential or asynchronous learning is being introduced in some courses at the UPC. The pilot project involves even the practical courses as the ECE.

on their experiment. Each team is allowed to propose a series of multiple-choice questions related to their topic that the faculty will discuss, ask for changes and eventually approve. Two thirds of the final exam will consist of a subset of the questions approved that will be selected by the faculty, while the other third will consist of questions proposed by the faculty regarding general lab aspects and problems discussed during the oral presentations. Of course, teams must be required to propose much more questions than the number to be selected and to propose them fairly before the exam day.

Certainly, this way for preparing the exam is more time consuming, but has proved more effective from the learning point of view: discussing the questions with each team provides the faculty with a very interesting feedback; allows the opportunity to clarify doubts; and also involves peer-teaching as the students are doubtless going to exchange their questions. Finally, the multiple-choice test has proved to be essential in this scheme, not only because it allows easily introducing slight changes to the questions in order to avoid students memorizing them, but mostly because inventing false answers, although tricky reasonable, is the most difficult and understanding demanding part of the exercise.

3 EVALUATION

The results of applying the LPM scheme are next presented. First, some personal perceptions along with some anecdotes are introduced as part of the subjective assessment. It is followed by the students perception and evaluation obtained from different surveys. The faculty feels there is a positive response from the students. Despite their compulsive complaint, they get very much involved in their projects and they work quite a lot on it, maybe too much as it will be shown.

Advantages

The main advantages seem related to motivation, internalisation and personal interaction:

- Students experience they are responsible and important. Although they initially feel a bit disoriented, then they became the experts and explain the experiment to their classmates and advise them of the errors they have found out, thus favouring peer teaching.
- Students do not repeat unconsciously the lab recipe, which is always easier, and they have initiative and make their own (supervised) decisions.

Some initiatives include proposing new samples or conditions for the experiments, some of them surprisingly interesting to the faculty. One of the most remarkable has resulted how they discover that verbal communication is not an effective way for asking their classmates for the list of measurements they are requiring: after the first frustrating experiences on the irresponsibility and carelessness of the "people" (this subset of the entire Universe excluding ourselves) they reach to the idea[6] of requiring their classmates to fill in the from they hand them over at the beginning of the session. The design of this form has shown to be a most enlightening exercise.

Regarding the experimental work, lab sessions are felt more dynamic, flexible and didactical, thus:

- Creativity and initiative produce more variability and more information on the system under study than the boring repetition of the same lab recipe every session.
- Questions arising on the experiment reproducibility produce very interesting thoughts about its nature:
  - ✓ "*Are we absolutely sure that the next team will repeat exactly the same experiment under the very same conditions next session?*"
  - ✓ "*Does room temperature or pressure influence the results we obtain?*"
  - ✓ "*Which are the variables each team must measure and record to be sure that experiments are comparable?*"
  - ✓ Despite the answer, these questions allow addressing important points such as degrees of freedom and the magnitude of errors.
- Data and results analysis is more convenient and graphs obtained more interesting. Dealing with information is another interesting point arising:
  - ✓ "*Is it better a graph for each experiment or a graph with all the data? Is it useful to show too much information*?"

[6] Some help is sometimes needed. It is difficult to describe the look you get when hinting them "You told them and it didn't worked? You are using old-tech, maybe you should try a more recent technology, one that's been developed in Mesopotamia just a few thousand years ago".

- ✓ "*When changing experiments conditions, we introduced a third variable: How we should represent now the information? Is it better to chose different graphs or to use iso-lines*?"
- ✓ "*Which is the purpose of this the graph*?"

Regarding the general feeling of the faculty it is worth noting that they enjoy more the task, it is possible to ask or to propose experiments for their own curiosity, and to guide and see teams progressing. Somehow, the faculty is delegating to the students part of the task, the most repetitive: initial explanation of the experiment each session, processing and comparing results obtained, etc. However, the task clearly continues still under the control of the faculty, but from a more gratifying position based on collaboration with the students rather than on watching over them.

Risks

Implementing LPM in an experimental course does not seem to involve clear disadvantages, even more considering that the essentials may be maintained while is it possible adjusting formal and material aspects to the particularities of each lab and each teaching institution. However, some logistics and some didactical risks may be taken into account. Firstly, the faculty must be aware that project monitoring would be more time consuming. Continuous monitoring is required for:

- Avoiding that some teams may be pulled away from the progress made by other groups, or simply that they might not be able to supervise their classmates, which could be irreversible.
- Forcing teams to plan (and re-plan) and not to wait for all the experimental results to start analysing, making decisions and working on other project aspects (report introduction, cost evaluation, etc.)
- Being aware of situations in which team progress is stopped and help is required. Suggesting tips or doubts may be needed for a team to make decisions and have ideas.
- Watching that the initiatives of the managing group may not provoke needless failure and frustration to the subordinate teams, thus keeping the compromise between a didactical error and a waste of time.
- Avoiding that excessive internalisation of a project could result in teams paying less attention to the experiments to be carried out for the other teams.

On the other hand, it is also worth noting that bad results involve the risk of causing students frustration and discouragement. Students used to mechanically reproducing an experiment by following the lab recipe are also used to the idea that the highest mark is given by the highest rate, or ratio or regression coefficient. They perceive the game as if the result was something the faculty had hidden and the student goal was to find it out. Hence, students may feel misled or cheated when they are told that the result is not known and would not be known until the end of the semester, when all results are compared and analysed. Time and patience has to be invested in dismantling this preconception and substituting it by the idea that experimenting is not reporting the "right" values, but acquiring knowledge backed up by experimental evidence.

Your interest for this course is					Nothing	Not Much	Quite	Very Much

To which extent do you expect to learn about the following subjects:

Accounting and economy					Management				
Analytical Chemistry					Mathematics				
Biology					Mechanics				
Communication Techniques					Numerical methods (calculus)				
Documentation and research					Office automation				
Ecology					Organic Chemistry				
English Language					Philosophy				
Environment Management					Physical Chemistry				
Equipment design					Process and operation design				
Industrial safety and hygiene					Project Management				
Informatics					Simulation (Computer aided)				
Inorganic Chemistry					Team working				
Instrumentation and control					Thermodynamics				
Lab Organization									

Figure 2 – Query from given to the students at the beginning of the semester.

Results

Objective assessment of the LPM experience has been performed since the academic year 2001-02 and consists of measuring the differential perception of students between the beginning and the end of the semester. The initial survey (Fig. 2) takes place the first day, before starting the opening lecture and before giving any information to the students.

The closing survey is taken the day of the final exam. The form is the same despite the tense change:

- Your interest has been…
- To which extent have you learnt…

As well as three additional questions:

- Regarding your formation and your future as a professional, do you think you have learnt: (NOTHING, NOT MUCH, QUITE, VERY MUCH) ?
- Regardless of the particular aspects, is the general design of this course is a right one? (YES / NO)
- Which are the particular aspects that need to be improved? (OPEN ANSWER)

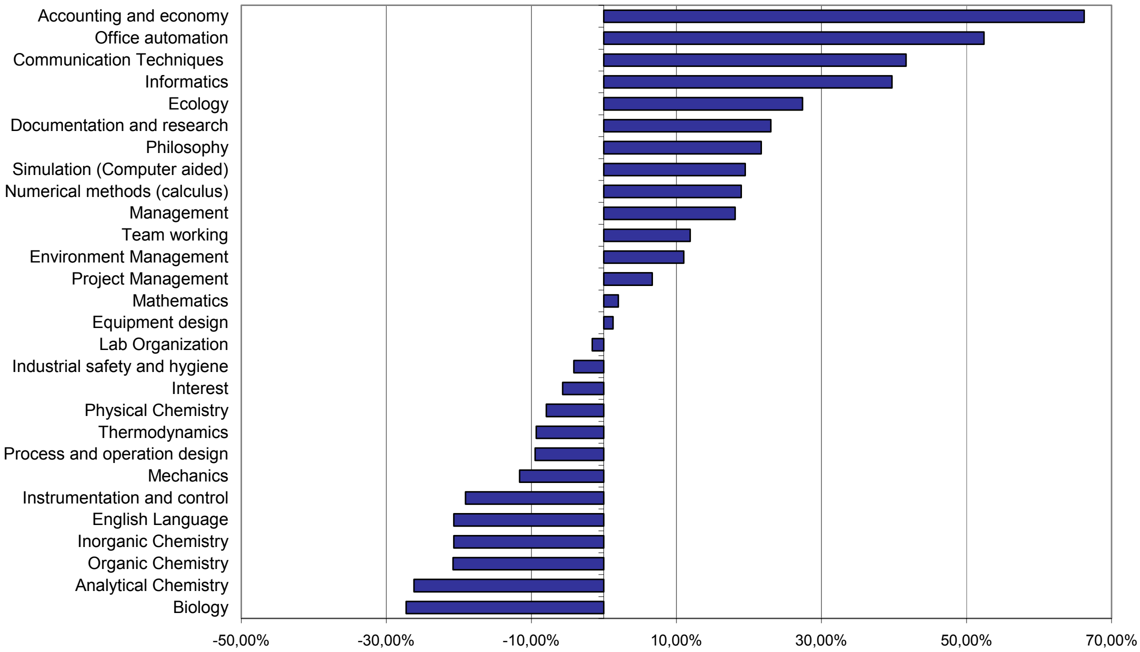

Figure 3 – Relative learning perception of the students. Autumn 2002.

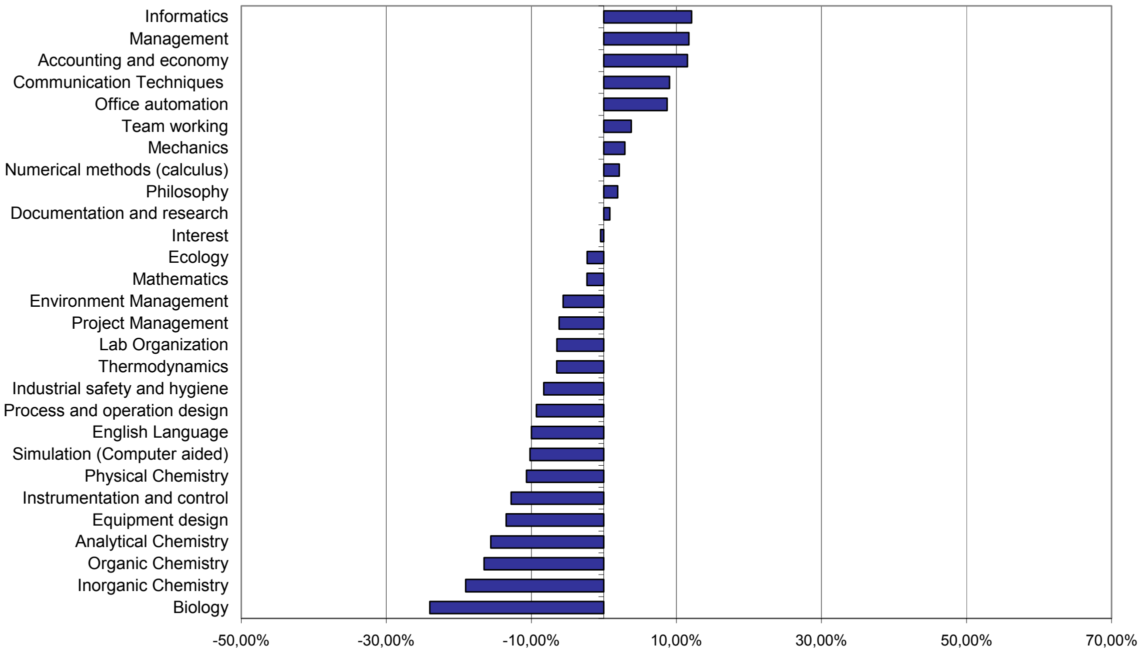

Figure 4 – Relative the learning perception of the students. Spring 2003.

Relative perception

The quantitative measure of students' perception per subjects is obtained by assigning the weights (1,2,3,4) to the options (Nothing, Not much, Quite, Very much) so that the mean value is 2.5. For each subject the class average is recorded at the beginning of the course (*Initial_Perception*) and at the end (*Final_Perception*). Thus, a change ratio may be evaluated following equation (1). It is important to note that this index includes both, the knowledge students perceive they have acquired but also their initial expectations, so that it may reflect simultaneously learning on a topic and surprise for having learnt on that topic.

$$\%_{subject} = \frac{\left[Final\_Perception\right]_{subject} - \left[Initial\_Perception\right]_{subject}}{\left[Initial\_Perception\right]_{subject}} \times 100 \qquad (1)$$

Figures 3 and 4 display the results obtained for index (1) during semester Autumn 2002 (September to January) and Spring 2003 (February to June). This graphs are fairly representative of the trends observed each semester as well as the evolving tendency that has been detected on the students response when comparing the results of consecutive semesters.

Subjects have been plotted in order of increasing values of the index (1) so that both figures may be regarded under a fuzzy sorting perspective: a middle unhelpful third and two significant extreme thirds. The first third corresponds to a clear increase in students' assessment, and this includes in both cases:

- Accounting and Economy
- Communication Techniques
- Numerical methods
- Informatics
- Office automation
- Philosophy

As well as some other subjects only appearing once such as Team working, Documentation and research, Simulation, Management, Mechanics and Ecology.

These results agree most of the ideas of the LPM scheme and also reflect the surprise of students at acquiring computer abilities, although they probably mix up informatics and office automation. The unexpected very first position of Accounting and Economy (it was in the list just as a tricky subject as Biology or Philosophy) appears when the cost evaluation of the experiment was first required. The really astonishing position of Philosophy fails to find and explanation, although it would be great if it meant students had learnt to think in abstract terms.

The other extreme corresponds to the subjects having a negative index, those clearly pointed by the students as the subjects that they do not perceive they have learnt, or to have learnt less than expected. In both graphs appear some common subjects:

- Analytical Chemistry
- Inorganic Chemistry
- Organic Chemistry
- Biology
- English Language
- Instrumentation and control

As well as some other subjects only appearing once such as Physical Chemistry, Process and operation design, Simulation, Thermodynamics, Equipment design and Mechanics.

The most important point to highlight here is the low rates obtained by the chemical disciplines: analytical, inorganic, organic, and also physical. Certainly, chemistry is used but not learned in the ECE course. But the index values are so low that an additional explanation is required. Students come to the ECE after the Experimentation in Chemistry course, which unfortunately is still known as the Chemistry lab (as it was at high school). It is very likely that students are expecting just another lab course as those they have already experienced. Furthermore, students probably continue mixing up Chemistry and Chemical Engineering to some extent. This results show that this preconception is confronted at the ECE course, although an effort is probably needed to make it explicitly.

The other important point in these results is that, although the subjects are ranked in a very similar way, the values are much lower in 2003 than in 2002. This trend is repeated also in the first results of the course 2003-04. In order to separate the two effects included in the relative index (1), the expectation values (*Initial_Perception*) at the beginning of Autumn 2002 are plotted against the same values obtained at the beginning of Spring 2003. Therefore, Figure 5 shows that the decreasing trend observed in the relative index (1) is because of the growth of the expectations students have.

This new perspective is most encouraging, as it shows that the ECE learning spreads beyond the limits of the course. In other words, culture, in its most wider sense, is produced at the ECE and is transmitted through the library, the cafeteria, the corridor, etc. and make students come to the course with a more accurate idea it.

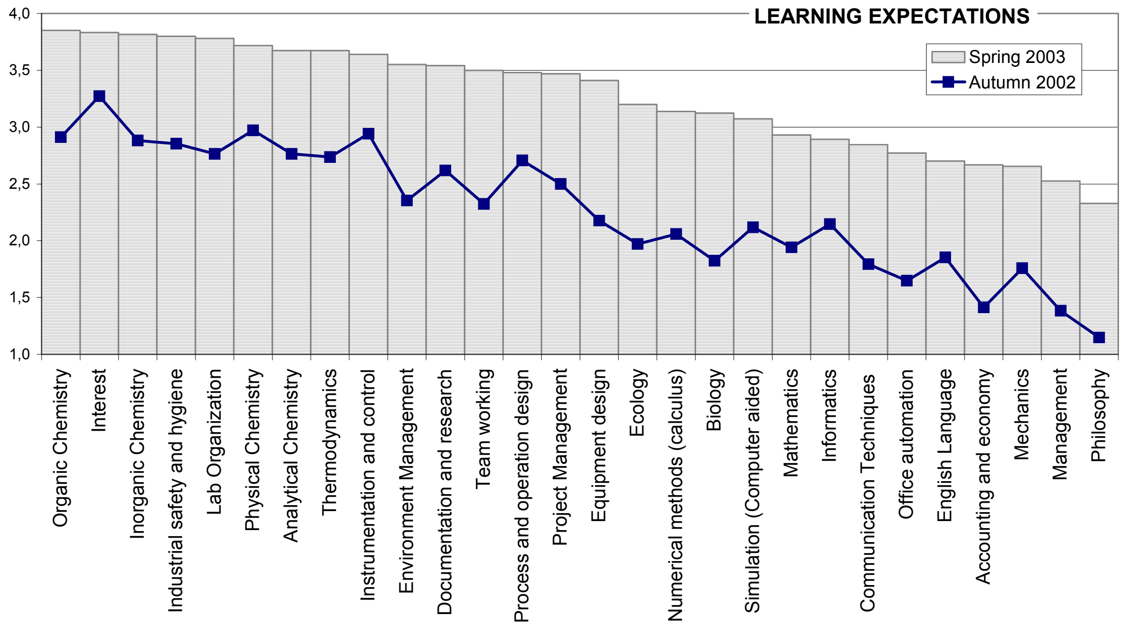

Figure 5 – Comparison of the beginning assessments. Students' expectations are growing.

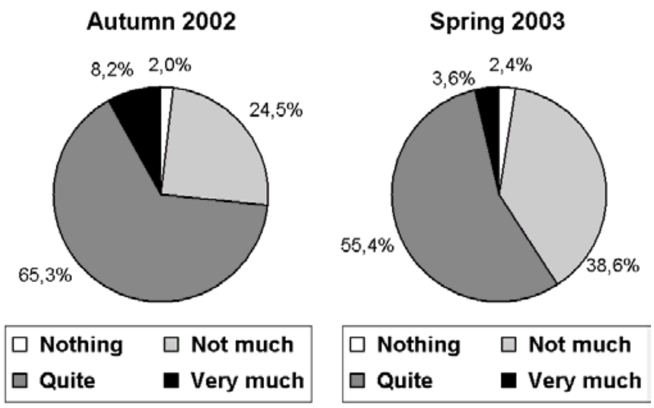

Figure 6 – Regarding your formation and your future as a professional, you have learnt… ?

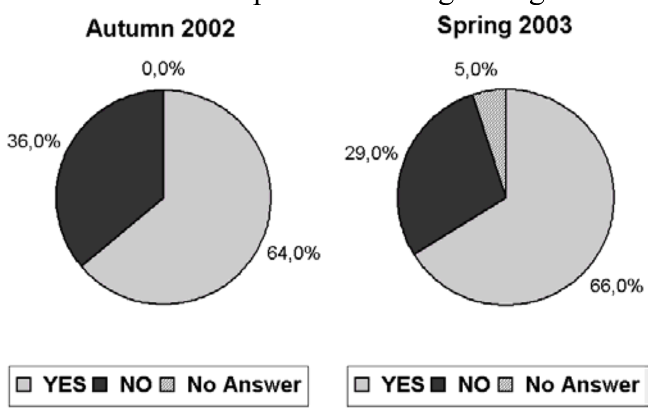

Figure 7 – Regardless of the particular aspects, is the general design of this course is a right one?

Absolute perception

Students learning perception is asked in absolute terms using the final questions:

- Regarding your formation and your future as a professional, you have learnt…?: (How much)
- Regardless of the particular aspects, is the general design of this course is a right one? (Y/N)
- Which are the particular aspects that need to be improved? (Open answer)

Answers related to the same semesters are given in figures 6 and 7. Results are encouraging, though not exceptional. The mean response of the students is positive and some aspects need to be remarked:

- Autumn 2002: while 73,5% of the students declared to have learned quite or very much, only 64% of them approved the design of the course.
- Spring 2003: while 59% declared to have learned quite or very much, 66% agreed the scheme.

This shows that some caution is required when considering the coherence of percentages. Of course, both answers should not be proportionally linked, but no information is available on the aspects students may consider or may mistake when saying to have learned despite the course design is not as it should be.

The decrease in the perception of the quantitative learning between Autumn 2002 and Spring 2003 (still maintained in the first 2004 data) may be attributed to the increase of the expectations also detected. The acceptation of the course design, indirectly the LPM scheme, is kept around two thirds, and no data is available to back any hypothesis on the reasons of the other third. Probably, and according to faculty perception, students may have gone from the initial defensive position of certain students, feeling uneasy at the changes, to a more critical position these days, when the changes and the scheme are assumed but other malfunctioning material or logistical aspects may be being pointed at.

Partial explanation is also found in the open answer. It has given interesting information on different particular items, a number of them quite surprising and some other already known by the faculty. Attending priorities and chances, some of them have been attended, such as revising written materials or providing help in the use of the spreadsheet. The most repeated claim is the excessive workload. Certainly, this is a very important point, but there is no quantitative measure still to corroborate this perception of the students. Further work is required.

4 FUTURE WORK

A continuous improvement scheme has been started in order not to stop monitoring and changing the course. One of the first points is workload measurement, since it is a requirement of the Bologna process and the European Credit Transfer System (ECTS). The basis exists through the cost evaluation of each project and students are to some extent recording the time they spend in their project. However, results are right now very frustrating because the extremely large deviation this measurements have. It is clear that students still do not know how to do the recording and the criteria used by teams (and individuals) are not the same.

More attention will be dedicated to the measurement of the perception of the learning of different abilities. Certainly, the increasing emphasis on abilities and social skills has partially provoked and guided the changes introduced lately in the ECE course. It was clear from the beginning that some sort of negotiation and communication capacities would obviously be enhanced by the LPM scheme.

A survey asking the students for the quantitative learning attained on the ABET general criteria has been carried out at the end of each the latest semesters.

- An ability to apply knowledge of mathematics, science, and engineering
- An ability to design and conduct experiments, as well as to analyse and interpret data
- An ability to design a system, component, or process to meet desired needs
- An ability to function on multi-disciplinary teams
- An ability to identify, formulate, and solve engineering problems
- An understanding of professional and ethical responsibility
- An ability to communicate effectively
- The broad education necessary to understand the impact of engineering solutions in a global and societal context
- A recognition of the need for, and an ability to engage in life-long learning
- A knowledge of contemporary issues
- An ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

When students where asked to rate from 1 to 4 their learning on theses aspects the results obtained were most inconclusive. Students seemed to rate 2 and 3 almost randomly and the survey was given up. Presently, a more specific survey consisting of 27 brief matters has been designed based on the items given by the Spanish Quality Management Club.

5 CONSLUSIONS

Since the academic year 2001-02 significant changes have been introduced to the ECE course at the UPC. Starting from a very traditional situation this changes have led to a new design of the course based on cooperative learning and the management of a complete experimental project during the whole semester. The experience has been evaluated and has been considered positive for the students and the faculty. Information is available for future improvement and the new changes are expected.

The LPM scheme offers advantages at the experimental and didactical levels as have been described. On the experimental side dedicating the whole semester to one specific experiment allows deeper insight into larger data sets, the need to process and analyse more information and the chance to make mistakes and learn from then. On the didactical side, the project based approach enhances students' internalisation and motivation, while the responsibility of the managerial role and the interdependence of the projects, allows students developing capabilities such as planning, communicating, negotiating, solving conflicts, etc. as well as favour peer-teaching.

The experience from the changes introduced to a classical lab course allows analysing the differences between the previous and the present situation. This has been summarised in Table 1 following the classical comparison by Johnson et al. (1998).

Table 1. The paradigm table for the lab courses (based on Johnson et al.)

Factor	**Old paradigm of lab courses**	**New paradigm of lab courses**
Target	Reproduce the measurements made by prominent scientists (maybe long ago). Confirm the laws they enunciated.	Design, run and manage a project for acquiring, building and communicating experimental knowledge.
Qualification	The closer the measurement to the right value, the higher the mark	The more the knowledge communicated, the highest the mark
Knowledge	Given at theory classes. Verified at the lab.	Constructed at the lab. Agrees theory.
Students	Witnesses and measurers of conveniently prepared phenomena	Active constructors and transformers of their own experiments.
Faculty purpose	Help the students getting the right results and avoid students making mistakes at the lab. Responsible for the mise-en-scène.	Help the students to get to their own conclusions and to learn from mistakes. Allow mistakes if didactical.
Horizon	One lab session for obtaining the right results and succeeding in each practical assignment. Data sets obtained are often too short.	The whole semester for projecting the experiment, gathering all the results from classmates and producing larger sets of results.
Context	Independent teams repeating the same measurements.	Cooperative learning among teams leading interdependent projects
Assumption	Any faculty member can run lab sessions (even -or preferably- the youngest and inexperienced). Watching over students at the lab is easier than lecturing theory.	Lab classes are complex and require adequate planning. Preparing, running and monitoring lab projects is more time consuming than lecturing.

The LMP experience has been long commented to other faculty members at the UPC and has been presented to some Spanish national meeting. The possibility of extending the model to other practical courses has always arisen and has been discussed. Certainly, it seems that the basics of the proposal is general enough to be implemented to any kind of experimental course since it is independent of the specific experiment being studied. Furthermore, practical projects requiring creativity such as industrial design have also been commented as possible candidates.

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