EVALUATION OF PROJECT BASED LEARNING IN THE AREA OF MANUFACTURING AND STATISTICS IN THE DEGREE OF INDUSTRIAL TECHNOLOGY

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Abstract

In the subject Project I in the second year of the Degree in Industrial Technology Engineering taught at the School of Industrial Engineering of Barcelona (ETSEIB), subgroups of 3-4 students within groups of 20 students develop a project along a semester. Results of 2 projects are presented related to manufacturing, measurement of parts and the statistical treatment of data, placing emphasis on cross-curricular issues, recording of oral presentations and how this helped improving its quality, as well as evaluation of the subject by the students by means of questionnaires and open-ended questions.

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1 INTRODUCTION AND AIMS

The subject Project I, in the second year of the Degree in Industrial Technology Engineering taught at the School of Industrial Engineering of Barcelona (ETSEIB), is based on a project developed during a whole semester. Students (around 300 in some semesters) choose among a wide list of projects (15 in total) related to different areas of industrial engineering, and finally up to 20 students work on the same project. In the case presented in this paper, two projects are explained. Each one of the 2 projects, with about 20 students, has been divided into subgroups of 3 or 4 people. Members of each team are decided by teachers, in order to minimize the presence of friends within groups. If students do not choose the team members, the will face a more similar environment to that in which they will work in the future. The projects are related to manufacturing and industrial statistics. In one of them, related to capability studies, students check if two different lathes are able to manufacture cylindrical parts with the precision required in terms of diameter and roughness. In the other project, related to gage repeatability and reproducibility studies (gage R&R), students must check if diameters of manufactured parts are measured correctly, thus validating the measurement system.

Two different departments are involved in these projects: Mechanical Engineering and Statistics and Operations Research. They are responsible of supervising, respectively, the manufacture and measurement of parts, and the data analysis. In this way, students begin to understand engineering not as a series of disassociated subjects, but as a sum of knowledge that, if worked together, provide solutions to more complex problems.

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The main objectives of this paper are:

- Presenting an innovative course in the field of Industrial Engineering.
- Explaining an evaluation method for improving oral presentations based on video recordings.
- Discussing the use of student surveys to assess the development of the subject.

2 DESCRIPTION

Although project-based learning was originally employed in medical subjects (Barrows, 1992), in recent years it is becoming more important in other areas (Moursund, 2002). It has also been applied to the field of engineering, for example in drawing and design (Berrio-Otxoa, Arias & Ochoa, 2012) or in design of machines and mechanisms (Mata, 2007). This fits in a social context where teachings tend to approach real life (Gustavsson, 2008). Gordon (1998) distinguished between academic challenges, scenario challenges and real-life challenges, where the latter should be addressed in project-based learning. In short, the idea is to develop learning curricula that fit well the needs of students when, after graduation, their professional career starts (McLellan, 1996). In particular, the format of the subject Project I is especially suitable to convey some transversal competences described in the curriculum, such as independent learning, effective oral and written communication and teamwork.

3 EVALUATION OF THE SUBJECT

All projects share a common structure in which students of each subgroup must carry out three oral presentations. For each presentation, they have to deliver corresponding written report. Presentations, but especially reports, become more complete as the course progresses. In order to evaluate both oral presentations and written reports, teachers use a rubric. In the rubric, evaluation of each oral presentation takes into account content, order and organization of the presentation, verbal skills, nonverbal skills, graphic resources and answers to questions. Regarding written reports, elements considered are written presentation, schemes, drawings, other figures, tables, objectives, conclusions and bibliography. A numerical mark between 0 and 10 is assigned by the teachers to each item in the rubric for each subgroup. An average numerical mark is obtained for each subgroup.

Second oral presentations are videotaped and, in the next class, a discussion session takes place about them. However, results of the discussion session are not being evaluated at the moment. In the wake of experience, in the coming years a rubric will be implemented. It will be used by each student in order to evaluate their own performance in the presentation.

In addition, along the course students have to solve exercises individually, both in the area of Mechanical Engineering and in the area of Statistics. Results of exercises are included in the final mark.

Final mark of the subject for each student is as follows:

$NF = 0.15 \cdot N1 + 0.20 \cdot N2 + 0.40 \cdot N3 + 0.25 \cdot Nind$

Where

- N1: partial mark 1 for each subgroup, taking into account both the first oral presentation and the first written report.
- N2: partial mark 2 for each subgroup, taking into account both the second oral presentation and the second written report.
- N3: final mark for each subgroup, taking into account both the third oral presentation and the third written report.
- Nind: individual mark for each student, taking into account results of exercises.

4 MAIN CHARACTERISTICS OF THE PROJECTS

For both the two projects described here (capability analysis and R&R study), there are some characteristics that make them partly different from other projects offered in the same subject, while being particularly innovative:

4.1 Projects led by teachers of two different departments

Multidisciplinarity is, without no doubt, important in today's world. Many people agree on the fact that collaboration among experts in different disciplines is essential in any current project. However, curricula in many degrees usually consist on a series of courses taught by professors from different departments, with no connection among them.

This subject is particularly suited to convey the importance of a multidisciplinary approach: we decided to do it by way of example, preparing the projects between two different departments. Of course, this does not come without efforts: a high degree of coordination is required, we needed to understand and share different ways of conducting a subject, and, obviously, learning technical content "from the other part" was necessary.

Some sessions of the course are responsibility of one department; other sessions are responsibility of the other department. But besides the presentation sessions, where teachers from both departments are present, other sessions are also shared by both departments. In this way, students perceive that teachers from both departments are doing teamwork. The course has been taught for 3 years already. The initial trend when sharing a course between two different departments is to divide the content, so that each teacher has "his part." Perhaps this is inevitable in the beginning (knowing the other takes some time!), and the rapport between teachers of different areas of knowledge takes some time. But in our case, it is curious and pleasant to notice how, as the years have passed, the number of sessions shared between both departments has increased.

Having sessions shared by different teachers from both departments also means that, at least to some extent, teachers stay in the classroom more hours than those marked in their teaching assignment. In the same way that some universities give more weight in the calculation of the teaching assignment when the subject is done in English (of course, in countries not having English as official language), this could be also done when a subject is shared by teaching staff from different departments.

4.2 Classes taught in the laboratory

All classes are, at the same time, theory and practice. Therefore, classes are conducted where "the action takes place", at the Manufacturing Technology Laboratory, so students have easy access to machine tools, manufactured parts, measuring instruments, etc. (Figure 1). For the analysis of collected data using statistical software students need a computer, so they are asked to bring a laptop to the class. Being at the lab having the appropriate tools promotes working deep in the projects.

Figure 1. Students in the measurement session

Furthermore, being physically in the right environment makes avoiding lecture classes almost automatic. Imagine a subject of botany: surely it can be done in the form of lectures (the teacher showing slides of trees and flowers and verbally giving information that could be transmitted more effectively by other means!). But if the whole class with the teacher walks out to the mountain, surely the environment itself makes the lesson less lecture-kind and more experiential.

4.3 Documents and data transferred between groups

Both developed projects (capability study and R&R study) involve different students and are in fact independent. However, they have in common the use of the same machine tools and the same parts. Therefore, in the final phase of the course, data collected by the two groups are exchanged, so that each group enriches their work with the work of students from the other group.

Knowing that work performed by each group will be used by other students creates a very interesting spirit of cooperative work (Prince, 2004). The quality of their work not only personally affects their outcome in the subject, but also influences the result of other colleagues.

Although competition among students may possibly encourage effort, probably creating conditions for cooperative work is more effective (apart from nicer). Based on our experience, the emotional implication of students in a subject is much more powerful than any threat of difficult exams, few people passing the course, etc. A really exciting statement received by one of the authors of this paper by a student read: "I've had a bad quarter for many reasons and I could not bring the subject to date. But now I will study a lot for the final test, because you worked so hard for us that I feel I cannot disappoint you". Certainly a motivated person is unstoppable.

4.4 Video recording of a presentation

Clearly a skill can only be improved if practiced. It is naive to think that students will be able to successfully communicate ideas orally when they finish their studies if they have never done that.

When students make written reports, receiving comments about the task is quite common; however, this is not so usual in oral presentations. Therefore, we thought it was necessary in our projects to devote time to explain how to make reports and presentations, and give feedback. In the case of oral presentations, we think an especially powerful feedback is recording the oral presentation and preparing an exercise where students have to view and analyze those recordings. We have seen that the use of recordings help improve the skills of students (Riba, Codina, Flaquer & Marco, 2006). Some suggestions for improvement are evident without any comments (for example, trying to avoid the excessive use of hesitation markers, looking at the audience rather than to the screen, maintaining a proper body language, etc.). Therefore it was decided to record the second presentation of the students, so that they had the opportunity to incorporate improvements in the final presentation.

Recording video is today very easy. Interestingly, if you put a camcorder to record a lecture given by a teacher, those more altered are the students (although the camera is recording the teacher). After all, teachers, better or worse, speak in public very often, and "practice makes perfect". Our students do not actually have many occasions to speak in public (as they themselves admitted), so recording one of the presentations of this course is very educational. Even if you do not make any further comment or analysis (making comments is something recommended and we do that), just giving the recording to each student is valuable: students will surely watch their presentation even out of curiosity, and will certainly take interesting lessons.

4.5 Evaluation of the results of learning activities

It is common to evaluate the result of the implementation of cooperative learning techniques such as those presented here (Martín et al., 2012). For Engineering Degrees and Masters, Valderrama et al. defined 6 steps for evaluating the final year project, including definition of skills, definition of milestones for evaluation, assignation of indicators to each assessment action, definition of a rubric for each indicator, definition of the reports to be completed and definition of the criteria for assigning the final grade to the final year project based on evaluation reports (Valderrama et al., 2009). Based on their methodology, Fermin et al. used three milestones (initial, follow-up and final milestone) and three actions of evaluation for assessing the final year project (Fermín et al., 2014). In order to evaluate the Final Thesis of the Electrical Engineering Degree, Bedialauneta et

al. (2012) use formative and continuous evaluation. By means of a rubric, teachers evaluate items such as formal quality of the presented documents, working procedures, scientific-technical quality of the work and oral presentations.

In this paper, evaluation of the results has been made based on three elements:

- The own ratings of students are, obviously, an indicator of their learning. If students who learn (that is, that fulfil the learning objectives) pass the course (and this is what should happen), the ratings are a good indicator of the degree of learning of the students. Until now, all students who have followed the course have passed it (although, of course, some with better marks and others with worse marks). In the same way that the goal in an industrial process should be producing all parts correctly at first (if not, quality is worsened, costs are increased, etc), we believe that an ideal subject should have all students passing at first.

- Informal conversations with students on their thoughts about the subject. The fact of having few students makes it possible to maintain this close relationship between student and teacher. The information by students spontaneously and in an unstructured way can be invaluable. Obviously, it is also difficult to process, compare, etc. But it can be very rich. Asking students what they like and do not like about the subject also has a lot of sense: we try not to invent what they value positively, we simply ask them.

- Surveys (questionnaire format and open questions). Questionnaires allow an easy understanding of student opinions and the assessment of possible improvements. The "quantitative" version of an open survey is to deliver questionnaires to students. The big advantage is that questionnaires can be easily processed and compared (have we improved or not over the previous year?).

- The survey contained 5 questions:

  - What is the main reason why you chose this project?

  - Tell three positive aspects of the project.

  - Tell three negative aspects of the project.

  - Did you find recording an oral presentation useful?

  - List four aspects where you have improved, either in oral presentations or written reports, thanks to the subject.

All three methods of data collection to evaluate results have been used in the subject. Some results are presented in the next Section.

5 RESULTS

In this Section we offer some results after evaluating last year's course with the subject. After a general overview, we will give a bit more detail on the opinions related with the recording of oral presentations.

5.1 Results of the use of surveys to improve the course

The use of student surveys to assess the development of the subject has provided valuable information for improvement in subsequent years. The surveys were delivered to class participants during the week when the oral presentation recording was analyzed. That week 16 of the 18 students enrolled in the two projects studied attended the lesson.

Regarding the first question, *What is the main reason why you chose this project?*, results are shown in Figure 2.

A number of 50% of students chose the project because they thought it was an interesting subject, while 29% chose the project because of the schedule and 21% had another reason (for example, the project they really wanted to choose was already full). It is remarkable the fact that half of the students have chosen one of the two projects as first choice. One student wrote literally: "Colleagues that worked on this project a previous year recommended it" (Figure 3), which indicates that the projects start to be consolidated after 3 years. Another student said: "I found it interesting that in this project we analyze parts made by machines, simulating how a real control of production would work". This idea can be used by teachers to try to explain the students the

subject of these projects as, a priori, the names "capability study" and "R&R study" mean little to a student in the second year of Industrial Engineering.
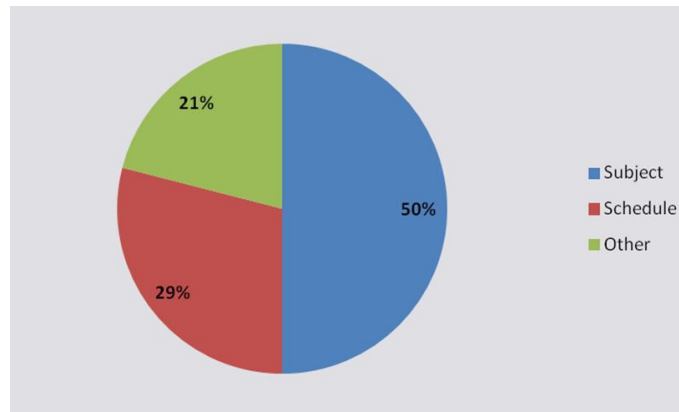

Figure 2. Main reasons for choosing this project, according to the students

What is the main reason why you chose this project?

a) Because of the subject

b) Because of the schedule

c) Other...colleagues that worked on this project a previous year recommended it

Figure 3. Student's answer to the question on the reason for choosing the project

Regarding question 2, *Tell three positive aspects of the subject*, there have been many different answers. The following are the answers given by 3 or more students:

- A lot of learning with the oral presentations.
- Knowledge of manufacturing processes.
- Multidisciplinary project (interaction of subjects).
- Application of statistical tools.
- Students work with real cases.
- Measurement devices have been made available to students during the course.
- Application of theoretical knowledge in a practical way.

In question 3, *Tell three negative aspects of the subject*, a greater disparity of answers was found. The most common answers (3 or more students) were as follows:

- I would like to see more importance given to the technical mechanical part instead of the statistical methods.
- Theory still is too preeminent in the course.
- I would have liked to also measure the roughness of the parts, not only the diameter.
- The parts were measured in the second part of the semester, and there was no enough time to prepare the studies.
- We could not directly manipulate the manufacturing machines.

It is worth to note that some of the students' requests, such as being able to manipulate the machines, cannot be allowed due to security reasons. However, we can think about asking students to prepare, for example, a numerical control program that the lab technician can later use. With the measurement of roughness, the problem is similar: since the roughness measurement instrument is a precision device that needs some experience to be used, students cannot manipulate it directly. However, we could ask them to prepare instructions on how to use the device.

For the next courses, we do plan to make some changes, such as offering more technical content, measuring the parts earlier in the quarter, and give a little more importance to practice.

In question 4, *Did you find recording an oral presentation useful?*, all students answered affirmatively. As an example, two answers are transcribed literally here:

"It has been a very positive experience trying different ways to teach stuff. I find it very educational and original. I would like you to continue with the subject in this approach".

"Yes, despite the fact that being recorded was a little uncomfortable, it is a good opportunity to learn how to deal with such situations, plus a good way to observe us from the outside...".

Finally, question 5 *List four aspects where you have improved, either in oral presentations or written reports thanks to the subject*, similar responses were obtained:

- To learn to control your nerves.
- To acquire more fluency when speaking in public.
- To learn how to correctly prepare a written report
- To avoid the use of fillers and hesitation markers.
- To learn how to properly organize a report (index, figures and tables, appendices, etc.)
- To learn to work together, even with colleagues that are not your friends.
- To have a deeper relationship with teachers (in most subjects this is very scarce).
- To distinguish which aspects are important to include in a report / presentation and which not.
- To know how to prepare a presentation in PowerPoint or Prezi (for example, not having too many words and adding graphs and figures).

An example of the answer of two different students is presented in Figure 4.

Student 1:

- Better fluency and more security when speaking in public
- Clearer ideas on how to prepare a report
- We learnt how to work in teams
- We acquired general knowledge of mechanics and statistics previously unknown

Student 2:

- Use of slides as a guide instead of sheets full of letters
- Report and presentation: aspects to consider (indexes, page numbers, images...)
- How to explain graphs in slides
- Preparation of Power Points: how to prepare and explain them

Figure 4. Students' answers to the question on issues where they detected an improvement

In short, surveys have provided valuable information that will enhance the subject in future editions.

5.2 Results of recording the video presentations

The evaluation of the second oral presentation using video has been key to improve the final presentation, having helped students in several issues such as looking at the audience and not at the screen, maintain a proper body language, avoid using fillers, etc.

All oral presentations were recorded, each group consisting of 3 people. During the following week, the students were able to review the recordings and were asked to note some positive and negative points detected in the presentations. It is well worth asking students to choose some video excerpts (starting minute and second) that can serve as an example to other colleagues and can be used as discussion starters. This also helps focus the discussion.

Regarding areas for improvement in the oral presentations, in Figure 5 a summary of the issues to be improved is presented (length of the bars is related to the total number of groups that showed the same issue, maximum possible length of the bar is 6 if all groups showed the same issue).
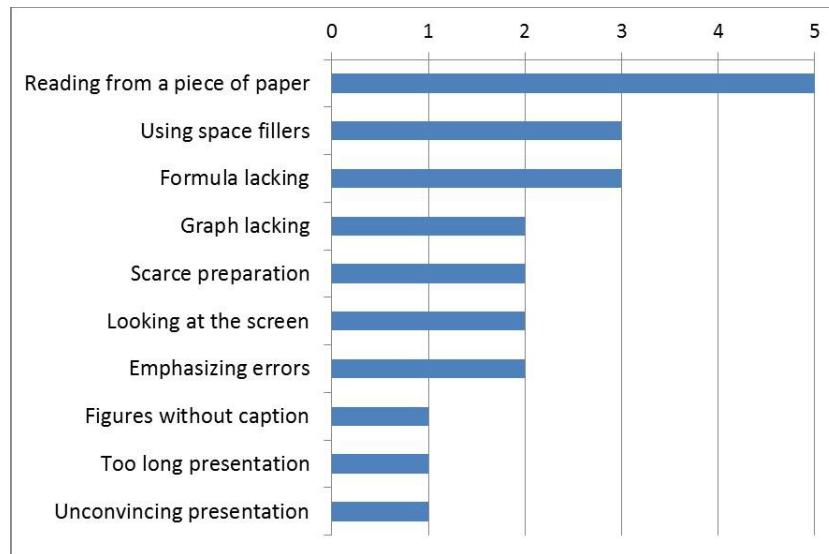

Figure 5. Issues to improve in oral presentations, according to the students

Almost all groups had at least one of the components wearing a sheet in his hand, which he read occasionally. In one of the groups the use of fillers and hesitation markers was very obvious. Also, to explain a particular concept, they mentioned a formula not written in the slide, so the explanation was quite difficult to understand. Two groups also used slides with a lot of words and without graphics, and some group members basically looked at the auxiliary screen while explaining.

Figure 6 shows positive aspects of the presentations (length of the bars is related to the total number of groups that showed the same issue, maximum possible length of the bar is 6 if all groups showed the same issue).

All groups used the resource of pointing to the screen and relating different concepts in their presentations. Four groups made a presentation of themselves at the beginning of his speech, and three of them explained the objectives and conclusions of the work.
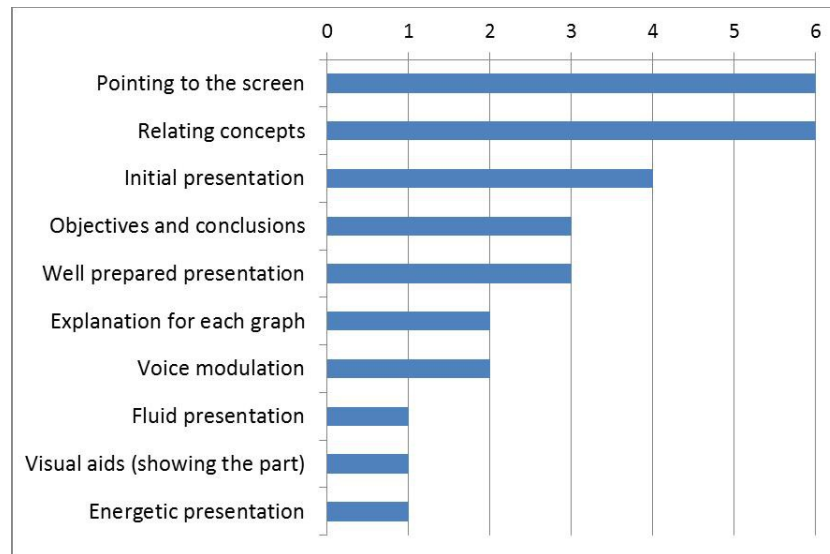
Figure 6. Positive issues in oral presentations, according to the students

6 CONCLUSIONS

The subject Project I in the Degree in Industrial Technology Engineering represents a unique opportunity to conduct a course of practical nature, in which students can learn, more closely and in an applied fashion, some of the areas of engineering.

Furthermore, in the case presented in this work, the course content is enriched by the presence of two teachers from different fields of Engineering: mechanics and statistics.

Recording the oral presentations has allowed the students to actively get involved in developing and improving their communication skills in oral presentations. Specifically, main areas of improvement of oral presentation were as follows: students stopped reading a paper when presenting, they also reduced use of space fillers, they noticed they should include a formula or a graphic in the presentation if necessary, they understood they have to previously prepare the presentation and they stopped emphasizing errors. Moreover, teachers have also focused their attention on specific aspects that students can improve, especially in regard to oral presentations, but also in relation to written reports.

The revision of surveys has verified that, in general, students are satisfied with the way the course has been developed in the two projects studied. As main positive aspects they include the possibility they had to improve their oral presentations, gaining knowledge of a manufacturing process and participating in an interdisciplinary subject. As key areas for improvement they ask for more emphasis in all technical aspects and keeping an even more practical approach.

Surely the survey results will help improve the development of the subject in future semesters.

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