Competency assessment in engineering courses at the Universitat Politècnica de Catalunya in Spain

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ABSTRACT: Presented in this study are the evidences and details of the tools used to assess and monitor projects assigned to student groups within the context of three subjects of the Universitat Politècnica de Catalunya (UPC, BarcelonaTech, Spain). During the process, the aim was to integrate generic competencies: teamwork, and oral and written effective communication. To facilitate learning throughout the process, follow-up meetings of teacher and student groups were held. Monitoring of progress was carried out in conjunction with a feedback process that enabled continuous improvement. The main conclusions from an analysis of the results are: 1) the projects developed were of higher quality; 2) motivation and student involvement was higher; and 3) greater satisfaction was experienced by the participating students and teachers.

INTRODUCTION

The Universitat Politècnica de Catalunya, Spain (UPC-BarcelonaTech), has promoted and instigated the creation of several Communities of Practice related to innovation teaching, learning methodologies or generic research competencies in engineering education. For this reason, the RIMA project (Research and Innovation in Learning Methodologies) was established, whose main objective is to become a forum for sharing experiences [1]. Among such communities there is one, Grup d'Avaluació de la Pràctica Acadèmica (GRAPA), whose main objectives are to collect and share assessment tools and strategies. The present study has been carried out by some members of the GRAPA community.

Assessment is a central feature of teaching and the curriculum. It powerfully frames how students learn and what students achieve [2-5]. In order for assessment to support the learning process, the teacher must consider that this exercise entails a series of activities related to formative and/or summative assessment [6-9] and, thus, involves the following principal steps:

- Planning of the proposed tasks corresponding to the course learning outcomes.
- The criteria established for assessment of each delivery.
- A systematic collection of evidence associated with the intended goals throughout the process.
- A quality feedback system during the learning process.

According to the first principle of effective assessment and feedback of the Re-Engineering Assessment Practices (REAP) project, such exercises must help to clearly define a good performance [10]. That is to say, prior to their execution, the goals of the task must be specified, as well as the assessment criteria and performance standards, with the objective being that the student is made aware of the expected standards of the results. The second principle of this project encourages spending adequate time and effort on challenging learning tasks. The third and fourth principles refer to feedback, indicating that information of a high quality must be provided to help learners self-correct, while at the same time making provisions for continuous improvement [11][12].

Other principles from the same project advocate that assessment must encourage interaction and dialogue pertaining to learning (among peers as well as teacher to student). Likewise, the development of self-assessment and reflection on learning must also be developed. The tenth principle is related to that fact that assessment must also promote group development and learning communities.

The aim of this article it is to explain how these principles of good assessment have been adhered to during the execution of an activity, involving the issuing of end of course assignments/projects in three subjects covering different

material and two engineering degrees at the Universitat Politècnica de Catalunya (Barcelona, Spain). The first subject: Experimentation in Chemistry II, (EQ II, 4th Term, Chemical Engineering) has the general objective of familiarising the student with industrial or environmental control analyses.

The overall objective of the second subject, Experimentation in Chemical Engineering I, (EIQ I, 6th Term, Chemical Engineering) is a study of the subject in depth by way of experimental assignments centred on the thermodynamic and physical chemical bases of industrial chemistry. The third subject, Projects (P, 10th Term, Engineering in Industrial Organization, semi-presentational) is designed to equip the student for the correct execution and management of industrial projects.

The assignments/projects issued are carried out in groups, so that the activities can be done within a team context, thus encouraging students to participate in challenging tasks [15]. Special emphasis has been placed on the topics covered in these activities, so as to be applicable to the future profession of the student. The time spent on this activity is important in that it favours positive interdependence.

To facilitate management and interaction among and between groups and the tutor, the virtual campus of the University (based on the Moodle platform) was used. Likewise, to encourage exercises of reflection on the running of the group, as well as learning in general, a few survey questionnaires were given out to the students at the end of the course.

METHODOLOGY

The activities or tasks carried out comprise the following stages:

- Planning: so that in advance, the student may become familiar with the expected learning results, how they are to be achieved and the tools and resources they will have increasing use of. It begins when students are confronted with an open-ended, ill-structured, authentic (real-world) problem and, then, work in teams to identify learning needs and develop a viable solution, with tutors acting as facilitators rather than primary sources of information [13].
- Development and monitoring of the process in order to ensure continuity and facilitate the gradual integration of the assignment into a team context. Considered within this stage are presentational meetings with the groups and tutor, intergroup encounters, the use of the virtual campus, the supply of materials, plus timely and effective feedback sessions that lead to improvement. It is in this stage where the group can be transformed into a team.
- A third measuring stage consists of the collection of evidences from throughout the process to allow the demonstration of both the accomplished objectives, as well as the students' final results in terms of knowledge, skill and attitude. This makes it possible to determine if the student is competent in what is required of them.

It is an important remark that, for the two first subjects, EQ II and EIQ I, the assessment of evidence collected during the process is a formative assessment, and should substantially increase the chances that a subsequent summative assessment will be favourable [5]. For Projects, formative and summative assessments were carried out during the process and with students' participation. Each of these stages differs, in part, based on the required competency level of the subject, although the methodology used, i.e. co-operative learning was applied in all cases [14][15].

In this manner, the two experimental subjects: Experimentation in Chemistry II and Experimentation in Chemical Engineering I follow a similar procedure in the sense that, in addition to being the same degree (Chemical Engineering), they are entirely experiment-based. They are carried out in laboratories and are offered in successive terms. Consequently, when the time comes for the students to do a second subject, the same methodology can be continued. In these two subjects, assignments are issued at the beginning of the year to groups made up of four students, with the total number of students being about 30, with three teachers. The marks for these assignments account for 25% of the total mark and it is the same for the group, with about 25 to 30 hours of time investment per student.

In the case of the Projects subject, work groups are made up of six to eight people, as the subject is taken by approximately 60 students and two teachers. In addition to the fact that it is a final year subject, the student at this point is better prepared to work with greater autonomy. The mark given for the project represents 60% of the total, with an approximate time dedication of 60 hours.

Regarding the objectives of the issued assignments/projects, those of EQ II make up most of the post-laboratory work with the objective of being useful in the real world, especially within the discipline area but also useful in day to day living. In EIQ I, the objective is to go into further depth in the area of study. This is done by way of an additional information search, coupled with the management of individual experimental data, as well as that of the other groups.

The objectives of the Projects subject are that the student be capable of planning and executing an industrial project while carrying out an adequate monitoring of the project. As well, the Projects subject aims to train students to execute technical and economic/financial feasibility studies for a given project, equipping them to demonstrate that their ideas are correct with a well-founded scientific or numeric base; in essence ensuring their reliability. For all subjects, it is expected that students will present their course assignments both orally and in written form.

OBJECTIVES OF EXPERIENCE

The objectives of the activities or tasks performed during the execution of the course project are the following:

- Motivate the student by a project that requires a significant level of commitment in an area that entails a challenge. At the same time the activity serves as a means to extrapolate knowledge, skills and attitudes for their future career.
- Plan the activities to be carried out throughout the process, such as the collection of evidences, as well as the use of tools that promote quality learning.
- Favour the continuity of the process in question through systematic monitoring to redirect it, if necessary, and, as a result provide feedback that allows for the improvement of the final product.
- Introduce general teamwork competency as a means of enhancing formative assessment and integrating the assessment of effective communication into the specific competencies associated with the different subjects.
- Involve the student in the assessment process by way of carrying out peer to peer correction for some of the deliverables.
- Facilitate self-assessment and reflection among students via the clarification of evaluation criteria at the beginning of the process and opinion questionnaires.

EVIDENCES AND ASSESSMENT TOOLS

The virtual campus of the University was used to manage the whole process from the general information and documentation of the subjects, such as those associated with the deliverables and tools for every work group. The first deliverables concerned planning and the internal rules for the running of each group. This information is only collected for the first two subjects, which have highly structured group assignments, whereas in the last subject there is more autonomy.

Table 1 is the planning table for the Projects subject, which describes the evidences that have to be handed in throughout the process. The project is monitored every other week. In the planning of EQ II and EIQ I subjects, laboratory sessions should also be considered, since the classroom time is once again focused primarily on performing laboratory experiments.

Table 1: Deliveries for Projects subject (year 2010-2011).

Delivery	Agent assessment	Assessment type
Initial report	Assessment tutor/Peer-assessment	formative/summative
Self-assessment	All group members' assessment. Also, thinking on the group's and members' work	formative
Co-ordinators' assessment	Co-ordinators' assessment to all the group members	formative
Second report	Assessment tutor/Peer-assessment	formative/summative
Oral presentation	Assessment tutor/Peer-assessment	formative/summative
Oral presentation	Tribunal assessment	formative/summative
Final report's presentation	Tribunal assessment	formative/summative
Video delivery	Peer-assessment and tribunal assessment	formative/summative
Poster delivery	Tribunal assessment	formative/summative
Self-assessment	All group members' assessment. Also, thinking on the group's and members' work	formative
Co-ordinators' assessment	Co-ordinators' assessment to all the group members	formative

Other evidences of group work are the minutes of the group meeting, in which the different responsibilities assigned to each team member are outlined. Also indicated are the contributions of each member, meeting time and the tasks assigned for the following meeting. The document is signed by all team members at the end of each meeting. Evidence is also collected about the running of the groups during classroom meetings to detect functional weak points that could be corrected. These group meetings give the tutor the opportunity to observe and/or interview the individual group members to verify that the exercise is progressing correctly.

At the end of the year, each student is approached individually on the virtual campus and asked to carry out a self-assessment, an assessment of the group work, as well as an evaluation of the overall running of the group. The first and final drafts of the written group report, as with the presentation of the project, comprise the principal evidences for learning assessment and for the skills of effective oral and written communication.

In order for competency in written communication to be acquired progressively in the different subjects, the same template is provided for the report in EQ II and EIQ I. However, in the case of the Projects subject, as it is the last

course of the degree, only format guidelines are given, instead of a template, thus strengthening the degree of creativity and innovation.

With respect to oral and written communication, the first competency level consists of a poster presentation for the EQ II subject, whereas in the other subjects the competency level is higher and consists of oral presentations. However, in Projects, oral presentations are used as a means of monitoring assignments and, therefore, take place on several occasions. The poster presentations, on the other hand, represent a synthesis of the project. In addition, at the end of the Projects subject, an additional deliverable is required, by way of a video presentation which, among other things, is employed to develop creativity. For such, templates are not provided only the general rules for the format, thus encouraging a greater freedom of creativity in design, given that it is one of the elements that are taken into account during the assessment.

The presentation of projects is carried out during a general class session at the end of the course, in which all groups defend their work in front of the rest of their peers, as well as the course faculty, with all those present having the opportunity to pose questions.

The assessment tools reflect, both implicitly and explicitly, the assessment criteria and indicators. The main tools used throughout the process for the three subjects were rubrics, although rating scales were also used [16].

From the start of the course, students have access to the tools necessary for compiling the final report and/or the oral presentation of projects. These tools enable self-assessment and, likewise, objectify assessment, while at the same time provide a basis for better work assignments in that the student is aware at all times of what is expected of them [17].

In addition to encouraging a critical spirit among the students, the fact that they also undertake the role of evaluators makes them aware of the importance of every parameter chosen in order for them to become good speakers. Listed in Table 2 are the assessment criteria used for the oral communication assessment in the Projects subject:

Table 2: Oral communication assessment criteria for the Projects subject.

Parameters	Scale		
5 Points			
Clarity of ideas (1 point) The content of the presentation is understood adequately.	o Clear	o Intermediate	o Incomprehensible
Confidence (1 point divided into 3 ratings of 0.5 0.25 and 0.25) Shows signs of nervousness, voice trembles when speaking:			
- *Confidence* (0.5 points)	o High	o Intermediate	o Low
- Vocalisation in the presentation (0.25 points)	o Clear	o Intermediate	o Incomprehensible
- Voice volume (0.25 points)	o Good and clear level	o Intermediate	o Incomprehensible
Explanation and non-paper reading (0.5 points) Offers additional information to that presented on the slides.	o OK	o Intermediate	o Reading
Coherent links between transparencies (0.5 points) Uses appropriate nexus of union between the different slides.	o Adequate	o Intermediate	o Non coherent
Duration of the presentation (1 point) The time employed compared with originally foreseen, appropriate speed.	o 15-20 min.	o = 2 min.	o > 2 min.
Position (0.5 points) Exhibits dynamism and shows the required items on the overhead projector.	o Is dynamic	o Intermediate	o Is very static
Coherency in responses (0.5 points) Ability to respond quickly and clearly to questions posed by faculty and fellow students.	o Quick	o Intermediate	o Slow and non-elaborate

Table 3 shows the rubric used in EIQ I, which is very similar to that applied in EQ II, to assess the written report (draft and final). This exercise highlights the fact that the general skill of written communication is integrated into the rubric together with that of the specific content of the subject.

Feedback is carried out during a period of 48-72 hours (classroom or virtual). The assessment performed during the process is fundamentally formative, so as to enable each group to identify the areas in which they need to improve.

Table 3: Rubric for the experimentation in Chemical Engineering I assessment project report.

Group: Names:	Evaluation criteria. Self-assessment/Peer-assessment/ Hetero-assessment	
Outstanding	Satisfactory	Unsatisfactory
FORMAT		
Communication (25%)		
• Document very well organised, and includes all the stipulated elements. • Follow format specifications. • Bibliographical references follow the regulations, are coherent and correctly cited in the text. • The report comprises a write up that is brief, clear and accurate and uses technical lexis. • The sentence construction consists of legible syntax and wording. • Tables and figures are numbered and accompanied by explanatory text. Sources are cited when not first hand. Good quality of graphics.	• Document well organised. Some of the stipulated elements are lacking. • Follow format specifications. • A few references do not comply with the regulations. Most are cited in the text. • Technicalities are often used without justification or otherwise are used inaccurately to express ideas. • Some of the sentences used are often of a complex structure that makes them difficult to comprehend. • The selection of graphs is, for the most part, acceptable and helps to explain the information relevant to the project. However, the quality for the comments in the text clearly has room for improvement. One or two graphs are not cited in the text.	• Document poorly structured. There is no connection between the principal and secondary information. More than two of the stipulated elements are either lacking or are, for the most part, incomplete. • Most of the references given do not follow the regulations. Some are not cited in the text and virtually none of the resources has been used as expected. • The text is generally difficult to understand. Very long and confusing phrases. Little use of appropriate lexis and terminologies for the context of the project. • Most of the graphs presented were not selected correctly nor are they referred to in the text, making it difficult to follow the material presented.
Abstract/Objectives/Principles (15%)		
• The abstract provides a synthesis of the objectives, the results, conclusions, recommendations and project outcomes. • The objectives define the purpose of the study. • The technical principles on which the project is based are well highlighted.	• The abstract provides a synthesis of either the objectives or the conclusions of the project. • The objectives addressed do not define the purpose of the study. • The selection of the principal bases concerning the topic chosen is incomplete. A few of the concepts are irrelevant. Although all have been correctly applied, there are some that require further elaboration.	• The abstract does not provide a synthesis of either the objectives or the conclusions of the project. • The objectives that are to define the purpose of the project are not specified. • The principal bases concerning the project have neither been identified nor correlated. There are serious conceptual errors.
CONTENT		
Experimental method (10%)		
• The experimental method has been described in a brief and clear manner. • A flow diagram has been included.	• The experimental method is described in a way that is incomplete. • The flow diagram is incomplete.	• The experimental method was not given. • Flow diagram non-existent.
Experimental results and discussion (25%)		
• The experimental and their respective conditions are well reflected in the graphs. • The graphs highlight the experimental points of the trend lines. • A discussion about the validity of the results is incorporated. • A model for the prediction of a studied system or phenomenon is proposed.	• The experimental and their respective conditions are not well reflected in all of the graphs. • Some of the graphs do not highlight the experimental points of the trend lines. • A weak discussion is given about the validity of the results. • The model proposed for the prediction of a studied system or phenomenon has not been well calculated.	• The experimental and their respective conditions are not well reflected in the graphs. • The graphs do not highlight the experimental points of the trend lines. • A weak discussion about the validity of the results is given. • No model has been proposed for the prediction of a studied system or phenomenon.
Conclusions (25%)		
• The conclusions were correctly argued and are coherent with the principal objectives of the project.	• Of the conclusions given, principal advantages and disadvantages of the study can be deduced. However, there were no arguments or reflections given based on personal opinion.	• The conclusions comprise a list of the results that can be gathered by reading the project report. No personal input was given.

RESULTS AND DISCUSSION

During the process, the standardisation of a series of documents marked a clear improvement for the students and teachers alike when it came to marking. Moreover, it permitted the introduction of the competency of written communication from the first level. The introduction of the virtual campus also proved useful as a management tool, making it possible from the start for a wide range of documentation to be available, as well as enabling the swift and non-lecture access to evidences and feedback.

Concerning the running of the groups, the first time that students use this methodology, they tend to try to conceal any dysfunctional elements during the process, giving rise to a lower quality of results with respect to the end of course assignment. Furthermore, in this context, the time spent on the assignments exceeds what is considered necessary. The best projects were always carried out by the groups that functioned most effectively. At the end of the course, when asked to perform self-evaluations, as well as evaluations of the rest of group members, the top groups tend to be more sincere and recognise when the group has or had not functioned well. There is also a clear identification of those group members who had not participated as they should.

According to the academic staff, the projects carried out were of greater quality and complexity compared to those written with a lower level of monitoring. The results also corroborate that students strongly agree that the course project gives them the chance to extrapolate their knowledge to real life situations. Regarding the use of rubrics, it can be affirmed they were very useful for the students, although they could have used more training on how to use them. Concerning the question of working in groups, better results were observed in the second experimental subject (i.e. once the students had already received training in the methodology).

CONCLUSIONS

The main conclusions reached from this experience are:

The monitoring and feedback of the evidences collected during the process affirm an increase in involvement and motivation of the student. This is also reflected in the improved quality of the assignments and projects presented. It has been confirmed that the incorporation of teamwork is an effective avenue for acquiring and developing both specific and generic competencies. The use of rubrics and rating scales assists in the definition of the quality criteria in the assignments set, while at the same time providing more objective assessment and allowing for both self- as well as peer-to-peer assessment.

ACKNOWLEDGEMENTS

The authors express gratitude for the collaboration of the Institute of Education Sciences from Universitat Politècnica de Catalunya, who provided the Grup d'Avaluació de la Pràctica Acadèmica (GRAPA) with both economic and material resource. These resources contributed to organisation and to the establishing of various lines of applied and theoretical research.

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