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Improving Engineering Students' Communication Competence: Designing Innovative Learning Strategies*

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This research presents an innovative and formal educational initiative that is aimed at enhancing the development of engineering students' specific competencies when studying Engineering Project Management subject. The framework of the experience combines theoretical concepts, the development of a real-case project carried out by multidisciplinary groups of three different universities, the use of software web 2.0 tools, and group and individual assignments of students that play different roles (project managers and team members). Under this scenario, this paper focuses on monitoring the communication competence in the ever growing Project Management virtual environment. Factors such as corporal language, technical means, stage, and management specific vocabulary among others have been considered in order to assess the students' performance on this issue. As a main contribution, the paper introduces an ad-hoc rubric that, based on previous investigations, has been adapted and tested to this specific context. Additionally, the research conducted has provided some interesting findings that suggest further actions to improve and better define future rubrics, oriented to communication or even other competencies. As specific Project Management subject concerns, it has been detected that students playing the role of Project Managers strengthen their competencies more than those ones that play the role of Team Members. It has also been detected that students have more difficulty assimilating concepts related to risk and quality management. However those concepts related with areas of knowledge like scope, time or cost have been better assimilated by the students.

Keywords: competency development; communication skills; communication rubrics; virtual learning experience; multidisciplinary learning

1. Introduction

After coursing for several years at technical schools, engineering students are used to the well-established general approach to problem-solving methodology that gives a well-defined and only-one-right solution to detailed technical problems. Instructors must cope with this reality when teaching Engineering Project Management (EPM), a subject that is based much more on the highly undefined and multi-disciplinary nature of the solutions to provide to clients. The length of the course (just 4,8 ECTS) is another issue to bear in mind, considering the students' lack of experience.

There are some important considerations for instructors to take into account when teaching EPM. The first one is its interdisciplinary intrinsic essence, which embraces a significant number of knowledge areas and practical approaches to cover. The second one is the character of the solutions to the proposed EPM problems, usually of an open-ended type. The third consideration is common to many other matters—time restrictions. All of these EPM aspects must be also considered in the actual implementation in Spain of the new educational model that was established by the Bologna process in the European Higher Education Area and which encourages the development of new experiences designed to reinforce students' competencies.

Within this global context, we introduce a Bologna-oriented learning framework for effectively teaching the basics of project management to students who possess no prior experience in the subject. This new approach combines theoretical and practical content, individual applied tasks and the use of EPM software systems and Web 2.0 tools, under a project-based learning methodology (instead of the traditional problem-solving approach). Based on previous experiences, the defined EPM learning framework seems to be very powerful and attractive for students to strengthen their competencies.

The objective of this study is to monitor the personal communication competence of students who are studying EPM, taking into account the virtual environment aspects that drive the experience, particular tasks to be analyzed and the instructors' requirements for its attainment.

As a result, we provide a rubric for communication competence which also includes a specific item that is designed to measure how students use the specific vocabulary of Project Management. It has been tested by students of Industrial Engineering,

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students of Chemical Engineering and students of the Master in Organizational Engineering (from the Technical University of Madrid, the University of La Rioja and the University of León).

The use of the information obtained, in terms of competence levels acquired, makes possible to bring additional feedback to the students involved in the experience, as well as the identification of new opportunities of behavioral improvement and new ideas for teachers in designing innovative learning strategies.

2. Literature review

2.1 Project based learning

Project Based Learning (PBL) is a model in which learning opportunities are organized around projects [1]. According to the definitions found in PBL papers, projects are complex tasks that are based on challenging questions or subjects that involve the students in design, problem-solving, decision making, or investigative activities. They give the students an opportunity to work relatively autonomously over extended periods of time and culminate in the creation of realistic products or presentations [2–4]. In PBL, the project is the central teaching strategy. Students encounter and learn the central concepts of the discipline by means of the project. There is a longstanding tradition in schools of "doing projects," incorporating "hands-on" activities, developing interdisciplinary themes, conducting field trips, and implementing laboratory investigations [5].

There is a shift in emphasis within engineering education from technical knowledge to performance skills [6]. These skills include problem analysis and problem solving, project management and leadership, analytical abilities and critical thinking, dissemination and communication, interdisciplinary competencies, intercultural communication, innovation and creativity, and social abilities. PBL has proved to be an excellent method for development of new forms of competencies [7, 8].

Research has shown that students retain minimal information in the traditional, didactic, teaching environment and frequently experience difficulty in transferring the acquired knowledge to new experiences [6]. A PBL environment enables students to draw upon their prior knowledge and skills, brings a real-world context to the classroom, and reinforces the knowledge acquired by both independent and cooperative group work [9].

The research presented fulfills the criteria that a project should have to be considered an example of PBL [10]: centrality, a driving question, constructive investigation, autonomy and realism.

2.2 Rubrics for assessing competencies

There are several proposals of rubrics to evaluate project management skills: co-operative work [11–13], learning in a science curriculum [14], writing attitudes [15], and the effect on students of problem solving [16].

Focusing on the main objective of this study, we selected a reference rubric (Table 1) that specifically allowed us to evaluate the students' individual communication competence when working on engineering project management and in a PBL methodological context. This rubric must be suitable for use in virtual environments, since one of the deliverables to be submitted by the students is a video, which is three minutes in duration. We also considered how students used the vocabulary and methodologies of Project Management that were developed during the course. The rubric that is presented in "Table 1" has been chosen for the particular interest of this investigation, once reviewed the existing rubrics and having taken into account all the above mentioned factors.

Four achievement levels are considered for each factor: "unsatisfactory", "needs improving", "satisfactory" and "excellent", all of them specifically characterized as presented in the research rubric (Table 3).

Some key factors are not reflected in the rubric and should be considered specifically for virtual environments as well as vocabulary regarding Project Management or active listening. They include corporal communication and the stage selected. Therefore, this study provides in the methodology section an adapted rubric that meets the particular requirements of virtual communications, as one of its main contributions to the research question of how to measure the achievement of this competence in this particular context.

3. Teaching and learning methodology

3.1 Experience framework

This experience was been carried out among three universities: the Technical University of Madrid, the University of La Rioja and the University of

Table 1. Communication Competence Reference Rubric

Communication Competence Factors
The student organizes the content of the presentation and uses an adequate style to facilitate the instructors' understanding.
The student uses graphics and other resources to effectively communicate the information.
The student uses oral communication techniques appropriately.
The student listens actively to the instructor, and answers questions and comments clearly and precisely.

Table 2. Students involved in the experience

Role	Master Degree	Industrial and Chemical Engineering Degree
Project Manager (PM)	12	5
Project Manager Work Package (PMwp)	–	52
Team Member (TM)	–	248

León. Three types of students of EPM have been involved: (1) from the Industrial Engineer degree, (2) from the Chemical Engineering Degree and (3) from the Master in Organizational Engineering. All of them, organized in project teams, had to develop a specific project in a collaborative manner, consisting of all technical and economic aspects related to the construction of a biofuels plant. They played different roles, depending on their different degrees as shown in Table 2.

Master's Degree students (Project Managers – PM–) developed the Work Breakdown Structure (WBS) as well as the Dictionary of the WBS at a high level for the full project (subdividing it into subprojects). Multidisciplinary teams of 9 to 12 members were formed combining industrial and chemical engineering students. Two roles were considered for these students in order to fulfill EPM academic objectives: (1) Project Managers of Work Package (PMwp), and (2) Team Members (TM). Each PMwp had to define the WBS of the subproject that had been assigned to him/her and to organize the team members' tasks to be done according to the scope negotiated with the instructors.

The course begins by asking the students to propose the definition and configuration of a solution to the problem to be solved. Multicriteria decision-making processes, milestones, different technologies and disciplines must be considered, since there is no one-right solution, but a group of partial answers to specific issues.

Teams' performance follow-up could be done at any point throughout the software-based support system, to which minutes of meeting and auto-evaluations must also be regularly uploaded. The instructors support the student groups by playing the role of technical, management and IT consultants, thus facilitating a smooth process workflow during the course. The above-mentioned basic fundamentals of similar experiences can be found in greater detail in [17–19].

As the particular interest of this study concerns, all the students must do an individual video presentation at the end of the course, to be uploaded in a specific web site in order to be evaluated by the instructors of the experience. As a global conclusion, the most relevant aspects of the project developed have to be remarked, i.e. achievements, weaknesses, found difficulties and main team's and personal's contributions.

Taking into account all of the aspects that characterize the experience, careful selection of the software-based support system is fundamental for its success, as well as for monitoring and evaluating the impact of Web 2.0 collaborative software tools on the acquisition of competencies. As regards the selection of the most appropriate web tool, the main objective was to provide to the students the best common platform to facilitate collaboration, communication and interaction among them. In this sense, some requirements were considered to be especially relevant for the experience's success. They are the following:

- Collaborative multiuser Web 2.0 environment and open-source software.
- Number of collaborative tools provided (blogs, wikis, forums, news, automatic e-mail reports, unified project calendar, document repository and forms to name a few).
- Possibility of real-time supervision of the work developed by the students (activity tracking), and forensic analysis.
- Performance logs and security management, roles and permissions.
- Multiple business capability in the same application.
- Management options for multiple projects and sub-projects.
- Documentation management tools and task assignment functions.
- Real-time supervision of the resource consumption.
- Import and export options from and to other applications like Openproj or MS Project.

According to these parameters, the software environment selected was *Project.net*. This software facilitates the students' adoption of the different roles that coexist in the management of a project, enabling the team members to communicate and work together even though there might be a significant distance separating them.

As competence acquisition concerns, this collaborative, virtual environment allows the students to develop specific abilities related not only with EPM subject issues, but also with other subjects' issues that are usually considered to be "behavioral," such as leadership, working in teams, and problem solving. In this way, the communication competence is

reinforced through both traditional and new interaction channels, on an individual and group basis.

3.2 Research design

As mentioned in the literature review section, there is a lack of specific rubrics that are oriented to evaluate all relevant aspects of communication competence. Thus, once the reference rubric of the Table 1 has been selected, we propose one that is better adapted to our investigation. This rubric includes three new factors: (1) corporal communication, (2) a stage for the video realization and (3) the proper use of the vocabulary and methodologies developed during the project management course. Factors and evaluation levels are shown in Table 3 below. In addition, the "active learning" factor has been eliminated, as it has no use in this particular context.

A contrast analysis was designed in order to test the new rubric. It has been used in a sample of 54 students: 13 students with the role of PMwp and 41 who played the role of TM. The three-minute videos (.flv format) were prepared by the students at the end of the first semester of the course. All personal works were recorded and uploaded to a specific site that was available only to instructors, guaranteeing the privacy of the materials provided.

With regard to the content of the presentations, detailed guidelines were given to students to ensure the most possible homogeneous presentation from all of them. That included the main aspects of the global project that was conducted by the group, the tasks assigned, and one's personal contribution to the overall work, any difficulties encountered and one's perception of the virtual experience. Evaluation of the 54 videos was conducted by four teachers experienced in EPM and competencies.

The responses were tabulated, assigning "1" for "unsatisfactory level", "2" for "needs improving", "3" for "satisfactory level" and "4" for "excellent". The results of the research are shown in the next section.

Table 3. Communication Competence Research Rubric

Communication Competence Factors	Achievement Levels			
	Unsatisfactory (1)	**Needs Improving (2)**	**Satisfactory (3)**	**Excellent (4)**
The student clearly organizes the content of the presentation.	The presentation is disorganized and lacks of a logic structure.	The presentation is structured in a confusing way. The organization by sections, titles, points, etc. is not clear.	The presentation is in general clear, although some points are not well structured.	The structure of the presentation is clear, coherent and logic.
The student uses the adequate oral style to ease the instructors' understanding.	The vocabulary used and overall level of the communication is not adapted at all to the audience.	In many aspects, the presentation is neither well structured nor oriented to the audience.	The style is adequate to the audience, although some ideas are expressed in a simple or complicated manner.	The presentation is perfectly done according to the audience, including the style and vocabulary used.
The student appropriately uses the corporal communication language.	Presentation is done under nervous status or supported by notes. Oral techniques are not used.	Presentation is not well supported by communication techniques.	Communication techniques are generally well used, although sometimes the volume and the oral expression are not correct.	Message is reinforced, getting the audience attention and using adequately the communication techniques.
The student uses graphics and other technical resources to effectively communicate the information.	Neither graphic nor additional resources are used. Video sound and/or image are not clear.	Graphic and/or other resources are poorly used or inadequately applied.	Graphics and/or other resources are commonly used, but are not always adequate for the content of the presentation.	Graphics and/or other resources are perfectly used and in a professional manner.
The student selects the appropiate stage for the presentation.	The stage doesn't help at all to the explanation of the presentation.	The stage selected made it difficult sometimes for the instructors to understand well.	The stage selected could be better somehow in lighting, color and general atmosphere.	The stage selected is ideal for the video presentation.
The student uses the vocabulary of Project Management properly in its areas of knowledge or processes (initiation, planning, implementation, monitoring and closing).	The students does not use the vocabulary and methodologies properly.	The student handles with difficulty the vocabulary and methodologies developed in class.	The student handles with ease the vocabulary and methodologies developed in class.	The student handles properly the vocabulary and methodologies developed in class.

4. Results

Figure 1 shows statistical measures of competence by factor and role (Team Member or Project Manager of Work Package).

The first result to highlight is that all factors are always higher for those students who played the PMwp role than for those students who worked as TM.

The communication competence factor that is best evaluated is the "message structure (M)" (3.2 points for PMwp and 2.5 points for TM) with a difference of +0.7 between the two groups of students. This is a logical and expected result, since detailed guidelines were provided by instructors as commented before. The factor "oral style (O)" (2.8 points for PMwp and 2 points for TM) presents a difference of +0.8 between the two groups of students, the highest for all factors. The factor "corporal (C)" obtained the lowest evaluation by both groups (2.5 points for PMwp and 2 points for TM) with a difference of +0.5 between the two groups of students. The "technical (T)" factor (2.6 points for PMwp and 2.3 points for TM) don't present a great difference between the two groups (+0.3). Finally, factor "stage (St)" (2.6 points for PMwp and 2.4 points for TM) shows the lowest difference, +0.2, between the two groups of students.

In regard with the proper use of Project Management's vocabulary (V), results also show a difference of +0.7 points between PMwp and TM.

The differences in results for the two groups of students (PMwp and TM) who were evaluated can be interpreted as meaning that those that play a Project Manager role strengthen their competencies more than those are playing a Team Member role. This should be considered for further initiatives.

Regarding the proper use of the Project Management vocabulary, the evaluation of the 54 videos confirms that students use it properly only for some areas of knowledge. The terms used most often by students are *Work Breakdown Structure (WBS), Work Package (WP), scheduling, critical path, resource allocation, and resource conflict*. It may be noted that those terms refer to scope, time and cost management of the project. A lack of knowledge of other areas, like risk or quality management, has been noticed even when they are part of the subject syllabus. This fact may suggest that a new teaching approach to reinforce these key Engineering Project Management (EPM) areas must be considered.

Analyzing the oral communication factors and the proper use of the EPM concepts in a virtual PBL context, there are some behaviors that acquire much more importance during communication, like the expression of the face, and others which lose importance, like the expression of the hands. We also find behaviors that are entirely new, such as the proper use of corporal language or the selection of the stage. In this sense, we have identified the need to adapt the behavior to each electronic mean used. Even more, in the modern IT world it is critical to take the former into account.

When students communicate in a virtual environment, technical means are very important to ensure excellent communication. Excellent communication is not achieved if we cannot hear properly, if the image is weak or if we have a distorted stage that makes it difficult to hold the listener's attention. Arguably, we can affirm that, if the basic technical communication standards are not met, communication collapses. Moreover, the use of texts, original staging or other resources, reinforce communication positively and thus the predisposition of the receiver.

We also detected the extent to which students and teachers are aware that what we have considered as elements of traditional communication (message, speech and body language), is affected and are less important. So, since we are aware of this impor-

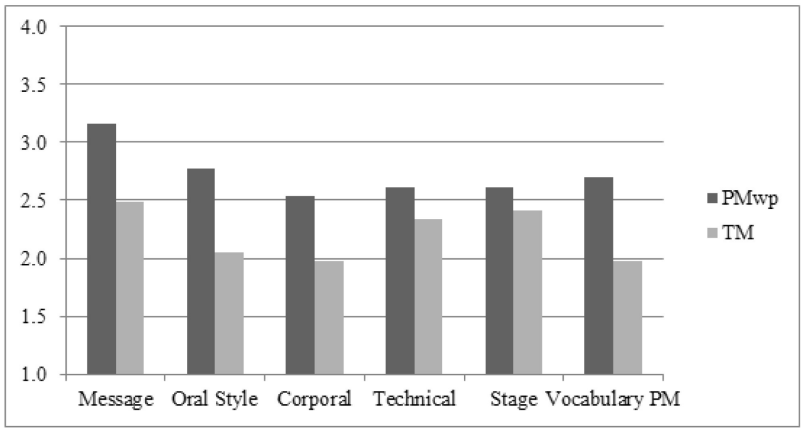

Fig. 1. Communication Competence evaluation results.

tance, some basic guidelines should be given to students. As identified, the rubric should be more precise and, since this is a key competence that may have a wide scope of coverage, the evaluators must adapt their behavior and rubrics to the case and the profile of the environment assessed.

5. Conclusions and future issues

The development of transversal and behavioural competencies is one of the most important challenges that the global educational community has to face under the new implemented Bologna framework. Under this scenario, the Technical University of Madrid (UPM) has established as a key strategic objective its firm commitment to the implementation of related activities within the current and future studies' plans.

Engineering Project Management presents an ideal framework for the development of both intrinsic technical and extrinsic transversal competencies. Leadership, teamwork and communication are considered to be of fundamental importance within the second group for good, practical learning of EPM basics. Additionally, the new powerful software Web 2.0 platforms allow new possibilities for teaching EPM in a way that is completely different from traditional problem-solving methods.

As a particular contribution, this study has discussed the goodness of the combined Project-Based Learning and a virtual context methodology for the implementation of innovative, value-added experiences aimed at strengthening students' individual competencies. Among these individual competencies, communication is in the priorities of UPM, and an understanding of communication in virtual workspaces is needed, particularly if we take into account that web 2.0 is the natural environment for students nowadays.

The second contribution is a description of an already carried-out activity that has been made in order to clarify all relevant aspects needed to understand the subsequent research objectives. In the research design, different communications channels are used by students, as well as different outputs that could be measured are produced.

Thirdly, the combination of formal presentation and recorded video was considered as the main focus to improve existing communication rubrics. The research introduces a rubric that was developed by the authors and based on existing ones, but more specifically adapted to assess the communication competence of students in their use of video presentations.

Nevertheless, communication competence includes another important topic that has not been considered in the scope of this study: formal documents and email writing communication aspects. Next experiences would be designed in a more comprehensive way in order to assess the overall students' performance in this field.

As another relevant contribution of this paper, it is important to highlight that, in the context of PBL; competencies are more strengthened when students play different roles than when they play the Project Manager's role. In this sense, it has been noticed that students who play the role of Project Managers have better results in strengthening their competencies than those ones who play the role of Team Members.

Taking this fact into account, we propose a new strategy for further development in the next courses that includes: (a) PM, PMWp and TM roles rotation between students by project phase, and (b) to provide feedback before the ending of the classes (e.g. two weeks before) about the competence achievement levels acquired by student and by group.

Concepts related to risk and quality management should be explained thoroughly in view of the difficulties that students encounter in acquiring them. Specifically, tools and techniques concerning risk identification and qualitative analysis, and methodologies to quality assurance and control, should be applied during this collaborative experience. The rubric designed could be particularly useful to assess students' writing and communication performance in these EPM areas.

Considering also the positive acceptance of the students which is based on qualitative comments in the standard evaluation form of the subject, we can conclude that the experience provides an excellent framework for communication personal skills development. The implementation of proposed actions for next courses entails nevertheless to overcome common difficulties such as time restrictions and the ever larger number of participants by classroom, issues to be carefully taken into consideration.

Finally, this investigation can be used as a reference for the design and implementation of similar innovative experiences that are aligned with the global objective of developing students' personal competencies. In fact, the experience here presented is coherent with other initiatives that are currently being implemented by UPM professors in other knowledge areas.

Once the comparative results are available, the usefulness of these rubrics in assessing and reinforcing students' personal competencies could be discussed in open forums, as well as the identification of good practices and lessons learnt. Indeed, all this experience feedback will definitively help to redesign further initiatives oriented to this aim.

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