

## Assessment of Student Participation and Critical Thinking in Engineering Students' Teamwork

M<sup>a</sup> ÁNGELES ANDREU-ANDRÉS<sup>1</sup>, MIGUEL GARCÍA-CASAS<sup>2</sup> and BEVERLY RISING<sup>3</sup>

<sup>1</sup>Departamento de Lingüística Aplicada, <sup>2</sup>Departamento de Biología, <sup>3</sup>Departamento de Traducción e Interpretación

<sup>1</sup>Universidad Politécnica de Valencia, <sup>2</sup>IES La Morería, <sup>3</sup>Universidad Pontificia Comillas

<sup>1</sup>Camino de Vera s/n, 46022 Valencia <sup>2</sup>Plaza País Valenciano n° 1, 46920 Mislata-Valencia, <sup>3</sup>Calle Quintana n° 21, 28008 Madrid

SPAIN

<sup>1</sup>maandreu@idm.upv.es , <sup>2</sup>mgcasas5@yahoo.es , <sup>3</sup>brising@chs.upcomillas.es

*Abstract:* - Aware of the qualities besides knowledge which are most valued by engineering firms (the ability to make decisions, a capacity for teamwork, initiative, capacity for solving problems and efficient communication, among others), an experience based on Problem-based Learning (PBL) has been carried out in which students have had to decide on what they understand as critical thinking and participation in multi-task teamwork in order to self-assess their own participation and critical thinking and evaluate that of their team-mates.

A quantitative analysis of the grades indicated that there were no significant differences except with regard to the students' preparation time. A qualitative analysis showed that the students experienced the process as one similar to that of facing their professional future.

*Key-Words:* - Assessment, Self-assessment, Participation, Critical thinking, Teamwork, Engineering, PBL.

### 1 Introduction

Collaborative teamwork is more than just asking students to form groups to carry out a task. Students must feel that the final product is the fruit of all the members' efforts and responsibility. This means they must interact with the other members of the team, but not individually nor competitively, since the members of effective teams do not compete among themselves but rather work together to reach a common goal [1].

The basic principles which help collaborative work (learning in this case) to function correctly are responsibility, collaboration, interpersonal abilities and teamwork abilities, communication and self-assessment. Of all these factors, the ones which stand out are collaboration and each person's taking responsibility for a common goal, as well as being held responsible by his teammates for that goal.

We are not going to deal here with the advantages that this methodology provides, as several authors have already done [2; 3; 4], nor with previous research of our own [5; 6], specifically PBL (Problem Based Learning)<sup>1</sup> used in this study,

but rather on three other issues. In the first place, we shall study the two concepts around which this study is based, critical thinking and participation, specifically in collaborative work and in PBL. In the second place, we will explain the research questions and objectives undertaken in order to, in the third place, describe the methodology used and the profile of the students participating in the study. The paper ends with the analysis of results.

### 2 Participation and Critical Thinking

#### 2.1 Critical Thinking

The most important job in the process of teaching/learning is teaching the student to think, to see what surrounds him/her, to teach him/her to observe and, at the same time, be able to detect and solve problems [7]. PBL, at its most basic level, is characterized as being a strategic methodology in which *real life* models are used as a context so that learners can acquire skills for problem-solving and critical thinking, as well as learning fundamental concepts and the content of the subject [8]. Using this strategy, students acquire learning skills which will be useful throughout their lives, including the ability to find and use appropriate learning resources.

Three different types of thinking abilities can be pointed out: first, those that can be used to infer,

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<sup>1</sup>Essential steps in Problem-based Learning (PBL): identify the problem, gather the necessary data and bibliography, consider the possible solutions, apply the best solution and evaluate the consequences.

classify, compare, synthesize, forecast, etc. (related to information or basic abilities); second, mental strategies such as problem-solving, critical thinking, creative thinking, etc. and, third, metacognitive strategies that permit directing and controlling these mental strategies through each person's planning and evaluation [9].

Critical thinking consists of thinking with a purpose, such as interpreting the significance of something, testing a particular question or solving a problem, individually or collaboratively [1]; critical thinking can also be considered research with the aim of analyzing a situation, a question, a phenomenon or a problem in such a way that a justified conclusion can be reached that integrates all the available information on the topic being dealt with [10].

Critical thinking involves capabilities and attitudes that play a fundamental role when discovering and analyzing the large quantity of information that characterizes our social context [11]. The business world exercised a fundamental role in the 1980s in producing an educational movement in the US built around the development of thinking and reasoning abilities. These abilities were required more and more by companies, together with the capacity for team work, fluency in their native language and in a foreign language as well. Collaborative learning represents a pedagogical advance in this period since it foments students' helping each other when analyzing a problem or a topic, besides forcing them to verbally transmit their ideas to others, facilitating an interactive approach to the treatment of information [12].

A trained *critical* thinker is able to formulate questions and solve problems with clarity and precision; s/he gathers and evaluates information efficiently and proposes well-reasoned solutions; s/he has an open mind and the ability to communicate with others effectively [13]. With all these advantages and the current social demand, it is worth the effort to propose tasks that foster critical thinking in students while they acquire knowledge and skills in their field, without forgetting that critical thinking does not guarantee reaching the truth, a conclusion or the correct solution. Nevertheless, it is one of the most valued qualities by businessmen when selecting degree-holders, together with sincerity, the ability to take decisions, initiative and the ability to communicate orally and in writing [14].

## 2.2 Participation

The second aspect studied in this paper is *participation* in collaborative work together with *critical thinking*: what the students think they entail and how to measure them. Teachers must try to make students feel motivated and willing to contribute to learning activities, taking participation into account in the final mark. If this mark is used arbitrarily, students reach the conclusion that it is a part of their evaluation over which they have no control and they lose interest in it. If, on the other hand, student participation is considered important, this relevance should be reflected in the final evaluation.

It has been noted that if a skill is evaluated, a student will make more of an effort to do it better. In the same way, if the student's effort (his/her participation in the task) is evaluated, s/he will work harder. If, in addition, s/he is asked to define what s/he understands as participation, and indicates the best way to measure it, something that might seem out of his/her control becomes something that is perceived as under his/her control. If the student decides not to participate and make an effort, it is his/her own choice, but, if the objectives and the method of evaluation are clear, students can reach these objectives [15].

The interaction between individuals [16] plays a fundamental role in cognitive development since students acquire knowledge and skills from one another and interchange experiences through discussion and interaction, where learning is an act of participation in communicative practice [17]. In general a student is understood to be participating in class if s/he asks questions and offers opinions and comments in a discussion. If the student does not participate in this way, s/he may be considered passive and even uninterested in the subject.

Nevertheless, before making a judgment about the activeness or passiveness of a student, his/her personality should be taken into account as one of the important affective factors when calculating and evaluating his/her participation in a task, i.e. whether the person is extroverted or introverted, more or less a risk-taker or not accustomed to working in a student-centred class [18]. Extroverts usually prefer learning situations in which interaction and independence play an important role whereas introverts usually prefer working in small groups [19].

### 3 Research Questions and Aims of the Study

In this multi-task teamwork, several different research questions were approached. On one hand, the questions related to the definition of *critical thinking* and *participation* in this activity as well as their evaluation were raised; on the other hand, self-assessment and peer evaluation of both concepts and their relationship with the group-work process were analysed. A specific breakdown follows:

1. According to the students, what is *critical thinking* and *participation* in multitasking?
2. How would they propose to measure these two concepts individually and collectively?
3. Are there differences between the scores given in self-assessment of the two concepts at the end of the group activity and the scores obtained in peer evaluation?
4. What happens throughout the process? What have they learnt?

This paper has three aims in measuring students' participation and critical thinking throughout the PBL. In the first place, students (in groups) have to define what critical thinking and participation are for each member of the group throughout the task and, in the second place, to decide how to measure these two variables individually and as members of a group (self-evaluation and peer evaluation) as two of the three ways to include students in the assessment process [33; 34; 35]. The second objective is to see if there are differences or not between the scores granted once the results of self and peer-evaluation have been gathered.

The third and last objective involves the analysis of the participants' opinions about the experience.

### 4 Methodology

Thirty-four engineering students took part in the study. The group was heterogeneous in its communication competence in English and nationalities included Dutch, Polish, Turkish, Czech, German and French (all of them on an Erasmus exchange) together with Spaniards who were about to finish their engineering studies.

For three weeks, these students centred their in-class and out-of-class activity on working collaboratively to conclude tasks involving a problem-based learning approach (with a deadline). The group (4-5 members per group) was distributed keeping the different nationalities and communication competences of each member in mind. In line with what will happen to them when

they start their professional careers, the students were not able to select their team-mates.

A basic advantage worthy of note is that the average age of the macro-group was around 23, since they had had to finish a three-year degree and to have finished and defended a final-year project before entering this upper level of engineering studies. A drawback was the problem of different cultures and ways of facing work responsibilities.

The protocol for analysis followed for all the groups was the following:

1. Decision on what *participation* and *critical thinking* are. Debriefing.
2. Decision on how to measure these two concepts: creation of a grid or headings. Debriefing.
3. Creation of a single grid for measuring participation and another for critical thinking at the end of the task.
4. Carrying out the task: peer assessment and self-assessment of participation and critical thinking using the grids agreed upon.
5. Individual assessment, in writing, of the process students had undergone, using open-ended questions.

The results obtained through a qualitative analysis—based on the theory proposed by Glaser and Strauss in 1967, called the Constant Comparison Method (CCM) and the Grounded Theory of Charmaz [24] and Glaser and Holton [32]—and a quantitative analysis were aided, respectively by the *ATLAS-ti* (Version 5.2) and *Statgraphics* (Version 5.0) programs.

### 4 Analysis and Discussion of Results

#### 4.1. What is *critical thinking* and *participation* according to the students and how can these two concepts be measured?

Table 1 shows the students' opinions on what they think critical thinking is and how it should be measured.

It should be noted that no group had access to any information that might have guided them in the definition and subsequent evaluation of these two concepts. The groups had only the problem as such and the condition that in order to start this multi-task, it was essential to decide and agree on what *critical thinking* and *participation* were and how each should be assessed.

If the six intellectual skills needed for critical thinking<sup>2</sup>: *interpretation, analysis, evaluation, inference, explanation* and *self-monitoring* are used as the structure for the first of these concepts, it can be observed that all the participants, to some degree, have put these skills into practice. They have had to *interpret* the ideas of others, *defend* their own ideas, *analyse and assess* them so that they can be put not only in tables 1 and 2 but also in the assessment grids found in the Appendix, whose numbers had to be *explained*, and lastly *self-monitor* their intervention.

**Table 1.** Critical thinking and measurement

<b>WHAT CRITICAL THINKING IS from the students' viewpoint</b>
<ul style="list-style-type: none"> <li>▪ Not copying others' ideas.</li> <li>▪ Offering your own ideas/opinions with arguments to support them.</li> <li>▪ Not believing others immediately without analyzing other aspects of the person and their way of behaving and speaking.</li> <li>▪ Not being afraid to offer your own opinion (if you are shy and don't know how to or can't speak in public, it is advisable to write down and prepare your opinion and the ideas you want to express beforehand).</li> </ul>
<b>▪ HOW TO MEASURE IT</b>
<ul style="list-style-type: none"> <li>▪ By the number of arguments put forth.</li> <li>▪ By the strength of those arguments.</li> <li>▪ By the way (the enthusiasm) in transmitting the message to other people (enthusiasm compared to shyness).</li> <li>▪ Bearing oral and corporal expression in mind.</li> <li>▪ By the conviction expressed and the power of persuasion.</li> <li>▪ A grid was proposed that took these criteria into account.</li> </ul>

The definitions shown in Table 1 have been analysed. *Offering their own ideas*, for example, refers to thinking with a purpose within the concept of critical thinking; *analysing* other aspects before deciding refers to a metacognitive thinking strategy [9], and offering *results* on how to assess this concept refers to critical thinking as a result of

problem solving [10], as in the experience under study.

**Table 2.** Participation and its assessment

<b>WHAT PARTICIPATION IS from the students' viewpoint</b>
<ul style="list-style-type: none"> <li>▪ Interaction between people in the group.</li> <li>▪ Offering opinions in a discussion.</li> <li>▪ Offering arguments that support your opinions.</li> <li>▪ Listening to others and trying to understand their points of view.</li> <li>▪ Participating in sports, creative activities, etc.</li> <li>▪ How much a student talks in class discussions.</li> <li>▪ The content expressed by someone taking part in a discussion.</li> <li>▪ Listening to others and answering the questions presented.</li> <li>▪ The effort of speaking and making yourself understood.</li> <li>▪ Explaining your point of view.</li> <li>▪ The courage to participate in a discussion.</li> <li>▪ Testing yourself.</li> </ul>
<b>HOW TO MEASURE IT</b>
<ul style="list-style-type: none"> <li>▪ Not everyone can be assessed in the same way:             <ul style="list-style-type: none"> <li>• Shy people who find it difficult to intervene in a discussion;</li> <li>• On the other hand, others like interaction more;</li> <li>• And others want to intervene but lack the communicative skills needed.</li> </ul> </li> <li>▪ According to the length (minutes) of the intervention.</li> <li>▪ According to the quality of their intervention (facts).</li> <li>▪ According to the individual contribution to the discussion.</li> <li>▪ According to how you listen to others.</li> <li>▪ According to the level of knowledge reflected in what you say.</li> <li>▪ Bearing in mind the time a student needs to explain his/her idea or point of view.</li> <li>▪ According to the work behind each intervention.</li> <li>▪ A grid is proposed which reflects these aspects.</li> </ul>

<sup>2</sup> Published as *The Delphi Report* in 1990 by Facione.

Table 2 shows what the students agreed upon with regard to *participation* and how to measure this concept in teamwork. It was precisely this interaction among the members of the group, their opinions, arguments, effort to communicate and understand others –as proof of what they are capable of– which led them to define and decide on how to assess one of the prime characteristics of active learning: participation. Asking them to evaluate their own participation and that of their classmates prepares them for real life situations in which they will have to share ideas, participate in discussions, listen and respect others' opinions as well as evaluate differing points of view.

Of all the definitions suggested, *interaction* among the members of the group was the most mentioned, along with *offering opinions and arguments*. The relationship between interaction and learning in the classroom has been documented by several authors [20; 21; 16]. If an activity fosters interaction, the active learning models which support Vygotsky's social constructivism predict, as an outcome, that learning will occur. Some studies suggest, however, that a passive interaction, similar to listening but not participating in a discussion, is not perceived by the students as learning [22]. In our case the students –perhaps unconsciously– mention *listening to others* as part of participation, but immediately add *and answering the questions presented*. From this we can understand the importance of listening actively as part of participation and, indirectly, learning.

A student's personality plays an important role, not only when participating in a task, but even when defining what is understood as participation. This is the case of the last two lines in Table 2 when

defining this concept as *the courage to take part in discussions and test yourself*. If we bear in mind that extroverted students participate more than introverted students, we can see how learners have taken these situations into account when they mention the effort and courage that shy persons must expend to participate actively in a task [19; 23].

Based on these opinions, the students constructed an evaluation grid in their groups and later agreed upon it in the macro-group (see Appendix). This was used to evaluate and self-evaluate the participation and critical thinking of each member of the group.

#### 4.2. Quantitative analysis of the scores given

For this analysis we discarded both those evaluation grids which did not specify the names of the students being evaluated together with the number assigned to each of the variables, and those grids which gave a global mark to all the members of the group in each of the variables analysed. Because of this, the quantitative analysis has a final sample of 31 individuals in the self-assessment of *participation* and 32 in *critical thinking*. Tables 3 and 4 show the parameters of each of the variables, separating *evaluation of participation* from *evaluation of critical thinking*. Tables 5 and 6 show the data for each of the variables, separating self-assessment of participation from self-assessment of critical thinking.

The data used in the analysis are found in the four tables: the average of the scores obtained in each of the variables measured (between 2 and 5 points) as well as the variance of the means.

Table 3. Parameters for the assessment of participation

	ATTENDANCE AND PUNCTUALITY	DEGREE OF IMPLICATION AND CONTENT OF PARTICIPATION	LISTENING TO OTHERS	PREPARATION	ATTITUDE AND BEHAVIOUR
DATA	85	85	85	85	85
MEAN	4.03	4.05	4.50	4.28	4.65
VARIANCE	0.74	0.63	0.38	0.68	0.46

Table 4. Parameters for the assessment of critical thinking

	ARGUMENTS OFFERED	QUALITY OF THE ARGUMENTS	MAKING YOURSELF UNDERSTOOD	LISTENING TO OTHERS
DATA	80	80	80	80
MEAN	4.0	4.25	3.9	4.2
VARIANCE	0.58	0.54	0.59	0.70

Table 5. Parameters of the self-assessment of participation

	<b>ATTENDANCE AND PUNCTUALITY</b>	<b>DEGREE OF IMPLICATION AND CONTENT OF PARTICIPATION</b>	<b>LISTENING TO OTHERS</b>	<b>PREPARATION</b>	<b>ATTITUDE AND BEHAVIOUR</b>
DATA	31	31	31	31	31
MEAN	3.87	3.95	4.40	3.91	4.61
VARIANCE	0.58	0.37	0.27	0.46	0.37

Table 6. Parameters of the self-assessment of critical thinking

	<b>ARGUMENTS OFFERED</b>	<b>QUALITY OF THE ARGUMENTS</b>	<b>MAKING YOURSELF UNDERSTOOD</b>	<b>LISTENING TO OTHERS</b>
DATA	32	32	32	32
MEAN	3.92	4.09	3.78	4.35
VARIANCE	0.25	0.34	0.56	0.64

If we start from the hypothesis that the students have been honest in their evaluations of participation and critical thinking for themselves and their team-mates, we can test this hypothesis using an analysis of variance of the means in both cases, i.e. how a set of individuals assess themselves and how another set of individuals assess others, variable by variable.

Classroom observation tends to uphold this hypothesis. Nevertheless, it must be the results of comparing the means of the variables of self-assessment of the two concepts, with the corresponding means in peer assessment which

indicate if there are significant differences or not. Significant differences lead us to question their veracity whereas no significant differences would show that the participants have been truthful, or at least not untruthful, when evaluating themselves and their teammates.

This comparison was carried out using an ANOVA between the means of each variable of self-assessment with the corresponding variable of participation and critical thinking (see Tables 3 and 5; 4 and 6 respectively). Tables 7 and 8 show the results of the analysis.

Table 7. ANOVA participation

<b>Evaluation</b>	<b>ATTENDANCE AND PUNCTUALITY</b>	<b>DEGREE OF IMPLICATION AND CONTENT OF CONTRIBUTION</b>	<b>LISTENING TO OTHERS</b>	<b>PREPARATION</b>	<b>ATTITUDE AND BEHAVIOUR</b>
<b>Self-assessment</b>					
ATTENDANCE AND PUNCTUALITY	df= 1/114 F= 0.87 P = 0.35 (NS)				
DEGREE OF IMPLICATION & CONTENT OF CONTRIBUTION		df= 1/114 F= 0.46 P = 0.49 (NS)			
LISTENING TO OTHERS			df= 1/114 F= 0.67 P = 0.41 (NS)		
PREPARATION				df= 1/114 F= 4.95 P = 0.02 (S)	
ATTITUDE AND BEHAVIOR					df= 1/114 F= 0.11 P= 0.74 (NS)

The results of the ANOVA indicate that there are no significant differences between the means of those variables with a P value larger than 0.05 (equivalent to 95% confidence level). From this, it can be seen that there are only significant differences in the scores related to preparation for group work.

Returning to our initial hypothesis, these results indicate that the only variable in which the participants may not have been truthful is when evaluating the time and effort put into their participation or that of their team-mates in preparing the assigned group work (in or out of class). This may suggest that not all have shown the necessary interest in preparing their final task. Reasons for adopting this attitude could be varied

and difficult to point out; nevertheless, if we take into account the data produced in the qualitative analysis, it appears that several groups had dysfunctions due to some of the foreign students who did not collaborate very much.

It is not possible to state that the statistically significant differences were caused by untruthfulness on the part of the self-assessors or the peer-assessors; nevertheless, classroom observation can help the teacher to confirm the difficulties in these groups and to find a basis for thinking that there was untruthfulness in some of the self-assessments with regard to effort and preparation.

Table 8. ANOVA critical thinking

Evaluation \ Self-assessment	ATTENDANCE AND PUNCTUALITY	DEGREE OF IMPLICATION AND CONTENT OF CONTRIBUTION	LISTENING TO OTHERS	PREPARATION
ATTENDANCE AND PUNCTUALITY	df 1/110 F = 0.28 P = 0.59 (NS)			
DEGREE OF IMPLICATION AND CONTENT OF CONTRIBUTION		df. 1/110 F= 1.14 P= 0.28 (NS)		
LISTENING TO OTHERS			df =1/110 F= 0.81 P= 0.37 (NS)	
PREPARATION				df =1/110 F= 0.31 P= 0.57 (NS)

### 4.3. Qualitative analysis of the experience

The qualitative analysis centres on the opinions of the participants about the process undergone in the PBL. The objective of a qualitative analysis is to develop a theory based on the study of social reality. Unlike quantitative analysis, qualitative analysis provides an oral description or explanation of the process undergone which complements the quantification of the data found. This type of analysis approaches the collaborative process experienced by the members of each group and studies the answers of the participants using Grounded Theory (GTA), one of the most detailed

qualitative analysis methods. It is a cyclical theory in the sense that data collection, analysis and reflection on what has been observed alternate constantly [25].

The basis of all qualitative analysis is the detection of the themes dealt with in the answers given by those surveyed. Mills et al. [26] describes this theory as 'a widely used qualitative research methodology that seeks to inductively distil issues of importance for specific groups of people, creating meaning about those issues through analysis and the modelling of theory' (p. 8). With this method, the significance of the answers by the

students is analysed so that the different categories arise from the data, trying as much as possible not to impose certain categories [27]. The data from qualitative analysis are generally obtained from written material such as notes, taped interviews, documents, surveys with open answers etc. [28].

This study centres around a survey involving short answers (see Appendix) at the end of the multi-task. The analysis of the surveys requires a codification of all the data, line by line and, at times, word by word according to Strauss [29] until data saturation is reached [30]. Following this procedure for analysis, the theory grounded in the students' words arises: the participants have lived through an experience similar to that which they will have to face in their professional future. This theory is based on four large categories that help to understand the process undergone in their PBL: their *learning*, what they understand as *teamwork* from the experience, the *difficulties* they have encountered and overcome, as well as the *applicability of what they learned*. Each of these categories is commented on below.

#### *Learning*

Basically the participants have learnt to *make a presentation, to get to know themselves by means of the task*, as part of a *learning process* coming out of *teamwork*. All this learning has been made possible through the teamwork that they have had to use and which they think has helped them "to work as they will have to do professionally" since they will have to communicate in English with people from other countries, just as in the multi-task.

As a result of the PBL, they have learnt to make a presentation, "improving their communication skills" and they have been able to "speak in public," "increase their vocabulary" and "write better" in a foreign language. Having to work as they would in a professional situation has brought with it "working with a deadline," as well as "explaining to others" different points of view, "listening" and "coming to agreements."

In the same way, they believe that the multi-task has helped them to know themselves, which involves "controlling their nerves," "trusting in yourself and being less obstinate," "controlling shyness" and "being patient" in order to give opinions and come to agreements.

#### *Teamwork*

As they describe their experience with teamwork, consciously or unconsciously they end up referring to what this ability consists of. It is very highly

valued in the working world but, in spite of being in the last years of their studies, they have had few occasions to put it into practice before taking part in this experience. For these students, teamwork has meant "planning the process," "working in and out of class," "cooperating" with their team-mates and making an effort, although the number of people per group which they considered ideal – three– shows a certain contradiction with the idea of "facing their professional future" where the number of members of a group can vary significantly.

In their opinion, working in a team was more complicated for them when it was done with "members from other countries and cultures" with heterogeneous levels of English and different ways of working. For this reason, some groups considered "distributing the work as in other subjects." However, they ended up considering this difficulty positive by "taking advantage of working" with other people of different cultures and ways of doing things. They confirm that they have learnt from one another and –perhaps without knowing it– they have become more flexible.

To work well together, they believe that everyone involved has to be "sincere", "responsible", "listen to each other", deal with each other "patiently" and "with good manners". This is something that could appear basic to someone trained in teamwork, but is totally new to those who experiment with it, perhaps for the first time.

#### *Difficulties*

Throughout the task, difficulties have been found which refer, in part, to the task itself, and, to a large extent, to working on a team with team-mates from different cultures and with a limited time frame. Although they felt that the deadlines "helped them to organise" and that they made them get the task done, at some point it began to "make them nervous". In some teams, in spite of the organisation, there was a last minute rush, which is also completely normal in a professional context. The fact that they needed communicative skills in a foreign language also made the task more difficult, at the same time as it increased action learning.

The beginning of the project was generally difficult and slow, although it was "problem-free" in the end. The students agreed that "almost everyone worked" on the team, making up for others' absences and tardiness. Some of the students thought that deciding on how to evaluate participation and critical thinking, for themselves and for others, during the PBL experience was the teacher's job, and not theirs. As the project



progressed they realised that if they knew how the project was going to be assessed, their results would improve. In this way they experienced the complexity that is intrinsic to the evaluation of any work or project and which they will have to put into practice in their professional lives as engineers.

#### *Applicability of what has been learned*

The students think that the results of the experience will “help them to face this type of situation with better probabilities of being successful” owing to having improved their communicative skills and learning to “speak in public” with less of a feeling of stage-fright. They feel able to “apply what they have learnt to other subjects”, including the defence of their final year project, either in their native tongue or in a foreign language. They think this is a skill which will help them “find a better-paying job”.

## 5 Conclusions

Referring back to the research questions posed and the results of the different analyses carried out, the following conclusions can be reached:

1. In answer to the first research question, the participants clearly agreed with Facione [31], Romano [9] and Kurfiss [9], among others (see Tables 1 and 2) about what *critical thinking* and *participation* in a task are.
2. In answer to the second question, the students agreed to evaluate the two concepts using the self-assessment and peer-assessment grids found in the Appendix.
3. In answer to the third question, the quantitative analysis showed no significant differences between the scores given in the self-assessment of the two concepts (critical thinking and participation) at the end of the group task and those given by their peers, except in one variable related with participation: task preparation time. This lack of significant differences supports the initial hypothesis regarding the sincerity of the scores given, except in the case of the variable mentioned. This could mean that not everyone invested the necessary time in the preparation of the final task and didn't want to confess this fact.
4. According to a Grounded Theory study of the words of the students interviewed, the participants experienced the process as similar to what they would have to face in their professional lives. This theory is based on four fundamental categories: *learning* gained, the ability to *work in a team*, the *difficulties* they

have had to face and the *applicability* of what they have learnt. It is worth noting that among the difficulties found, they realised that *almost* all, but not all, of the members of the group worked, a difficulty which, from a statistical point of view, led to the existence of significant differences in the self-assessment and peer-assessment scores on preparation.

It should be underlined that the critical thinking and the participation invested by each of the students helped them to successfully solve the PBL presented, at the same time as they learnt content, put the concepts studied into practice and improved skills and abilities that would be useful in their professional careers. In the same way, we should note the difficulty and importance of the qualitative analysis to better understand how they felt during the experience –the beginning, difficulties and learning. This encourages us to continue using qualitative analysis in future studies as a complement to quantitative analysis (as used here) or independently.

We might question, in future studies, whether the results obtained here, with a lack of statistically significant scores on self-assessment and peer-assessment, would appear in a larger population. In any case, the analysis presented in this study was carried out with a large enough sample to support the quantitative results. Likewise, repeating the qualitative analysis with another sample of students might be useful to confirm the results of this first analysis, along with helping to develop worthwhile questions to be used in future studies.

#### *References:*

- [1] Facione, P.A. Critical Thinking: What it Is and Why it Counts. *Insight Assessment*, 2006 update (1992 ed. 1996). [http://www.insightassessment.com/pdf\\_file/s/what&why2006.pdf](http://www.insightassessment.com/pdf_file/s/what&why2006.pdf) [Last access: 12th April 2008].
- [2] Anson, C.M., Bernorl, L.E., Crossland, C., Spurlin, J., McDermotr, M.A. and Weiss, S. Empowerment to Learn in Engineering: Preparation for an Urgently-Needed Paradigm Shift. *Global Journal of engineering Education*, Vol. 7, No. 2, 2003, pp. 145-155.
- [3] Christoforou, A.P., Yight, A.S., Al-Ansary, M.D., Ali, F., Aly, A.A., Lababidi, H., Nashawi, I.S., Tayfun, A. and Zribi, M. Improving Engineering Education at Kuwait University Through Continuous Assessment. *International Journal of*

- Engineering Education*, Vol. 19, No. 6, 2003, pp. 818-827.
- [4] Hedberg, T. The Impact of Bologna Declaration on European Engineering Education. *European Journal of Engineering Education*, Vol. 28, No. 1, 2003, pp. 1-6.
- [5] Andreu-Andrés, M<sup>a</sup> A. and García-Casas, M. Evaluación, coevaluación y autoevaluación del trabajo en grupo en la lectura de mapas topográficos in Watts, F. and García-Carbonell, A. (eds.), *La evaluación compartida: investigación multidisciplinar*. Universidad Politécnica de Valencia, Valencia, pp. 69-90, 2006.
- [6] Labrador-Piquer, M<sup>a</sup> J. and Andreu-Andrés, M<sup>a</sup> A. (eds.) *Metodologías Activas*. Universidad Politécnica de Valencia, Valencia, 2008.
- [7] Pompa, A., Mohar, F., Lam, F., Pérez, G., López, E., Falcón, M., Trujillo, A. Álvarez, A., Peraza, M., De la Cruz, T. and Pérez, H. Contribución al desarrollo del componente investigativo en los estudiantes del primer año de la carrera de Medicina Veterinaria. *Revista Pedagogía Universitaria*, Vol. 4, No. 3, 1999, pp. 36-42.
- [8] Duch, B. Problem-Based Learning. *About Teaching*, 47, January, pp. 45-57, 1995.
- [9] Romano, G. Comment favoriser le développement des habilités de pensée chez les élèves, en J.P. Goulet, *Enseigner au collégial*, Association québécoise de pédagogie collégiales, Montreal, 1995.
- [10] Kurfiss, J.G. *Critical Thinking: Theory, Research, Practice, and Possibilities*. Ashe-Eric Higher Education, 1988.
- [11] Boisvert, J. *La formación del pensamiento crítico. Teoría y práctica*. Fondo de Cultura Económica, México, 2004.
- [12] Forgarty, R. and McTighe, J. Educating Teachers for Higher Ordering Thinking: The Three-Story Intellect. *Theory into Practice*, Vol. 32, No. 3, 1993, pp. 161-169.
- [13] Paul, R. and Elder, L. *The Miniature Guide to Critical Thinking: Concepts and Tools*. The Foundation for Critical Thinking, 2006.
- [14] Mariani, M. What Employers want from College Grads. *Occupational Outlook Quarterly*, Vol. 38, No. 2, 1994, pp. 42-44.
- [15] Stiggins, R. *Student Centered Classroom Assessment*. Upper Saddle River, Prentice Hall, NJ, 1998.
- [16] Vygotsky, L. *Mind in Society*. Harvard University Press, Cambridge, Massachusetts, 1978.
- [17] Lave, J. and Wenger, E. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press, Cambridge, 1991.
- [18] Brown, D. *Principles of Language Learning and Teaching*. Longman, White Plains, 2000.
- [19] Myers, I. *The Myers-Briggs Type Indicator*. Consulting Psychologists Press, Palo Alto, 1962.
- [20] Menzel, K.E. and Carrell, L.J. The Impact of Gender and Immediacy of Willingness to Talk and Perceive Learning. *Communication Education*, Vol. 48, 1999, pp. 31-40.
- [21] Powers, S. and Rossman, M.H. Student Satisfaction with Graduate Education: Dimensionality and Assessment in College Education. *Psychology: A Quarterly Journal of Human Behavior*, Vol. 22, No. 2, 1985, pp. 46-49.
- [22] Rovai, A.P. and Barnum, K.T. On-Line Course Effectiveness: An Analysis of Student Interactions and Perceptions of Learning. *Journal of Distance Education*, Vol. 18, No. 1, 2003, pp. 57-73.
- [23] Galvan, J. and Fukada, Y. Asian International Students' Preferences for Learning in American Universities. *The CATESOL Journal*, Vol. 1, 1978, pp. 29-49.
- [24] Charmaz, K. *Constructing Grounded Theory. A Practical Guide through Qualitative Analysis*. SAGE Publications Ltd, London, 2006.
- [25] Wester, F. and Peters, V. An Introduction to the Principles and Practice of our Method of Qualitative Analysis. In Pieterse (ed.) *Desmond Tutu's Message. A Qualitative Analysis*. Brill, pp. 112-136, 2001.
- [26] Mills, J., Bonner, A. and Francis, K. Adopting a Constructivist Approach to Grounded Theory: Implications for Research Design. *International Journal of Nursing Practice*, Vol. 12, No. 1, 2006, pp. 8-13.
- [27] Williams, M., Burden, R., Poulet, G. and Maun, I. Learners' Perceptions of their

- Successes and Failures in Foreign Language Learning. *Language Learning Journal*, Vol. 30, 2004, pp. 19-29.
- [28] Strauss, A.L. and Corbin, J. *Basics of Qualitative Research: Grounded theory Procedure and Techniques*, Sage Publications Newbury Park, CA., 1990.
- [29] Strauss, A.L. *Qualitative Analysis for Social Scientists*. Cambridge University Press, New York, 1987.
- [30] Mikel, G. ESL Teachers' Views on Visual Language: A Grounded Theory. *The Reading Matrix*, Vol. 3, No. 3, 2003, pp. 137-168.  
<http://www.readingmatrix.com/articles/petrie/article.pdf> [Last access: 25th April 2008]
- [31] Facione, P.A. *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction, Executive Summary. The Delhi Report*. The California Academic Press, CA, 1990.  
<http://www.insightassessment.com/dex.html> [Last access: 25th February 2008]
- [32] Glaser, B.G. and Holton, J. Remodeling Grounded Theory, *Forum*, Vol. 5, No 2, 2004, pp. 1-17.
- [33] Dochy, F., Siegers, M. and Sluijismans, D. The Use of Self-, Peer and Co-assessment in Higher Education: A Review, *Studies in Higher Education*, Vol. 24, No. 3, 1999, pp. 331-350.
- [34] McGourty, J. Using Multisource Feedback in the Classroom: A Computer-based Approach, *IEEE Transactions on Education*, Vol. 3, No. 2, 2000, pp. 120-124.
- [35] Fisher, P.D. Zeligman, D.M. and Fairweather, J.S. Self-assessed Student Learning Outcomes in an Engineering Service Course, *International Journal of Engineering Education*, Vol. 21, No. 3, 2005, pp. 446-456.

### Appendix

Self-assessment and peer-assessment grids for critical thinking and participation, designed by the students themselves to measure the two concepts when they have finished the PBL, are included here. The open questions on the experience and what students learnt (debriefing) are also included.

*Advanced*<sup>3</sup> — **PARTICIPATION**  
**PEER-EVALUATION AND SELF-EVALUATION**

<b>CRITERIA</b>	<b>2 LIMITED OR NO COMPETENCE</b>	<b>3 SOME COMPETENCE</b>	<b>4 COMPETENCE</b>	<b>5 GOOD COMPETENCE</b>	<b>SCORE AND MEMBERS' NAMES</b>
<b>ATTENDANCE AND PUNCTUALITY</b>	Rarely attends class sessions where group work takes place.	Generally attends the sessions in which group work takes place – but not on time.	Always attends the group work sessions and usually arrives on time.	Always attends the group work sessions and arrives on time.	
<b>DEGREE OF COMMITMENT THROUGHOUT THE GROUP TASK (IMPLICATION). CONTENT OF PARTICIPATION</b>	Never contributes with any ideas or questions. Doesn't like to ask questions or participate and doesn't possess language competence.	Rarely contributes with ideas or questions. Has some language competence and does his/her best to communicate.	Actively contributes with ideas and questions. Has communicative competence and is usually willing to communicate.	Actively contributes with many ideas and interesting questions. Confident in communication and is always ready to communicate.	
<b>LISTENING TO OTHERS</b>	Does not listen when others are speaking. Often interrupts.	Rarely listens to whoever is speaking.	Generally listens to others and gives opinions and ideas.	Always listens to others and gives opinions and ideas to others.	
<b>PREPARATION</b>	Never prepares what is required.	Rarely prepares what is required.	Generally prepares what is required.	Almost always prepares what is required.	
<b>ATTITUDE AND BEHAVIOR</b>	Is ill-mannered and does not worry about his team-mates.	Is rarely well-mannered with the rest of his team.	Is generally well-mannered and tries to help his team-mates.	Is always well-mannered and tries to help his team-mates.	

<sup>3</sup> Students of Geodesy and Cartography Engineering at the Polytechnic University of Valencia (Spain).

*Advanced — CRITICAL THINKING:*  
**ASSESSMENT AND SELF-ASSESSMENT**

CRITERIA	2 LIMITED OR NO COMPETENCE	3 SOME COMPETENCE	4 COMPETENCE	5 GOOD COMPETENCE	SCORE AND MEMBERS' NAMES
<b>NUMBER OF ARGUMENTS</b>	When I offer arguments, they are not valid.	I often give opinions instead of valid arguments.	I often try to give some arguments or offer opinions or judgments.	I always try to give valid arguments together with my opinions and judgments.	
<b>QUALITY OF ARGUMENTS</b>	I don't worry about the quality of the arguments I may offer.	I rarely question the quality of my arguments.	I know how to identify valid arguments although sometimes I forget to offer them.	I question the strength of arguments before I offer them and when I listen to them.	
<b>MAKING YOURSELF UNDERSTOOD</b>	I don't know how to communicate. I am shy.	I try to communicate. I do my best in spite of my shyness.	I normally manage to communicate satisfactorily.	I know how to communicate effectively.	
<b>LISTENING TO OTHERS</b>	I don't usually listen to others.	I only listen to those who interest me.	I sometimes find it difficult to listen to others but I generally make an effort to do so	I listen to others and I am willing to change my opinions after listening to others' arguments.	

**OPEN-ENDED QUESTIONS ABOUT THE PROCESS<sup>4</sup>**  
PROBLEM-SOLVING TASK: *DEBRIEFING*

### What is debriefing?

In a debriefing discussion, **participants are asked** (under the guidance of a questioning facilitator) to **reflect on their experiences and to discuss points of learning that they believe took place.**

#### 1. Questions about the activity:

- How did it work?
- What happened in your group?
- How did the deadline affect the quality of your work?
- How easy or hard was it compared to other exercises/activities? Why?

<sup>4</sup> Questions based on *Results Through Training*, www.RTTWorks.com.  
[http://216.239.59.104/search?q=cache:GbtlBA\\_NE0oJ:www.rttworks.com/images/downloads/Debrief.HTML+debriefing+%2B+questions&hl=es&ct=clnk&cd=1&gl=es](http://216.239.59.104/search?q=cache:GbtlBA_NE0oJ:www.rttworks.com/images/downloads/Debrief.HTML+debriefing+%2B+questions&hl=es&ct=clnk&cd=1&gl=es) [Last access: 29<sup>th</sup> September 2009]

**2. Questions about feelings and reactions:**

- How do you feel about the problem-solving task?
- How confident are you about the work you did?
- How did you feel about the process?
- How did you feel about the deadlines for your team activity?

**3. Questions about learning:**

- What did you learn?
- What do you still need to learn?
- Which personal objectives have been addressed?

**4. Questions about application:**

- How can understanding this process help you academically and professionally?
- How can you use this in your professional career?

**5. Proposals for Improvement:**

- How would you improve the experience as a whole?
- How would you improve the dynamics of your group?
- How would you improve your own contribution to your group?