Critical thinking skills assessment with PENCRISAL test in a hybrid approach to PBL

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Abstract

Undoubtedly, the level of achievement that can be expected when implementing PBL methodology is linked to substantial changes in connection to the institution, faculty and students, in such a way that a successful transition towards a learning-centered environment can be achieved. The different PBL approaches, commonly called hybrid methods, frequently show experiences in single courses belonging to a traditional curriculum, which are much more sensitive to the effects of different institutional, administrative and academic factors on expected achievement. The benefits in developing higher order thinking skills than can be achieved in implementing the PBL model, particularly in the training of engineers, are well known. However, in hybrid PBL approaches, these benefits may be affected. Our previous studies in the context of implementing a hybrid PBL approach with freshmen engineering in a Peruvian university showed that one of the most sensitive points was the consolidation of an efficient teamwork dynamic, which is one of the fundamental pillars on which PBL entire process is sustained. These results also showed the influence of this factor on indicators of students' academic performance. In this paper the results of the evaluation of achievements in the development of critical thinking skills in a similar context to the above studies are reported, in addition the level of influence of the teamwork dynamics on the development of these abilities are examined. For the evaluation of the critical thinking skills PENCRISAL test was used, this instrument was developed by a research group at the University of Salamanca (Spain) and validated in both Spanish and Peruvian population. PENCRISAL is set on five factors: deduction, induction, practical reasoning, decision making and problem solving.

Keywords: critical thinking assessment, hybrid PBL, teamwork, higher order skills, engineering education

1 Introduction

Incorporating the development of critical thinking skills in higher education, has become an important need in any professional profile, as they are key tools to address the complexity of life and workplace. It is now recognized that traditional science education does not meet the needs of individuals and societies, as it does not prepare individuals to face current and future challenges of their environment and the world. It is necessary to prioritize the acquisition of methods and ways of thinking in higher education, promoting the acquisition of knowledge through a series of intellectual methods, such as: documentary research, experimental and systematic practice, verification and testing information, modeling, argumentation and performing simulations and stimulating critical reflection on the knowledge handled.

Halpern (1998) remarks the growing demand for a new type of worker who can perform multiple operations, manipulate symbols, abstract and complex ideas, acquire new information efficiently and be flexible enough to recognize the need for continuous change and new paradigms for lifelong learning. On the other hand, the exponential rate at which knowledge grows and people can access a wealth of information; constitute another reason underlying the need for teaching critical thinking. If people do not develop skills to select, interpret, digest, evaluate, learn and apply information, they likely can access many answers but without being able to give them a meaning. Education, then, should prioritize the development of the skills to know how to learn and how to think clearly and with this goal in mind, it is necessary to define precisely the concept of critical thinking and its constituent aspects, particularly those that can be improved through education.

Consequently, it has started the review and reconsideration of curricula and teaching strategies that encourage the development of higher order skills inherent to a person who assumes the leading role of their learning processes and capable of facing challenges beyond their field of expertise, using a relevant and reasoned judgment. In this context, Problem-Based Learning (PBL) has become a useful tool for the development of these desirable skills in university education, among which are critical thinking skills.

1.1 Problem-based learning, teamwork and critical thinking

Hmelo-Silver (2004) refers to PBL as “a pedagogical technique that situates learning in complex problem-solving contexts. It provides students with opportunities to consider how the facts they acquire relate to a specific problem at hand. It obliges them to ask what they need to know. PBL offers the potential to help students become reflective and flexible thinkers who can use knowledge to take action”.

Effective problem solving skills development is one of the main goals in PBL and it includes the ability to apply appropriate metacognitive and reasoning strategies. In Gueldenzoph and Snyder (2008) review, some research results are reported whose conclusions showed that Problem-Based Learning activities promoted critical thinking and problem-solving skills; active participation in the learning; teamwork and knowledge acquisition.

The PBL facilitator plays an important role in modeling the problem solving and guiding the development of higher order thinking skills. This is made by encouraging students to justify their thinking and by directing appropriate questions to individuals.

The learning process in PBL begins with the presentation of a problem in a real or realistic scenario. The design of this scenario is critical to ensure that the desired learning outcomes occur. Hung (2006) proposes an interesting model (3C3R model) that clearly illustrates the different components of the scenario or problem design. The core components of the model: content, context and connection are mainly related to the ownership and adequacy of content knowledge, and their contextualization and integration. The processing components: research, reasoning and reflection facilitate conscious and meaningful involvement of students in their learning process. Researching and reasoning components are critical to PBL problem design in activating the effects of the core components and directing learners to construct knowledge and develop problem-solving skills. The cognitive activities involved in the researching and reasoning processes are higher-order thinking skills. Frequently, students require training to enhance their critical thinking skills, and this must develop along the university education.

In PBL, students work in collaborative groups. The influence of interpersonal relationships and communication with others about learning is recognized in both learner-centered psychological principles proposed by APA (1997), and the constructivist view of teaching and learning (Coll, 2001). In a team work dynamic the students develop learning skills through positive interaction among group members. This implies establishing common goals, resolving discrepancies, negotiating the decisions that a group is going to take, and coming to an agreement. These tasks require an active exchange of ideas and engagement by all members of the group, so an efficient teamwork dynamic enhances learning and promotes critical thinking (Hmelo-Silver, 2004).

1.2 Critical thinking assessment in this study

To find a precise definition for critical thinking has long been an extremely complex task. The main difficulty has been the nature of the underlying basis for the various theories and models proposed, which can be located in the philosophical or psychological tradition.

An important reference is the theoretical approach to critical thinking proposed by Diane Halpern (1998, 2003). Halpern defined critical thinking as: "the use of those cognitive skills or strategies that increase the probability of a desirable outcome". Thinking is described as purposeful, reasoned, and goal directed – the kind of thinking involved in solving problems, formulating inferences, calculating likelihood, and making decisions. Critical thinkers are predisposed to think critically, that is, they are evaluating the outcomes of their thought processes –how good a decision is or how well a problem is solved.

All the skills considered in Halpern's taxonomy for the critical thinking teaching are present in a PBL process, despite PBL is not a specific program for the instruction of thought. As the student addresses the problem, develops skills related to identify problematic situations, ask questions, investigate, reasonably support his own ideas, compare his ideas with those of others, reformulate the problem and strategies for addressing it, and draw reasoned and thoughtful conclusions and judgments.

Based on the theory of Halpern and others as Ennis (1996), Facione (2011) and Walton (2006), Saiz and Rivas (2012), researchers at the University of Salamanca, developed an instrument (PENCRISAL) to assess critical thinking skills. The concept of critical thinking they assume is: "thinking critically involves reflection and action, all aimed to achieve our goals. In a simple way: critical thinking is reasoning and making decisions to solve problems as effectively as possible".

PENCRISAL test was validated in Spanish population with very good results (Rivas, Saiz, 2012). It was shown that this instrument is an appropriate tool to assess reasoning skills, problem solving and decision making.

The content of the items have been prepared taking care to use culturally neutral situations, in order that the instrument can be applied in contexts other than Spanish. In order to study the applicability of the test in a Latin American context a linguistic adaptation to Peruvian context was made and applied to freshmen of Science and Engineering (PUCP). The results indicate that the Peruvian version of PENCRISAL has good psychometric properties that corroborate the results obtained in the original version (Rivas, Morales Bueno, Saiz, 2014).

The PENCRISAL test was used to assess the achievements in the implementation of a strategy for the explicit teaching of critical thinking skills with seniors of psychology at the University of Salamanca. The strategy includes the use of PBL methodology and the results showed positive and significant achievements in all dimensions of the test (Saiz & Rivas, 2013).

In Latin American Universities, the necessary change to student-centered environments has different levels of difficulty in higher education institutions mainly due to more conservative convictions and beliefs that still prevail. The different PBL approaches, commonly known as hybrid forms, most often show implementation experiences in isolated courses belonging to a traditional curriculum. These approaches involve a greater tutor's intervention, assuming the role of facilitator for learning through individual or group pre-designed activities, classroom demonstrations, mini-exhibitions, etc. These adjustments to PBL process make possible their implementation in a variety of disciplines and contexts (Wilkerson and

Gijselaers, 1996). However, students keep on working in collaborative groups, assigning roles, distributing responsibilities, exchanging information, contrasting, reflecting and discussing new knowledge with their peers.

The hybrid PBL approaches are much more sensitive to the effects of different institutional administrative and academic factors on the expected achievements, as discussed by Bouhuijs (2011). The benefits in developing higher order thinking skills than can be achieved in implementing the PBL model, particularly in the training of engineers, are well known. However, in hybrid PBL approaches, these benefits may be affected.

Our previous studies in the context of implementing a hybrid PBL approach with freshmen engineering in a Peruvian university showed that one of the most sensitive points was the consolidation of an efficient teamwork dynamic, which is one of the fundamental pillars on which PBL entire process is sustained (Morales Bueno, 2014). These results also showed the influence of this factor on indicators of students' academic performance. In this paper the results of the evaluation of achievements in the development of critical thinking skills in a similar context to the above studies are reported, in addition the level of influence of the teamwork dynamics on the development of these abilities are examined.

2 Research

2.1 Participants

The participants in this study were first year engineering students of a Peruvian university who were enrolled in a General Chemistry course. In this course a Hybrid PBL approach was implemented. Table 1 summarizes the participants' characteristics.

Table 1: Characteristics of the participants (N = 57)

Age	Age mean	Gender (%)	
		Male	Female
16 - 20	18	66,7	33,3

2.2 Context of the study

The hybrid PBL approach implemented in the general chemistry courses implies that the groups of students work independently their solution proposal to the PBL scenario presented at the beginning of each unit of the course, but, in parallel, develop a series of learning activities related to the content and designed previously by the teacher. Learning activities are worked in classroom sessions, collaboratively, under the mediation of the teacher. Thus, it was ensured that the contents were properly worked by students, while the teacher could monitor the development of skills for teamwork in the student groups.

2.3 Instruments

- PENCRISAL test: consists of 35 items which raise problems of everyday situations, have open response format, propose different thematic issues of knowledge and have unique answers.
  The items are configured on 5 dimensions:
  Deductive reasoning: evaluates propositional reasoning and categorical reasoning.
  Inductive reasoning: evaluates analogical reasoning, hypothetical and inductive generalizations.

Practical Reasoning: evaluates the skills of argumentation and identification of fallacies.
Decision making: evaluates the use of general procedures of decision, implying making accurate judgments of probability and using appropriate heuristics to make solid decisions.
Problem solving: evaluates the implementation of specific strategies to solve the situations presented.
Scoring criteria assign values between 0 and 2 points depending on the quality of the response. 0 points is assigned when the answer is wrong; 1 point is assigned only when the solution is correct, but not adequately argued (identifies and demonstrates understanding of basic concepts); 2 points are assigned when in addition to the right solution, justify or explain the response (where more complex processes that involve real production mechanisms are used). The maximum test score is 70 points (14 points for each dimension).
Cronbach's alpha value is 0,734.

- Team work questionnaire: the instrument allowed students to identify positive and negative attitudes displayed by individuals and also identify the attitudes held by the group as a whole during the team work. The first part of questionnaire describes ten most frequent personal attitudes in a working group. The student must select three attitudes that best describe each of the members of the group, including him. The score for this part is calculated as the percentage of positive attitudes assigned to each individual. The second part is composed of 10 semantic differential items related to different aspects of teamwork: mutual confidence, collaboration, coordination, implementation of goals, conflict management, engagement, monitoring, feeling toward the group and compliance roles. These items are valued on a gradient of 1 to 4 points. The score for each aspect assessed is calculated as the percentage of maximum value. The sum of the scores achieved in the two parts of the questionnaire corresponds to the total score, the maximum value is 1000.

2.4 Procedure

The PENCRISAL test was administered to all participants, as pre- and post-test. The time between the application of pre- and post-test was 4 months. There is no time limit to answer the test; but it is estimated that the average length is between 60 and 90 minutes.

The team work questionnaire was administered during the last week of the course. The average time to answer the questionnaire is between 20 and 30 minutes.

2.5 Analysis of data

The data were analysed using Statistical Package for the Social Sciences (SPSS) 19 software ®. The level alpha was established a priori in 0,05. From the data collected, a descriptive analysis of the scores obtained in each PENCRISAL dimension and the whole test was performed. To verify significant differences between the results obtained in the pre and post-test, t test for related samples was performed.

Additionally, descriptive analysis of the scores obtained in Team work questionnaire was performed. In this case total score was transformed to z score, then the participants were organized into three categories, they are shown in Table 2:

Table 2: Participants categories according Team work questionnaire total score

Category	z	N° participants
Higher	> 1	26
Intermediate	-1 < z < 1	19
Lower	< -1	12

In order to verify the differences between the categories, the analysis of variance (ANOVA) was used, considering as dependent variable the difference between the scores of post and pre test corresponding to each PENCRISAL dimension and the whole test and, as independent variable the team work category.

3 Results

Table 3 shows the descriptive statistics for pre- and post-test PENCRISAL scores and Table 4 the descriptive statistics for Team work questionnaire scores expressed as percentage. In both cases the results for the whole group of participants were considered. It can be seen that post test scores were higher in all PENCRISAL dimensions except decision making. The PENCRISAL total score was higher in the post test too.

The results in Team work questionnaire scores show a higher mean in the first dimension “positive attitude”. Means for the two dimensions and total score were higher than 70%.

The inferential analysis performed with a t test for related samples showed statistically significant differences in the total score, $t(56) = 2.607$, $p = 0.012$; in solving problems dimension, $t(56) = 2.128$, $p = 0.038$ and inductive reasoning dimension, $t(56) = 4.753$, $p < 0.001$. No significant differences were found in the dimensions: deductive reasoning, $t(56) = 1.717$, $p = 0.091$; practical reasoning, $t(56) = 0.106$, $p = 0.916$ and decision making, $t(56) = -0.534$, $p = 0.596$.

Table 3: Descriptive statistics for pre- and post-test PENCRISAL scores (N = 57)

Dimension	Pre-test		Post-test	
	M	SD	M	SD
Deductive reasoning	2,51	2,229	3,05	1,968
Inductive reasoning(*)	3,89	1,633	5,02	1,788
Practical reasoning	5,04	2,383	5,07	2,389
Decision making	4,56	2,036	4,40	2,103
Problem solving(*)	5,46	2,472	6,11	2,358
Total score(*)	21,46	7,476	23,65	6,828

(*) Significant differences between post and pre test

Table 4: Descriptive statistics for Team work questionnaire scores expressed as percentage (N = 57)

Dimension	M	SD	Minimum	Maximum
Positive attitude	81,95	15,198	42	100
Group performance	78,98	10,494	63	97
Total score	79,35	10,592	63	97

In Table 5 the descriptive statistics for Team work questionnaire obtained for each category (described in Table 2) is reported. In the first two categories "positive attitudes toward the group" had higher scores than "group performance". The opposite occurred in the third category, where "positive attitudes toward the group" obtained the lowest score.

Table 5: Descriptive statistics for Team work questionnaire scores for each category

Category	Positive attitude		Group performance		Total score	
	M	SD	M	SD	M	SD
1 (N=14)	96,57	2,766	92,14	2,445	92,57	2,277
2 (N=31)	83,87	7,839	78,68	6,046	79,26	5,739
3 (N=12)	59,92	13,681	64,42	1,311	64,17	1,115

The ANOVA analysis performed to verify possible differences in critical thinking achievements, considering the team work categories described in Table 2, showed homogeneous variances for all dimensions and total score. The Tukey-b post hoc test revealed that there was not significant differences between the team work categories, comparing the PENCRISAL score difference between pre and post-test. A Linear regression analysis, introduce method, using PENCRISAL total score as dependent variable and the scores obtained in team work questionnaire as independent variables confirmed this result. None of the dimensions of the questionnaire teamwork and the total score were predictive variables for the PENCRISAL score.

4 Conclusions

There is no doubt that social factors play an important role in the learning process and are influential aspects on expected achievements in PBL implementation. Collaborative work allows students to share their opinions and individual perceptions on certain issues. In this way the student is motivated to use prior knowledge to identify, based on his observations and discussions with his teammates; relationships, difficulties, needs, discrepancies, etc. that should be addressed to deal with PBL scenarios. This promotes the use and development of skills for problem solving, critical thinking, communication, creativity, among others.

When the implementation limits the space and opportunity for this dynamic to develop with adequate autonomy (as unfortunately happens in PBL hybrid modes implemented in isolated courses of a conventional curricula), the influence of team work achievements will be lower than expected, as it has been seen in the results reported in this study. However, the general results have shown positive achievements in the total score of PENCRISAL test, revealing that critical thinking skills have been enhanced. The dimensions with significant positive achievements were “inductive reasoning” and “solving problem”. The latter are skills especially promoted in PBL process and further in the case of engineering education. Commonly, hybrid PBL models are used in situations where students do not have previous experience as autonomous learners, so that the scenarios and the process have a more controlled design to scaffold the learners’ researching and reasoning processes. However, with a more controlled process it is common to expect lower reasoning ability in the student.

According the results obtained, the adoption of hybrid PBL approaches could have the risk of not considering essential aspects of the underlying educative vision of this methodology. It is necessary to incorporate opportunities to promote the enhancement of self-learning skills, and if it is required, some activities for the explicit learning of some critical thinking skills, as deductive and inductive reasoning. The other three dimensions considered in PENCRISAL test are more directly related to the PBL process characteristics. Students learn to face professional discussions in situations such as the definition of the problem or argument to support a proposed solution. In PBL context, students develop their abilities to explain in scientific terms their proposal of solution to the problem, since it is not enough to say that the approach is correct. They must also be able to convince the other members of the team explaining the reasons that support their assertion, as well as listen and analyze the reasons of others, as it is expected to occur during the performance of a professional engineer.

As it was commented above, the results of an earlier study with the same group of students showed that teamwork had a positive effect on learning achievements, particularly on "group performance" dimension. The present study has shown that it is not the same case with the critical thinking skills. Although they have improved but have not shown a significant relationship with the dimensions considered in teamwork assessment.

Finally, PENCRISAL test has proven to be a suitable instrument to assess achievements in critical thinking skills in PBL environments, whether in a context of explicit teaching of thinking as demonstrated by a previous study, as in a hybrid model such as the present study. The assessment results are useful to identify the different aspects that have been promoted and those that need special attention, so that it is a useful tool for future research.

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