New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION
5th Edition

Evolution of the Application of an Educational Innovation in a General Chemistry Course

Patricia Morales Bueno
Pontificia Universidad Católica del Perú PUCP (Perú)
pmorale@pucp.edu.pe

Abstract
The teaching-learning process involves a complex set of relationships, in which some critical aspects are involved, such as cognitive and emotional characteristics of students; conceptions of teaching and learning for teachers and students; educational vision, objectives and resources of the institutions and others. All of them take part of the environment in which the process unfolds, and exert direct influence on the quality of achieved learning. These variables have a direct effect on the success or failure of the implementation of any educational innovation. In this work the evolution of the implementation of a hybrid PBL approach in general chemistry courses for engineering students at a Peruvian university is analyzed. The interest in applying PBL arises from the need for a radical change in teaching practices in basic science courses in our university, which led to start a project at institutional level just over ten years ago. The achievements in some aspects involved in the methodology, such as motivation, development of skills for problem solving and critical thinking have been studied at different times of the experience, with varying results that can be analyzed taking into account the changing context in which it has been developed.

1. Introduction
Currently the concept of educational innovation is closely linked to the quality of higher education and generally refers to the planned process that lead to further improvements in the educational context, according to their characteristics and objectives [1]. Thus, a variety of strategies has been reported to improve student learning in which the learner has the central role, however, not necessarily the results are as expected because the teaching-learning process involves a complex set of relationships between three major dimensions: characteristics of students, teaching and institutions, all of them exert direct influence on the quality of achieved learning [2, 3].
This article discusses the evolution of the implementation of a hybrid PBL approach in general chemistry courses for engineering students at a Peruvian university. This implementation was started in 2002 and the context in which it developed had some changes that influenced the achievements in some aspects involved in the methodology, such as motivation, skills for problem solving and critical thinking.

2. Context of the educational innovation
Problem Based Learning (PBL) has had a major impact on higher education and particularly in engineering education [4]. In this context, between the years 2002-2004, the Problem-Based Learning in Peruvian Higher Education project was developed with participation of the Institute for Transforming Undergraduate Education (ITUE), University of Delaware (USA). The project's main objective was to incorporate the PBL methodology in science and engineering teaching practices of the Peruvian university and, indirectly, to promote this methodology in other local and regional institutions.

2.1 PBL implementation
PBL adoption implies the transition to a learning-centered environment, involving significant changes in various aspects of the institution, teachers and students. Therefore, implementation is not easy and so that a variety of implementation modalities has been reported [5].
Moesby has proposed a four-step process to implement a new educational model, as PBL [6]. In the case of the Peruvian university this process was performed as described below.

a. Preliminary activities (1999-2001):
- A Commission of Pedagogical Modernization is formed.
- Opportunities for reflection and discussion about university teaching practice are promoted.
- Some visits to American and European universities are organized.

b. Adoption stage (2001-2002)

- Coordination with ITUE (U. Delaware) to establish the cooperation agreement.
- Some professors were selected to assume the role of change leaders.
- Leaders training in U. Delaware.

c. Implementation stage (2002-2004)
- Round development of teacher training programs, monitoring and evaluation of the experience.
- A hybrid PBL approach was performed in isolated courses of Science and Engineering curriculum.

d. Institutionalization
- It failed to achieve this state.
- The implementation continues only in some isolated courses. General Chemistry courses are the most representative. Over time, the context in which the implementation is carried has suffered important changes that caused the loss of sustainability. Some of these were resistance to change of professors and students, policy changes of the authorities in charge of the academic unit and the characteristics of students, who currently show a greater degree of immaturity, some weaknesses in their prior knowledge and no experience in self-learning.

In this study, three variables linked to the goals of PBL [7]: achievement motivation, critical thinking and knowledge structure were assessed at different times of hybrid PBL implementation in General Chemistry courses at the Peruvian university.

3. Methodology

3.1 Participants

In this study, different cohorts of first year engineering students were considered; each one was enrolled in a General Chemistry course in a different semester. Table 1 summarizes the groups' characteristics.

Table 1. Characteristics of the participating groups

	Achievement Motivation					Knowledge Structure					Critical Thinking				
Group	Year	N	Age mean	% male	% female	Year	N	Age mean	% male	% female	Year	N	Age mean	% male	% female
G1	2007	31	18	77,4	22,6	2008	49	17	73,1	26,9	2010	48	18	66,7	33,3
G2	2009	149	17	65,8	34,2	2011	60	18	69,0	31,0	2011	49	17	69,4	30,6
G3	2015	87	18	80,5	19,5	2013	60	17	70,5	29,5	2012	57	18	66,7	33,3

3.2 Instruments

Attributional Achievement Motivation Modified Scale (EAML-M) [8]: The items are configured in six dimensions: Interest and effort, interaction with faculty, task / ability, influence of peers on learning skills, exams, and collaborative interaction with peers.

PENCRISAL test [9]: The items are configured on 5 dimensions: deductive reasoning, inductive reasoning, practical reasoning, decision making, and problem solving.

Knowledge structure tests [10]: Three tests to assess the three levels of Knowledge Structure (cognitive component of Sugrue's model for assessment of problem solving skills): concepts, principles and link the concepts and principles to conditions and procedures for application. The topics related to each of the three tests are: Thermodynamics, Kinetics and Chemical Equilibrium.

3.3 Analysis of data

The data were analyzed 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 test application was performed. In order to verify some differences between the participant groups or between dimensions of each test applied, the analysis of variance (ANOVA) was used. For all the analysis the scores were expressed as percentage.

4. Results

4.1 Achievement motivation

Figure 1 shows the dimensional profile, expressed as maximum score percentage in each dimension, for each participant group.

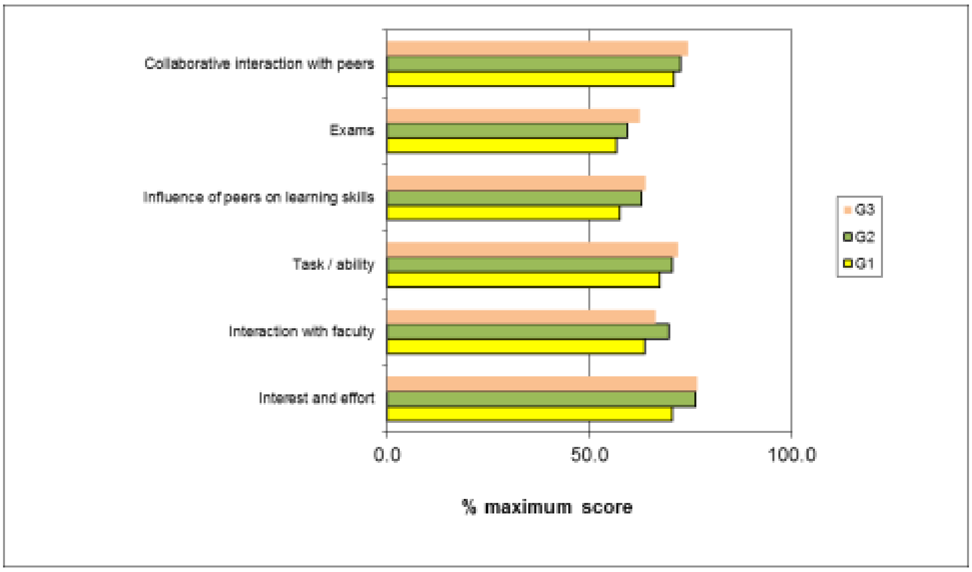

Fig.1. EAML-M dimensional profile for participant groups (G1: 2007, G2: 2009, G3: 2015)

The three participating groups showed similar dimensional profiles in which the dimensions Interest and Effort, and Collaborative Interaction with Peers were those with the highest score and differed significantly from the other, according to the results of ANOVA. These results show that, despite the difficulties arising in the implementation context over time, the student was engaged in a process wherein the challenge of the task complexity and the collaborative interaction with peers were equivalent to the interest and effort that students made to reach learning objectives and together represent aspects that contributed to increase motivation.

4.2 Critical thinking

Figure 2 shows the PENCRISAL dimensional profile and total score, expressed as maximum score percentage in each dimension, for each participant group.

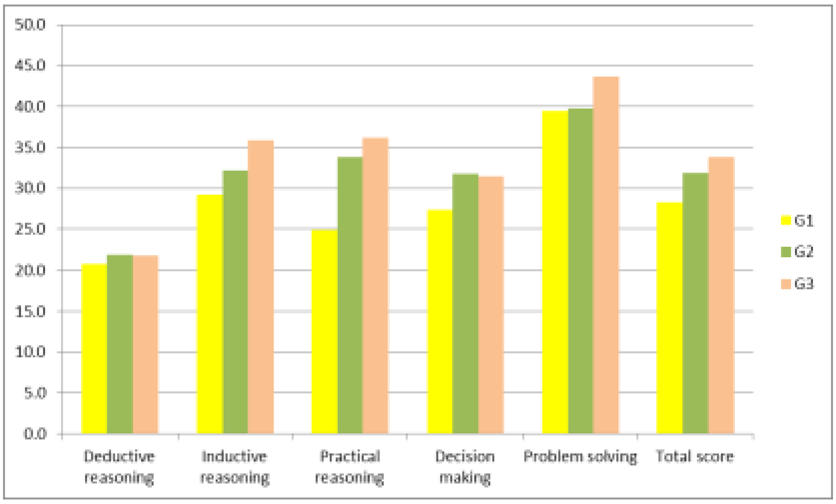

Fig.2. PENCRISAL dimensional profile and total score for participant groups (G1: 2010, G2: 2011, G3: 2012)

Total score for the three groups was quite low (<35%), which shows that the critical thinking skills have not had the expected development in the implementation. The three groups showed similar dimensional profiles, Problem Solving dimension achieved the highest score and differed significantly from the other according to the results ANOVA. This result was not surprising since the skills for problem solving are promoted with greater emphasis on science education.
The application of hybrid PBL models, with students who have no experience in self-learning, implies that scenarios and processes designs have a high level of control and scaffolding that somehow limits the development of argumentation and making decisions skills, which are important components of critical thinking.

4.3 Knowledge structure

Figure 3 shows the results for each level of knowledge structure, expressed as maximum score percentage, for each test applied and each participant group.

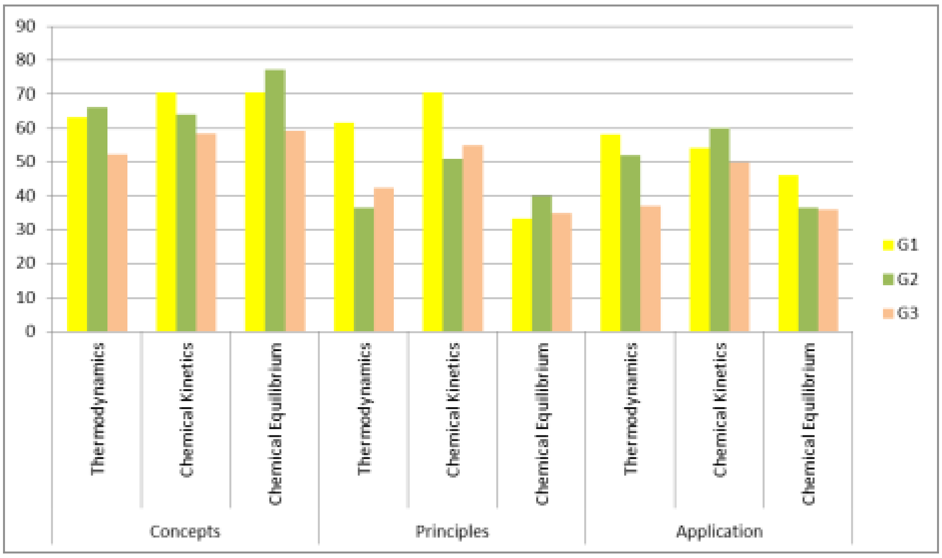

Fig.3. Knowledge structure results for participant groups (G1: 2008, G2: 2011, G3: 2013)

As noted, in recent years our students have shown some weaknesses in their previous knowledge and experience for self-learning, this makes the learning process more difficult for them, in a context in which it is intended that the learner assume the leading role. This was evident in the low scores achieved by G3 group in the concepts level, which were significantly different from the other groups in thermodynamics and chemical equilibrium tests, both topics especially difficult for students. G1 group corresponds to a more favorable implementation environment and so that, this group had higher scores in the principles level, which were significantly different from the other groups in thermodynamics and kinetics tests. The third level is of particular interest to assess progress in hybrid PBL implementation, as it is expected that students develop skills to apply the concepts and principles learned in new situations. The results showed that G1 group had better scores in this level, which were significantly different in thermodynamics and chemical equilibrium tests.
The growing academic weakness of G2 and G3 groups made necessary the use of more structured designs for scenarios and processes, so opportunities for deeply and meaningful learning were limited.

5. Conclusions

Despite the limitations during the reported hybrid PBL implementation, in an isolated course from a predominantly traditional curriculum, the motivational profile of students from an attributional perspective has been favorable, as the most positive attributes for learning prevail, such as interest and effort and, collaborative interaction with peers.
The weaknesses of student academic profile are frequently the reasons that explain the use of more structured scenarios and process and a higher level of professor control. This has negative effects on the development of critical thinking skills and particularly to the level of application of knowledge to

new situations. However, if these risks are known, faculty could take the challenge of incorporating new elements to their teaching strategies, so that these limitations can be overcome to some extent and it could be possible to achieve improvements in the quality of student learning, as this is the main goal of our role.

References

[1] Hannan, A. & Silver, H. (2005). La innovación en la enseñanza superior. Enseñanza, aprendizaje y culturas institucionales. Madrid: Narcea S. A. de ediciones.
[2] Biggs, J. (2005). Calidad del aprendizaje universitario. Madrid: Narcea S. A. de ediciones.
[3] Entwistle, N. (2000, noviembre). Promoting deep learning through teaching and assessment: conceptual frameworks and educational contexts. Paper presented at Teaching and Learning Research Programme, Leicester, UK.
[4] Fink, F. (2002). Problem-based learning in engineering education: a catalyst for regional industrial development. World Transactions on Engineering and Technology Education, 1(1), 29-32.
[5] De Graaff, E. and Kolmos, A. (2003).Characteristics of problem-based learning. International Journal of Engineering Education, 19(5), 657-662.
[6] Moesby, E. (2006). Implementing project oriented and problem-based learning-POPBL- in institutions or sub-institutions. World Transactions on Engineering and Technology Education, 5(1), 45-52.
[7] Hmelo-Silver, C. (2004). Problem-based learning: what and how do students learn? Educational Psychology Review, 16(3), 235-266.
[8] Morales B. P, Gómez N. V. (2009). Adaptación de la Escala Atribucional de Motivación de Logro de Manassero y Vázquez: incorporación de dimensiones relacionadas al aprendizaje colaborativo. Educación y Educadores, 12(3), 33-52.
[9] Rivas, S.F., Morales Bueno, P. & Saiz, C. (2014). Propiedades psicométricas de la adaptación peruana de la prueba de pensamiento crítico PENCRISAL. Avaliação Psicológica, 13(2), 257-268.
[10] Morales B. P. (2014). Assessment of achievement in problem-solving skills in a General Chemistry course. Journal of Technology and Science Education (JOTSE), 4(4), 260-269.