An analysis on the theoretical foundations and practical applications of the PBL and the PLE methodologies in Engineering Education

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Abstract

Modern day engineering professionals need to master skills and competencies that go beyond technical knowledge, and include collaborative skills for troubleshooting, for technological development and for practices innovation. However, current engineering programs still favor the unidirectional and linear transmission of fragmented content, and as a result, teachers complain that students are less interested in studies and more disrespectful of their authority, while students find themselves insulted by teachers, whose classes they deem to be boring and meaningless. Experiences with PBL (Problem-Based Learning) and PLE (Project-Led Education) methodologies in engineering programs have reportedly been increasing in recent years, with results that seem to raise the future engineers' technical and collaborative skills. However, although the educational potential of both methodologies, literature reveals that it is still very difficult for teachers in general and for those in engineering classrooms in particular to understand why they should give these methodologies a try, and to decide when and how to do it. The purpose of this paper is to analyze the theoretical foundations and practical applications of PBL and PLE methodologies in engineering programs.

Keywords: engineering education; PBL; PLE; engineering teaching and learning

1 Introduction

The expansion of higher education and the growing pressure from the productive sectors for qualified people have increased the demand for a university that facilitates social and economic progress through knowledge generation and dissemination (Faust, 2010).

However, as a general rule, the university as a whole, and engineering programs in particular, are failing to recognize that human action is less related memorization and reproduction, and more connected to prediction and intervention, and to perceive education as the intentional bond between thought and action (Lima, Carvalho, Sousa, Alves, Moreira, Mesquita & Fernandes, 2011).

Broadly speaking, students are not being enabled to look for solutions to existing and emerging problems by means of the dynamic and critical relationship between theory and practice, as engineering programs usually favor the unidirectional and linear transmission of fragmented content (Graham, 2012).

As a result, in classrooms throughout the world, teachers complain that students are less interested in studies and more disrespectful of their authority; students, in their turn, find themselves insulted by teachers, whose classes they deem to be boring and meaningless (Santos & Soares, 2011).

Therefore, universities and engineering programs should re-examine their relationship with knowledge, for this failure in allowing students to internalize the techno-cultural elements for human activity and life improvement has added up to college evasion rates and poor educational quality, with academic, economic and social worldwide damage (Blondel, 2005).

Analysis on successful cases has long revealed that teaching and learning are not separate elements, but constitute a whole structure, marked by mutual interaction, based on dialogue and on the gradual construction of knowledge by teachers and students (Cordeiro, 2006; Masetto, 1997).

In these contexts, teachers obtain better results in the intellectual development and social emancipation of the learners by serving as guides, tutors, promoters of discoveries, encouraging their students to listen and speak, to read and write, and to reflect on the concepts discussed and the activities carried out in classes (Alencar & Fleith, 2004; Carvalho, 2008; Paul & Barbosa, 2008).

Since the mid-70s, the Problem-Based Learning (PBL) methodology has been used in universities and engineering programs as an educational approach, strategy, technique and method by such teachers who, rejecting the post theory exercises, began using topics from students' everyday life to start, focus and motivate meaningful learning (Ribeiro & Mizukami, 2005).

In this methodology (Figure 1), inductive (from practice to theory) non-linear (simultaneous access to multiple knowledge) teaching and active (doing more than just seeing and repeating) learning have reportedly allowed students to tap into interdisciplinary knowledge and to build a broader and more cohesive base of competencies and abilities (Amador, Miles & Peters, 2006).

main features	PBL (*problem-based learning*)
expected results	students must provide explanations or suggestions to authentic situations of the real world
educational approach	a research model with emphasis on diagnosis on contextualized interdisciplinary knowledge
educational curriculum	educational curriculum is organized based on a problem with educational focus
educational design	analysis of the problem in large groups (ten or more members) looking for an answer for 1 or 2 weeks
theory-practice integration	students look for information in order to develop a hypothesis and offer an explanation or suggestion in class, when theory is finally elaborated
teachers' role	act as facilitators of students' doubts and as specialists in classes
students' role	analyze, discuss and generate tasks of learning from the proposed problem

main features	PLE (*project-led education*)
expected results	students must develop new products (materials, artifacts, processes and systems) from a project theme according to the real world
educational approach	a production model with emphasis on practice based on the real world professional environment
educational curriculum	educational curriculum is organized based on support courses that help to implement a solution for proposed project with educational focus on the product
educational design	orking in small groups (maximum 8 members) students plan and develop their projects for 10 or more weeks
theory-practice integration	after elaborating on theories in classes, students devise and develop a product, while managing their projects
teachers' role	act as supervisors of students' projects and as specialists in classes
students' role	analyze, discuss, plan and generate an open solution from the project theme in order to create a product, process or system

Figure 1: main features of PBL and PLE methodologies

Specifically in engineering programs, experiences with the PBL methodology coexist with another methodology that according to literature seems to raise the future engineers' technical and collaborative skills to solve problems, develop technology and generate innovation: the Project-Led Education (PLE) methodology (Weenk & van der Blij, 2011a).

Going beyond the case problems, with small tasks and known answers to known difficulties, that characterize the PBL methodology, the PLE methodology (Figure 1) focuses on creating products, with big tasks and multiple innovative solutions to challenging unknown questions (Weenk & van der Blij, 2011b), and adopts an even more hands-on educational approach, where students, while creating materials, artifacts, processes and systems, closely related to future professional situations, identify, analyze and apply the most suitable theories to develop and manage their projects (Powell & Weenk, 2003).

However, although the educational potential of both methodologies, it is very difficult for teachers in general and for those in engineering classrooms in particular to understand why they should give these methodologies a try, and to decide when and how to do it (Lima, Carvalho, Flores & van Hattum-Janssen, 2007; Prince, 2007).

The purpose of this paper is to analyze the theoretical foundations and practical applications of PBL and PLE methodologies in engineering programs.

2 Methodology

As the research aimed at uncovering the features of the PBL and the PLE methodologies in engineering programs, defining their nature and establishing relationships between the variables that constitute and/or influence them, it characterized a descriptive study (Vergara, 1998).

As method of approach – the more abstract and broader methodological behavior for investigating events (Marconi & Lakatos, 2006) – the study used the inductive method, which constructs or evaluates general propositions that are derived from specific examples (Fachin, 2005).

As method of procedure – the methodological behavior adopted in the more concrete phases of a study (Marconi & Lakatos, 2004) – the research was based on the comparative method, which seeks to investigate things and facts according to their similarities and differences (Fachin, 2005).

As method of investigation – the methodological behavior regarding the way the researcher intervenes in reality (Vergara, 2005) – information was gathered from published, printed, audio and video recordings, photographs, films and online materials, constituting a bibliographic investigation (Fachin, 2005).

From among the different techniques for data collection, this study used documentary research (Marconi & Lakatos, 1990), and, with regard to the techniques for data analysis, both the quantitative – the objective analysis of facts which can be measured and expressed numerically (Gil, 2006) – and the qualitative – the subjective detailed description of observed phenomena (Gil, 2006) – treatments were applied.

The basic instruments used for identification of similarities and differences between the PBL and PLE methodologies were Bloom's Taxonomy (Bloom, 1994) and Kolb's Learning Cycle (Kolb, 1984), which, by showing that information is processed in different ways and timing by people, have contributed to the apprentices' development of technical and interpersonal skills, in line with the new challenges to be overcome by future engineers.

3 Results

The starting point for analyzing the theoretical foundations and practical applications of PBL and PLE methodologies in engineering programs was the comparison of their main characteristics (Figure 2).

In PBL methodology, whose main objective is theoretical elaboration, after the presentation of a problem, students, working in large groups for 1 or 2 weeks, gather information that will allow them to elaborate a hypothesis, which will eventually lead to an explanation or suggestion to overcome the proposed problem.

In PLE methodology, whose main objective is project management, after the presentation of a project theme, students, working in small groups for 10 or more weeks, engage in the theoretical elaboration that characterizes the PBL methodology (information gathering, hypothesis elaboration and explanation or suggestion), which will allow them to create and develop a product to fulfil the proposed project theme.

This comparison led to finding a complementary relationship between PBL the PLE methodologies, in which the former can be seen as part of the latter, insofar as the PBL aims at helping students provide explanations and suggestions to given problems, which are, in turn, key elements to the creation process of new products (objective of the PLE).

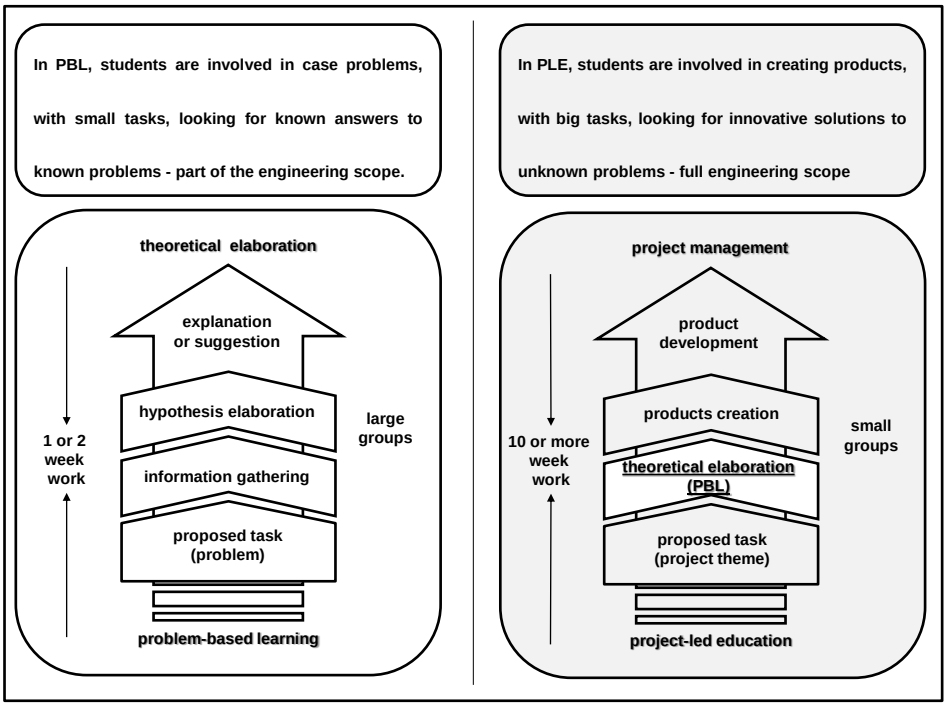

Figure 2 – Comparison between the PBL and the PLE methodologies

The next step was the identification of the learning objectives and phases concerning both methodologies.

With reference to the learning objectives, Bloom's Taxonomy (Bloom, 1994) was inspiring, as it offers a classification for the different learning objectives educators can set, encompassing a more holistic form of education, which allows learners to acquire specific competences from lower (factual) to higher (conceptual) abilities: its cognitive domain (Figure 3) is a model that classifies thinking according to six levels of complexity, depicted as a stairway, whose lowest three levels are knowledge, comprehension, and application, and whose highest levels are analysis, synthesis, and evaluation.

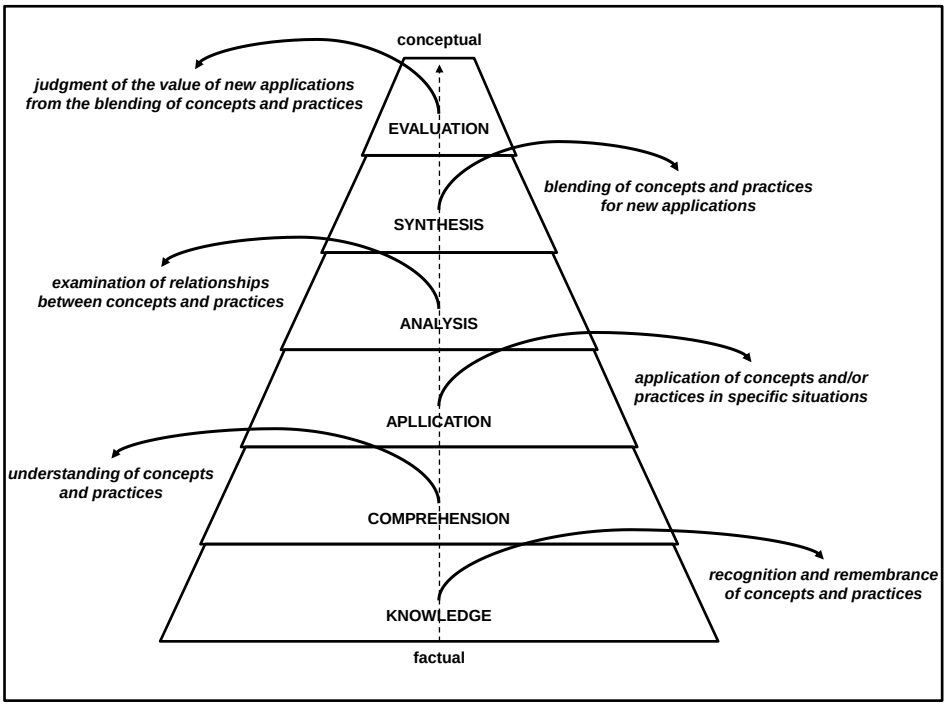

Figure 3 – Bloom's Taxonomy (Based on Bloom, 1994)

Concerning the learning phases, Kolb's Learning Cycle (Kolb, 1984) was influential, since it elaborates on the idea that learning involves the acquisition of abstract concepts in a process whereby knowledge is created through the transformation of experience, in a four stage learning sequence (Figure 4): concrete experience (the contact with real and authentic situations with emphasis on feeling); reflexive observation (the contrast between experience and understanding with emphasis on watching); abstract conceptualization (the distilling of reflexive observation into new concepts and models with emphasis on thinking); and active experimentation (the testing of new concepts or models in real and authentic situations with emphasis on doing).

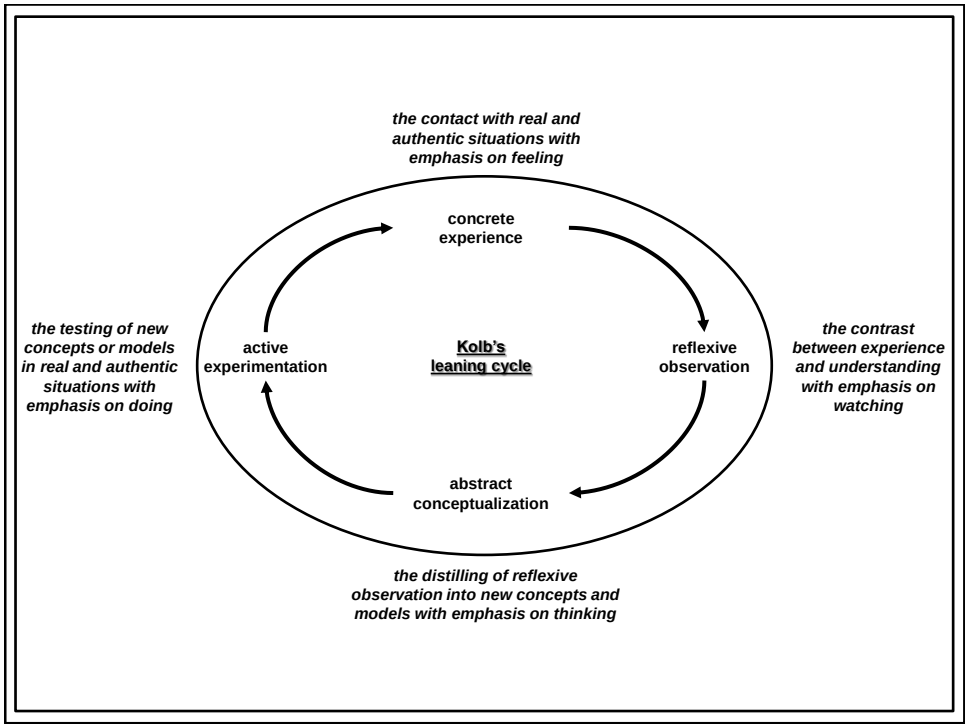

Figure 4 – Kolb's Learning Cycle (Based on Kolb, 1984)

When these two theoretical models were put together and compared (Figure 5), it became clear that they bore a close connection, in which Bloom's six learning objectives could be specifically associated to Kolb's four-step learning cycle:

- Bloom's recognition and remembrance of concepts and practices (knowledge) was directly linked to Kolb's contact with real and authentic situations with emphasis on feeling (concrete experience phase);

- Bloom's understanding of concepts and practices (comprehension) was directly linked to Kolb's contrast between experience and understanding with emphasis on watching (reflexive observation phase);

- Bloom's application of concepts and/or practices in specific situations (application) and examination of relationships between concepts and practices (analysis) were directly linked to Kolb's distilling of reflexive observation into new concepts and models with emphasis on thinking (abstract conceptualization phase);

- Bloom's blending of concepts and practices for new applications (synthesis) and judgment of the value of new applications from the blending of concepts and practices (evaluation) were directly linked to Kolb's testing of new concepts or models in real and authentic situations with emphasis on doing (active experimentation phase).

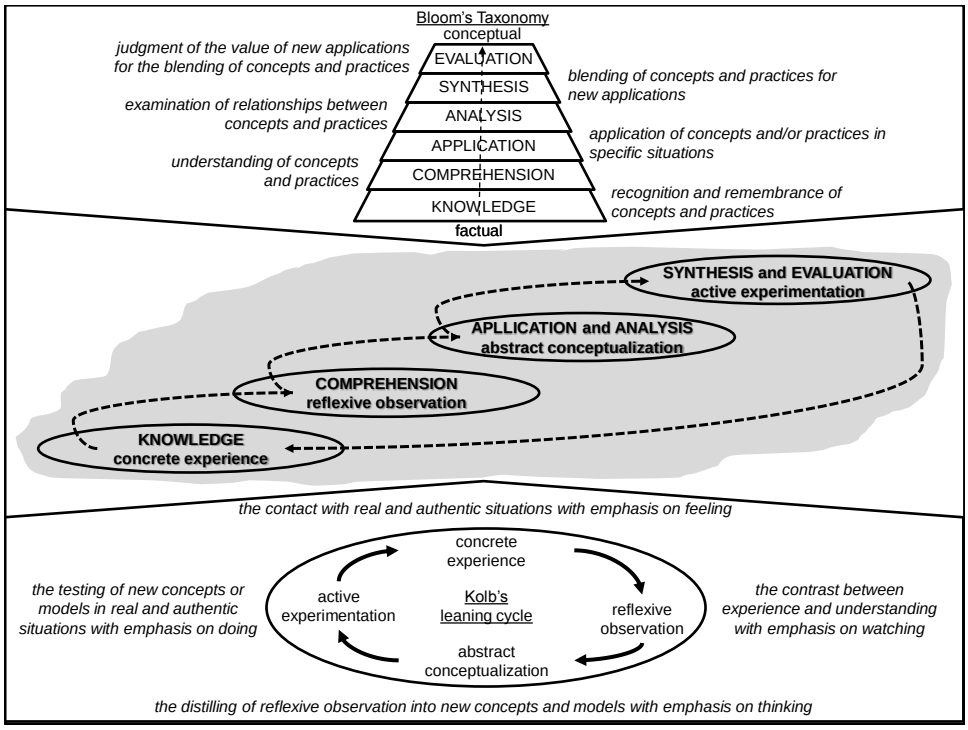

Figure 5 – Bloom's and Kolb's theoretical models close relationship

And this connection became the theoretical tool for the identification of the learning objectives and phases concerning the PBL and the PLE methodologies in engineering programs (Figure 6):

- since explanations or suggestions constitute the expected deliverables of the PBL methodology, it encompasses the first four objectives of Bloom's taxonomy (knowledge, comprehension, application and analysis) and the first three stages of Kolb's Learning Cycle (concrete experience, reflexive observation and abstract conceptualization);

- once the development of a new product is the PLE methodology expected deliverable, it covers all six objectives of Bloom's taxonomy (knowledge, comprehension, application, analysis, synthesis and evaluation) and all four stages of Kolb's Learning Cycle (concrete experience, reflexive observation, abstract conceptualization and active experimentation).

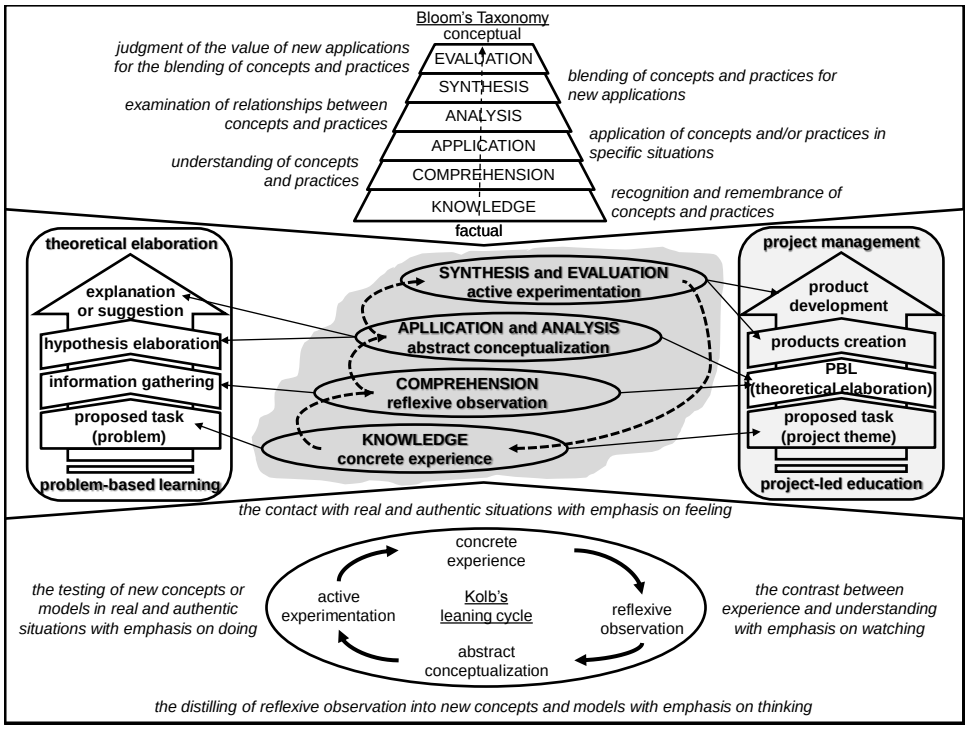

Figure 6 – learning objectives and phases concerning the PBL and the PLE methodologies

Therefore, in light of this connection between the educational elements of Bloom's taxonomy and Kolb's learning cycle, it is possible to argue that the PBL methodology is part of the PLE methodology, since all the elements that constitute the PBL are part of the elements that make up the PLE.

This, however, does not mean to say that one is better than the other; only that they share common elements: the PBL and the PLE methodologies are distinct approaches, with specific objectives, and whose effective application depends on a conscious choice by teachers.

In this sense, if the objective established by the teachers is the interdisciplinary analysis and contextualization of knowledge, the PBL methodology is more appropriate; if teachers have as their objective the practical application of knowledge to develop new products, the PLE methodology is more suitable.

4 Discussion

This paper analyzed the theoretical foundations and practical applications of the PBL and the PLE methodologies in engineering programs.

In face of the examined data, it can be argued that the PBL and the PLE methodologies are distinct complementary methodologies, whose effective practice depends on a conscious choice by teachers: for analysis and contextualization of knowledge, the PBL methodology is more appropriate; for the practical application of knowledge to develop new products, the PLE methodology is more suitable.

References

Alencar, E. M. L. S., & Fleith, D. S. (2004) Inventário de práticas docentes que favorecem a criatividade no ensino superior. Psicologia: Reflexão e Crítica, 17, 105-110.

Amador, J. A., Miles, L, & Peters, C. B. (2006) The practice of problem-based learning: a guide to implementing PBL in college classrooms. New York: John Wiley Professional.

Blondel, D. (2005) Dificuldades, riscos e desafios do século XXI. In: Delors, J. (Org.) A educação para o século XXI: questões e perspectivas. Porto Alegre: Artmed.

Bloom, B. S. (1994) Reflections on the development and use of the taxonomy. In Anderson, L. W., Lauren A. S. (Eds.). Bloom's taxonomy: a forty-year retrospective. Chicago: National Society for the Study of Education.

Carvalho, M. (2008) Ensino superior: reflexões sobre práticas docentes. São Paulo: Musa.
Cordeiro, J. (2006) Didática. São Paulo: Contexto.
Fachin, O. (2005) Fundamentos de metodologia. São Paulo: Saraiva.
Faust, D. G. (2010) The Role of the University in a Changing World. Speeches, June. Available at: <http://www.harvard.edu/president/speech/2010/role-university-changing-world>.
Gil, A. C. (2006) Didática do ensino superior. São Paulo: Atlas.
Graham, R. (2012) Achieving excellence in engineering education: the ingredients of successful change. The Royal Academy of Engineering, March. Available at: <www.raeng.org.uk/change>.
Kolb, D. A. (1984) Experiential learning: experience as the source of learning and development. Englewood Cliffs: Prentice Hall.
Lima, R. M., Carvalho, D., Sousa, R. M. A. S., Alves, A., Moreira, F., Mesquita, D., & Fernandes, S. (2011) PLEE Methodology and Experiences at the University of Twente. In: 3rd International Symposium on Project Approaches in Engineering Education: aligning engineering education with engineering challenges. Lisbon: PAEE.
Lima, R. M., Carvalho, D., Flores, M. A., & van Hattum-Janssen, M. A. (2007) A case study on project led education in engineering: students' and teachers' perceptions. European Journal of Engineering Education, 32(3), 337-347.
Marconi, M. A., & Lakatos, E. M. (1990) Técnicas de pesquisa. São Paulo: Atlas.
Marconi, M. A., & Lakatos, E. M. (2004) Metodologia científica. São Paulo: Atlas.
Marconi, M. A., & Lakatos, E. M. (2006) Metodologia do trabalho científico. São Paulo: Atlas.
Masetto, M. T. (1997) Didática: a aula como centro. São Paulo: FTD.
Paul, J. J., & Barbosa, M. L. O. (2008) Qualidade docente e eficácia escolar. Tempo Social, 20, 119-133.
Powell, P. C., & Weenk, G. W. H. (2003) Project-led engineering education. Utrecht: Lema Publishers.
Prince, M. (2004) Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223-231.
Ribeiro, L. R. C., & Mizukami, M. G. (2005) An experiment with PBL in higher education as appraised by the teacher and students. Interface, 9(17), 357-368.
Santos, C. P., & Soares, S. R. (2011) Aprendizagem e relação professor-aluno na universidade: duas faces de uma mesma moeda. Est. Aval. Educ., 49, 353-370.
Vergara, S.C. (1998) Projetos e relatórios de pesquisa em Administração. São Paulo: Atlas.
Vergara, S.C. (2005) Métodos de pesquisa em Administração. São Paulo: Atlas.
Weenk, W., & van Der Blij, M. B. (2011a) PLEE Methodology and Experiences at the University of Twente. In: 3rd International Symposium on Project Approaches in Engineering Education: aligning engineering education with engineering challenges. Lisbon: PAEE.
Weenk, W., & van Der Blij, M. B. (2011b) Tutors and teachers in project-led engineering education: a plea for PLEE tutor training. In: 3rd International Symposium on Project Approaches in Engineering Education: aligning engineering education with engineering challenges. Lisbon: PAEE.