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PBL and Engineering Curriculum Change in Latin America: 10 examples and the lessons learned

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Abstract

In the spring of 2016, the Aalborg Centre for PBL in Engineering Science and Sustainability, under the auspices of UNESCO at Aalborg University (Denmark), took the initiative to collect and compile examples of PBL cases implemented in engineering education in Latin America. To fulfil this purpose, the Aalborg UNESCO Centre joined forces with three universities from Colombia: Universidad Nacional de Colombia, Universidad de Los Andes, and Universidad del Valle. The aim is to: i) compile and describe PBL models implemented in engineering education in Latin America, ii) summarise underlying learning principles, and iii) reflect upon challenges and drivers of the curriculum change towards PBL. The project also provides examples and inspiration for the engineering education community who envision changing their curriculum and implementing more student-centred learning approaches in engineering programs. The procedure for collecting the PBL cases follows five steps: i) create guidelines for case descriptions and selection; ii) call for abstracts; iii) select abstracts based on pre-defined criteria in the guidelines; iv) submit full chapters for peer review; and v) compile and publish them in book format. The book compiles 10 cases of PBL in engineering education from Brazil, Colombia, Puerto Rico, Chile, Peru and Costa Rica. In this paper, we summarise the main lessons drawn from the PBL cases and their implementation in Latin America, anticipating the content of the book.

Keywords: Problem-Based Learning, Project-Based Learning, Latin-America engineering education

Type of contribution: Best practice paper

1 Introduction

In recent decades, engineering education institutions have been putting considerable effort into revising their curricula. One of the purposes is to develop the skills required by the profession to perform in global contexts and meet market, customer and social demands (National Academy of Engineering, 2004; UNESCO, 2010). As an example, the accreditation boards refer to critical thinking, communication, problem-solving and teamwork as part of their criteria for quality assurance of engineering programmes (ABET, 2015; Gnaur, Svidt and Thygesen, 2015).

Similarly to other parts of the world (De Graaff and Kolmos, 2007; Du, De Graaff and Kolmos, 2009), Latin American countries have been changing their curricula by implementing active, student-centred learning approaches, such as problem-based, project-organized learning (PBL) (e.g. PAEE, 2017). PBL is an innovative learning methodology in which a team of students learn by solving real problems. By doing so, students select, learn and apply new knowledge, and develop collaborative, communication and self-directed learning skills.

PBL can be defined in terms of three dimensions which encompass its core principles: i) the learning dimension, ii) the content dimension, and iii) the social dimension. The learning dimension involves organising the process around real problems carried out in projects, which contextualises students' learning. On the content dimension, learning is interdisciplinary (i.e. traditional subject boundaries are expanded, and students integrate knowledge from different disciplinary fields), is exemplary (i.e. activities performed are examples of the curriculum's overall objectives), and it emphasise the relationship between theory and practice (i.e., students apply theoretical knowledge and research methodologies in real contexts and practice). On the last, the social dimension, PBL is teamwork-focused and collaborative, and students collectively decide what activities to carry out (Kolmos, Graaff and Du, 2009).

The literature shows many examples of PBL implementation sharing these fundamental learning principles. Nevertheless, each PBL model is unique because it is designed and implemented in, and for, specific contexts (e.g. institutions, groups of students and educators, and programmes). It takes into consideration the discipline, institutional and country cultures, resources, learning objectives, facilities, academic staff and assessment. It is necessary to revise the curriculum to implement PBL, and it is important to have the knowledge, resources and inspiration to start and carry out these processes. Perhaps inspiration is the main purpose for gathering PBL cases and compiling them into a book, which illustrates how some institutions design and implement PBL. The book will be published in July of 2017 as part of the 6th International Research Symposium on PBL (IRSPBL2017) activities.

This paper anticipates the book's formal presentation and provides a sneak peek at PBL models implemented in Latin America and the lessons learned. We start by providing the context and initial process to gather the cases (section 2), followed by the learned lessons (section 3). We finish the paper by making final recommendations.

2 Setting the stage: From vision to case examples collection

The vision for compiling and publishing PBL cases in Latin America emerges from the need to provide engineering educators with examples of curriculum change and innovation. The overall aim of curriculum change and PBL implementation is to develop engineering education and qualify future engineers for the work force by helping them develop skills needed for professional practice. Finding Latin American authors who have been implementing PBL in engineering education was the point of departure to identify PBL models. To do so, we started by doing a search of publications on related themes, resulting in a list of 60 references and, consequently, authors, who also took a scholarly approach to curriculum change. In this section, we describe the process where we define criteria and guidelines based on vision and goals (subsection 2.1), and identify and gather the PBL case examples (subsection 2.2).

2.1 Organisation and guidelines

We start by defining criteria and guidelines to identify and describe PBL cases. In a two page document, we stated: i) the overall goal of the book, ii) its organisation and guidelines, iii) its format, iv) criteria for submissions and the review process, v) deadlines, and vi) target audience. This document not only provides a share understating of how the process has been carried out but also what content the cases should cover. Consequently, this document was used as a guideline and sent in the call for extended abstracts.

The guidelines started by being inspired by the PBL curriculum elements in Kolmos *et al.* (2009) (see Figure 1). All these elements are elementary in a curriculum and must be aligned. They also provide a holistic understanding of the curriculum, and if one element changes, it will affect all the others.

Figure 1: PBL alignment of elements in the curriculum (adapted from Kolmos *et al.*, 2009, p. 15)

Furthermore, the contributions should not only give a description of the PBL model and its elements but also a story of how the change process has been triggered, the type of challenges faced, and how they were managed. Therefore, we add drivers for change, implementation process and challenges, future perspectives and visions to the guidelines. In sum, the guidelines for authors are as follows:

- Drivers for change
- PBL model and elements of curriculum
- Implementation process and challenges
- Future perspectives and visions

We also encouraged authors to use their experiences, bring testimonies of people involved in the process of change, and refer to previous work.

By using these guidelines, we identify and gather examples that tell the story of the change process and its contextual, complex and dynamic nature. The guidelines also make the process of selection and review more transparent. In the following, we describe the process of gathering the PBL case examples.

2.2 Collecting PBL cases from Latin America

Once the guidelines document was prepared, we proceeded to the identification and collection of PBL cases. The process includes the following steps: i) identification of PBL cases in the literature (approximately 60 potential cases gathered through literature search), ii) call for contributions as extended abstracts, iii) review of abstracts (where primary criteria for selection was PBL and engineering education), iv) call for full chapters of the selected abstracts, v) review of full chapters (where primary criteria are the points given in the

guidelines) involving experts in PBL, and vi) compilation of selected chapters for the book's publication. Figure 2 shows the process from identification, selection and gathering of PBL cases.

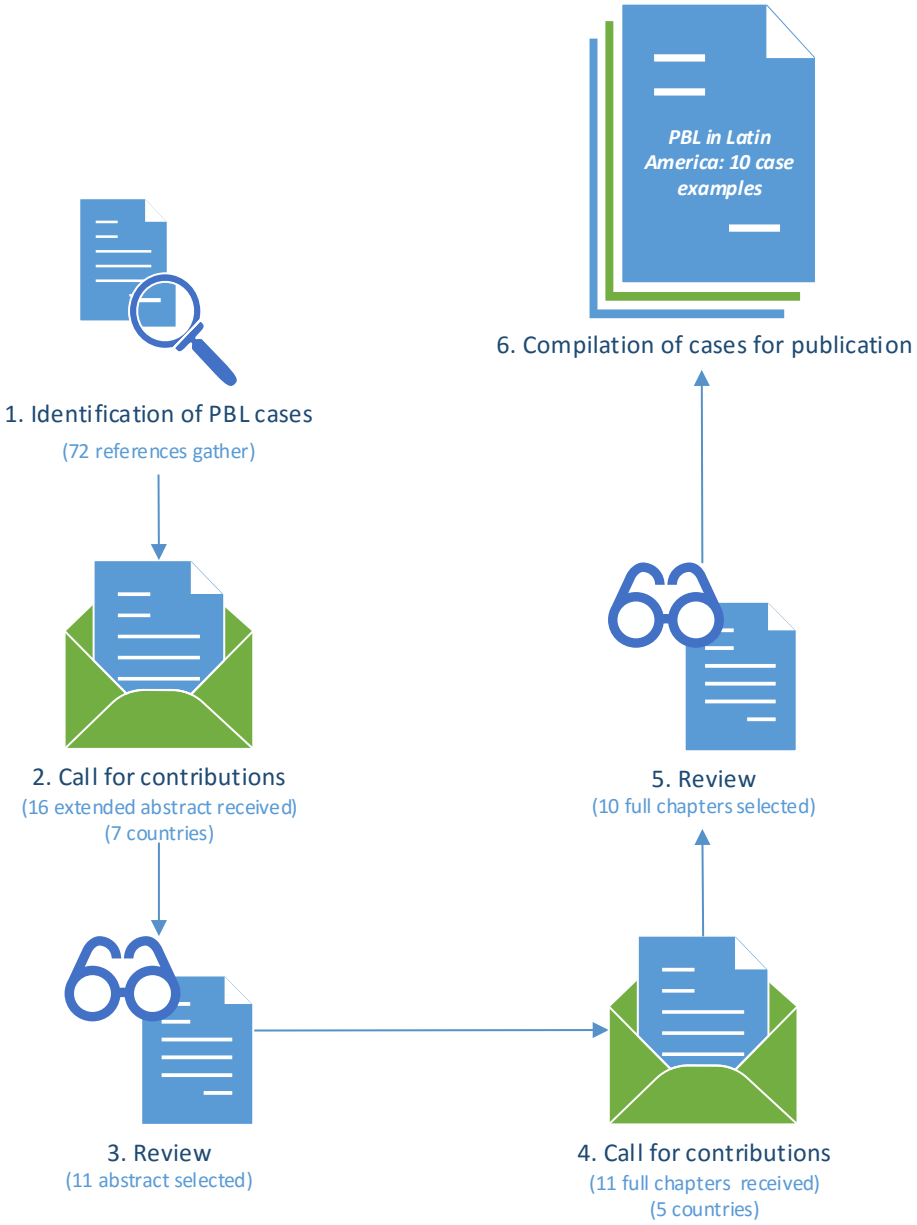

Figure 2: Scheme of process of Latin America PBL cases identification and gathering

This process resulted in ten PBL cases from Latin America, namely from Brazil, Chile, Colombia, Peru and Costa Rica.

3 Lessons drawn

This section summarises the selected PBL cases in Latin America, referring to aspects such as drivers and strategies to change, a variation of PBL models and the challenges reported during the implementation process. As stated above, ten cases of PBL implementation in engineering education from five countries among Latin America were collected: four from Brazil, one from Chile, three from Colombia, one from Costa

Rica and one from Peru. All cases present different approaches to PBL and describe students' learning through curriculum and learning activities in engineering undergraduate programmes. Table 1 summarises the selected cases of PBL in five Latin American countries.

Table 1: Summary of PBL cases

COUNTRY*	INSTITUTION	PBL IMPLEMENTATION	CODE NAME
Brazil	Universidade Virtual do Estado de São Paulo - Universidade de São Paulo	Institution Level	UNIVESP-USP
	Universidade de Brasília	Course Level	UNB-1
		Course Level	UNB-2
	Universidade de São Paulo	Program Level	USP
Chile	Universidad de Los Andes	Course Level	Uniandes
Colombia	Pontificia Universidad Javeriana	Program Level	PUJ
	Universidad de los Andes	Course Level	UNIANDES
	Universidad Pedagógica y Tecnológica de Colombia - Universidad del Valle	Course Level	UPTC-UV
Costa Rica	Universidad Nacional	Program Level	UNA
Peru	Universidad de Piura	Program Level	UDEP

*By alphabetic order

3.1 Main drivers and strategies to change

The major issue taken up in this subsection is to show the common drivers for ten PBL cases and to provide an understanding of all different elements that motivated change, type of implementation and which existing educational model (PBL or not) served as the basis for the curriculum change. At first glance, the curriculum change is observed from many different angles because various institutions use PBL principles with different purposes and approaches. The process of change from a traditional curriculum into a student-centred curriculum is a demanding task. Also, it is a comprehensive process aiming to address social demands and enhance knowledge, lifelong learning skills and competencies. Regardless of the process, each subject (i.e. institution, program or course) utilising PBL principles has its history to tell.

Brazil in recent years has invested in computer resources and computers for teaching. Also, the investment in innovation and research has been growing from 2001 and with impacts on education (Calmanovici, 2011; OECD, 2015). The new resources in the classroom promote alternative ways of pursuing educational goals and enhance collaborative learning (Abreu *et al.*, 2011; Araújo *et al.*, 2015). There is also a concern to strengthen professional skills (Roberto and Ribeiro, 2008; Siqueira-Batista and Siqueira-Batista, 2009).

In the Brazilian context, the UNIVESP-USP and UNB universities have experience in working with different active learning strategies. The UNIVESP-USP is a public higher education institution (the first Brazilian university that is exclusively virtual) based on a didactic-pedagogical model focused on active learning and problem-solving approaches. The UNB, the Federal University of Brasilia, is built with the promise of reinventing higher education in Brazil and presents two particular cases: The first is the undergraduate Production Engineering program, which implemented a PBL model with solutions through projects. The

second is an undergraduate Mechanical Engineering course called "Integrating Projects" with an emphasis on interdisciplinary projects. Finally, the undergraduate Civil Engineering program at the USP adopted PBL combined with the use of distance-learning platforms as a pedagogical strategy. All of these universities agree that the PBL model is an educational approach that allows developing a set of skills and competencies through the educational process.

Two national programs have had an impact on educational change in Chile. In 1998 a program to improve the quality and equality of education in Chile, MECESUP, was conceived. With this program, many universities could get funds for academic innovation. The Clover Engineering 2030 program is a joint project of the *Pontificia Universidad Católica de Chile* and the *Universidad Técnica Federico Santa María*. The Chilean universities began the initiatives in 2014 (see for example, Graham, 2016; INGENIERIA 2030, 2017).

Since 2012, the Faculty of Engineering and Applied Sciences of UANDES in Chile has been developing a systematic change in teaching-learning methodologies for engineering education. The combination of PBL and JITT (i.e. Just-in- Time Teaching) in two courses (e.g. programming and databases) has proved to be an excellent way to improve course's grades, increase student's motivation and participation, and support students' independent work outside the classroom. It is important to highlight the reduction in using the institutions' main resources (e.g. infrastructure and teachers' time) due to the participation of institutional authorities in the methodological intervention process.

In Colombia during the first decade of the 2000s, there were problems with the training of engineers related to educational level, high repetition rates in basic science courses, dropout and a low number of new students because of the low level of secondary school graduates. There were also a small number of Ph.D. graduates. Only in 2008, 3.7% had a PhD degree, so not very much research could be expected (Peña-Reyes, 2011). In this decade there were governmental and private initiatives to evaluate the competencies of graduates who have motivated academic innovation (Rodríguez, Peña and Peña-Reyes, 2015). In 2006, the Visión 2032 was created in order to improve the competitiveness and development of the country with participation of government, companies and industrial sectors including guilds and workers (Consejo Privado de Competitividad, 2007). In addition, since 2006, high school students in the PISA international have been showing a deficiency in critical thinking and competencies in solving real problems. Therefore, combined efforts to improve secondary and tertiary education were created. The ministry created committees, and with the spirit of being the most educated in Latin America in 2025 at all levels. I also raised funds to improve the quality of education, accreditation, and participation in the industry (Ministerio de Educación Nacional, 2013, 2015, 2016). Although they have been approached with different initiatives, the educational problems of the decade of 2000-2009 persist, and it is necessary to deepen in the actions that must be followed (CPC, 2014).

In Colombia, the Universidad Pedagógica y Tecnológica and the Universidad del Valle (UPTC-UV universities) have been working together with the objective to implement a PBL model as an "add-on" strategy in a traditional curriculum. It is exemplified with courses in Automatic Control Systems in both universities. At the Pontificia Universidad Javeriana (PUJ) there was a curricular reform to foster skills and competencies in undergraduate students. PBL is implemented in the course of digital systems in Electronic Engineering, where students solve problems through product development cycle. The UNIANDES presents a particular case of PBL implementation in a graduate program (i.e. Master of Education) focused on the integration of Science, Technology, Engineering and Mathematics (known as STEM).

In Costa Rica, the initiatives to improve education seek to provide graduates with competencies relevant to the industrial reality of the national context (Rivera, Chotto and Salazar, 2014). Cases such as the pedagogical

model of the *Universidad Nacional de Costa Rica* have opened up, and encouraged academic innovation. Its model was born in 2004 and is based on the results of the UNESCO World Conference in 1998 on education (Contreras *et al.*, 2013). The pedagogical model included aspects such as the need for training in skills and sustainability. In 1998, there were also initiatives to incorporate information technologies into the *Tecnológico de Costa Rica* **(**TEC). However, in 2007, those initiatives were reformulated with the purpose of incorporating changes in educational policies and expanding the academic offerings, in order to improve process competencies, relationships between teachers and students and administrative processes (Garita and Chacon-Rivas, 2012).

Since 2006, the Universidad Nacional de Costa Rica (UNA) has been developing a bottom-up strategy to implement a PBL model in Systems Engineering courses. At UNA, the aims are closing the gap between industry and academy, promoting more practical classes, and development of transversal and technical skills. This example highlights the importance of involving the faculty in the processes of change to encourage more inclusive and participatory work.

The *Consejo Nacional de Educación* in Perú proposed the *Proyecto Educativo Nacional* (PEN, or National Education Project) for education with the aim of meeting the demands of society, development of the country and the inhabitants. It was approved in 2007 and focuses on access, equal opportunities and quality (Consejo Nacional de Educación, 2005, 2007). In 2008 the Ministry introduced the program "Un laptop per niño" (One laptop per child) for students and teachers in primary and rural schools. These programs have not been effective in meeting the PEN goals (Ames 2016). Its subsequent efforts have focused on rural access to education. The low student performance on international tests in the area of science and the lack of computer skills have motivated different teachers to pursue academic innovation (e.g. Cueto et. al (2016). Therefore, from the *Ministerio de Educación* (Ministry of Education) of Peru, emergent initiatives such the program "*Enseña Perú*" with the participation of several universities and the program Construyendo Escuelas Exitosas have been implemented (Castro-Carlín and Lavado-Padilla, 2016; Enseña Perú, 2017).

The *Universidad de Piura* (UDEP), in Peru, has been using a PBL model for nine years in the chemistry courses, which have been assessed by students and professors. The results show increased motivation and student involvement that arguably is attributable to students taking responsibility for their learning. The teachers' participation and training are decisive factors for achieving a sustainable PBL model.

In sum, the above-mentioned examples and the main drivers to change are inserted in a wider context and reflect efforts and initiatives to potentiate the countries' human capital by implementing new educational approaches, tools and development of skills. Furthermore, the examples also present different responses to curriculum change.

Kolmos *et al.* (Kolmos, Hadgraft and Holgaard, 2016) refer to three curriculum change responses and strategies. They are: (i) add-on strategy characterised by course level changes, (ii) integration strategy characterised, mainly, at the program level, and (iii) re-building strategy characterised as systemic change at the institutional level. Frequently, course level changes are initiated by academic staff while changes at the programme and institutional level have their point of the department on middle and top management. The add-on strategy is a component strategy that adds or modifies elements without disturbing the existing structure. The integration strategy goes one-step further by mapping and coordinating various courses and integrating different aspects in the curriculum structure of the entire academic program. The re-building strategy corresponds to a new kind of emerging university with strong institutional support. Based on the above, there are cases representing all levels of change, where PBL implementation at the course and programme levels are the dominate ones. That indicates the existent of highly motivated academic staff in

improving their teaching practices, who also take a scholarship approach to curriculum reform by evaluating the outcomes and impacts of change implemented.

3.2 Variation of PBL models and practices

Like any other learning environment, PBL is a complex and dynamic one with actors (e.g. academic staff, students), structures (e.g. curriculum, facilities) and frameworks (e.g. content and assessment). PBL practices and models exist in different areas of education, contexts, countries and cultures (De Graaff and Kolmos, 2007). Even though the cases used the same guidelines and overall structure (see section 2.1), there is a variety of PBL models developed and practised. This variation results from the interplay of the different elements of the curriculum such as the type of problems, resources and time allocated, role of teacher, learning spaces, and institutional/ country culture. For example, the UDEP case presents an active hybrid approach, where PBL is combined with pre-designed learning activities to replace lectures. The USP case implements PBL along with distance-learning platforms as a pedagogical strategy. The PUJ case uses role-play as an activity within the PBL approach. The Uniandes case combined the Just-in-Time Teaching (JiTT) methodology with PBL, and finally, the cases from UNIVEST, UPTC-UV, UNIANDES, UNB and UNA describe the use of the Project-Oriented Problem-Based Learning as an “add-on” strategy in a traditional curriculum. Also, in most Latin American cases the contributors emphasise project organisation of PBL and not so much in the problem orientation. However, this is closely related to disciplinary and professional traditions of the engineering and architecture practices.

In this way, each one of these PBL cases is unique even though in earlier stages inspiration and knowledge are gathered from established models such as the ones from McMaster University, Maastricht University, University of Minho and Aalborg University.

3.3 Challenges to overcome

The process of change usually involves different strategies and levels at the institution and it is not absent of challenges. The cases have mentioned the following as the most common challenges when implementing PBL:

- Developing learning activities with PBL principles implies a new curricular conception, and changing the paradigm of the traditional educational model is sometimes a challenge. If the curriculum is part of a rigid system, then trying to make a change in the curriculum structure of an academic program is a difficult task to achieve.
- Motivating change of pedagogical activities in professors is a challenge that all universities must overcome. No matter the type of educational approach, the professor must be continually improving their teaching skills.
- The process of change must include students; otherwise, there is a risk of failure in teaching-learning activities. The student is the main actor in the PBL model.

Institutional support is important for any process of change and a key element for a successful implementation of the PBL. Also, it is up to the institution to nurture and support these pioneering changes to achieve educational innovation.

4 Final remarks

In the above, we briefly present and summarise ten cases of curriculum change and PBL implementation in Latin America. The overall aim is to implement a student-centred curriculum and active learning activities capable of fostering the skills needed for professional practice, increasing students' motivation and lowering dropout rates. The cases presented use mainly problem oriented, project-organized learning strategies implemented at course, programme and institutional levels. They provide examples of add-on, integrated and re-building strategies.

The cases were described regarding drivers for change, PBL model (e.g. learning objectives, assessment, teacher & student roles, facilities and progression) and learning process, challenges and future perspectives. Moreover, even though a common frame is used, the cases show a variety of PBL models emerging from different drivers, available resources, contexts and countries. Each model is uniquely linked by a common vision of what education should be (e.g. student centred) and to what end (e.g. to prepare students for professional practice as best as possible). In this sense, designing and implementing PBL does not take a "copy paste" approach, but rather a social construction approach where a knowledge of PBL theory, context culture, structures, resources and actors involved are needed, and the existent models are used as examples to collect knowledge and inspiration for change. The change process also requires time and is not absent of challenges. In this sense, knowledge sharing and multinational collaborations, institutional and governmental support, staff training and evidence-based evaluations are important factors to overcome the challenges countered.

Unfortunately, we could not elaborate more on what each specific case presents; however, these will be fully compiled and published along with the 6th International Research Symposium on PBL, in Bogotá (Colombia). Moreover, we hope that these examples inspire the wider engineering educators and teachers' community to develop engineering education and educate the next generation of engineers for Latin America and contribute to countries' development and growth.

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