

Teaching Problem-Based Learning to engineering interdisciplinary graduate students

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Abstract

Like worldwide, at the Universidad Nacional de Colombia, by the Direction of the Engineering Faculty, there is a growing interest in modifying the traditional lectured-based teaching model. A PBL course was designed to encourage problem-based learning (PBL), and to improve teaching practices within graduate students. In the PBL course participated students who were teaching assistant at the engineering program. Often, graduate students have their pedagogical training by imitation due to their formation process; therefore, they don't have pedagogical knowledge. The course was organised in two parts: the first one focused on issues about learning and philosophical theories of learning as a teaching model, using lectures and workshops. The second part was to learn PBL using the PBL model to do so. The 64-hour course was done in the second half of 2015. It had the participation of 24 graduate students, between different disciplines of engineering. After students had been training, we collected student views from both, PBL course program and the importance of PBL as a method for undergraduate students learning. The results were analysed by qualitative methods.

Keywords: Curriculum design; Problem-based learning; Inter-disciplinarily; Engineering Education.

1 Introduction

Nowadays around the world, the traditional educational systems do not respond to emerging demands from the workplaces. There is a general clamour about knowledge and skills for demanding performance at work. There are a substantial number of government initiatives to change the old methods to teach or learn for more innovative and efficient ones to fit social requirements. Some universities are implementing new models or incentive the change. Also in Colombia, there is a growing interest to get better indicators in education. At Universidad Nacional the Colombia, there are some initiatives concerns with curricular change. Currently, some teachers are exploring new models because many options are ranging from IT tools to active learning approaches. We try to explore with PBL because it could fill many of the expectations from graduates (Kolmos & Graaff, 2007; Prince & Felder, 2006). In this work, we explore some student's perceptions about the PBL initiative in engineering at Universidad Nacional in Bogotá.

2 Educational context

At the European Unión, the European Commission 2010 began an initiative to promote innovation and transversal skills Hoidn & Kärkkäinen (2014). The council takes action plans of UE and roadmaps in which priorities are set for cooperation between the Member States and the Commission (CE, 2015a). To improve economic growth as one of the key elements that it has set is develops necessary skills to have success in the labour market, with a policy of clear objectives through 2020 (ET-2020, 2013). In the December 2014 meeting, it was established that the venture requires the development of a set of skills that need to be addressed at all levels of education and training. Also, education ministers of the participating countries in this Commission pointed the importance to strengthening the links between education and the business world (CE, 2015b).

Like in Europe, the US government calls for change to prepare for the challenges of the 21st century and created organisations like the 'New Commission on the Skills of the American Workforce'. In Japan, the Ministry of Education, Culture, Sports, Science, and Technology uses funds for projects that encourage experimentation

on technological innovation and learning in Higher Education. In the year 2004 in Australia, the Australian Council for Teaching and Learning was established to improve the quality of Higher Education and practice with awards, scholarships, and grants. In Germany, across of the national contest for Excellence in Teaching is a newly introduced subsidy program that recognises and supports innovative teaching in education. In France, in 2008, the education reform includes a plan to encourage innovation in undergraduate teaching (Hoidn & Kärkkäinen, 2014).

As is said in the McKinsey report about the worldwide graduate educational problems, there is a significant lack of talent in the graduates (Mourshed, Farrell, & Barton, 2012). In 2014, in Colombia, 57 % of companies reported having difficulty finding required talent, but 35 % in 2010 (CPC, 2014). Mainly there is a lack of expertise, lack of education and lack of certifications and experience. The competencies require for more companies are handling technological tools, capacity for analysis and decision making, oral and written expression, math skills and second language. As for attitudes, companies report needing for staff emotional intelligence and teamwork, ethical sense, service orientation and achievement, adaptability, creativity and efficiency (Manpowergroup, 2014).

There is an awareness on improving the Colombian educational system. With the 2034 vision of a flexible system of HE, academic quality and vocational training, the proposal for education reform began with difficulties in 2011, to change the actual education law. This process started with strengths and had to be rethought. Reflexion meetings with roundtables, forums, debates, etc., took place in 2012. It worked on several proposals: quality, coverage, equity, relevance, sustainability, autonomy, internationalisation, inclusion and diversity (MEM, 2013). It was recommended to improve tertiary education in many ways. But one could be to invest in innovation and programs. Likewise, it should create a program of evaluation of qualifications to review in broad the graduate skills needed (CPC, 2014, p. 34). But there are some difficulties.

Most university systems are based on the Humboldtian tradition, which emphasises the freedom of research and teaching. At first, universities were administered by teachers with strong autonomy and independence, though it has been lost as time has passed by and it has given space to the neoliberal ideas of postmodernism which has taken the power of the university's management, and has altered patterns of university education. The student is seen as a customer and the teacher as a tool to produce and use resources efficiently. Thus, decisions are not taken from the teachers, but from staff members, at high levels of the organisation, affecting the program's evaluation, in favour of the sovereignty of these clients (Bellah, 1999 cited by ; Levine, 2000).

As a consequence, they are focused on strengthening the quality of teachers in some cases and in others to allow lower academic performance. Change efforts on the educational model have been difficult to implement and many teachers do not want to betray the old model, as indicated Pritchard (2004) in relationship to the German ideas about Humboldt.

Therefore, educational policies should be continually reviewed and reflect on the university management or adapt this to new approaches or models of teaching. Social requirements indicate that efforts to improve education at all levels must be from teachers and university staff, schools, government policies and society, including businesses and also various groups and associations, who should be part of the efforts and change strategies. There is growing interest in taking new actions.

Harvard University, in 2011 received a donation of \$40 million to support excellence and innovation in teaching and learning. This grant was motivated by the need for new methods to make a better and efficient Higher Education for this generation (Walsh, 2011). In its 2014 report (cit. HILT, 2014), some of the most exciting projects have involved multiple generations of students, graduates, doctoral and staff members with student-centered methods. The innovation projects for teaching-centered learning have shown fewer experiences and shorter conclusions.

The Stanford University has made profound changes in the curriculum models. In 2007, the Business School changed its curriculum to a much more customizable, more global and deeper regarding intellectual experiences (Stanford Business School, 2006).

The Olin College of Engineering was founded since 1997 with the idea of training engineers differently. The learning experience occurs through independent study group, led by students, teachers or staff members and also in competitions or clubs. Its orientation is to promote technical innovation through a less structural curriculum or different to traditional and giving real authentic spaces from young students (Olin College of Engineering, 2015).

The MIT, is worried about change its educational model. The initiative for future of education proposed an online survey to determine how it should be that education. In its 2014 report determined among other things that should be expanding the use of different methodologies such as PBL and Flipped classroom projects and an inclusion of a flexible curriculum, and study new approaches to assessing students (MIT, 2014). Also on interdisciplinary approaches, creating a 'synergy' between different institutions; build learning communities designed to help students establish pathways engagement between the university and the world.

The University of Berkeley in California also has a program called Instructional Improvement Grants 2015-2016 to strengthen academic innovation. It focuses on multidisciplinary, project-changing education involving social services, improving diversity, foster teamwork, active learning, and participation in acquiring the skills of literacy or to improve assessment (UCLA, 2015).

In the UK, the University of Cambridge has a fund to finance programs for implementing innovative practices in teaching and learning. Its focus is on creative or exploratory projects. Additionally, it provides strong support for personal, professional and career of all members by its mission and core values. To achieve this supports people in the ongoing development of a variety of academic skills and training (University of Cambridge, 2015).

Aalto University in Helsinki was founded in 2010 with a multi-disciplinary approach. Combines science, art, technology, and business to create solutions to meet the greatest challenges faced by society through high-quality research and pioneer education (Aalto, 2015).

The 'Pohang University of Science and Technology was founded in 1986 in South Korea. The main idea is providing a student-centered education in a highly collaborative community that encourages students to work in close collaboration (POSTECH, 2015). This university is financially supported mostly by Folco, the largest steel industry in South Korea. By 2012, was leading of the group of best new universities (Adams, 2012)

The Hong Kong University of Science and Technology, founded in 1991 is the third in the same scale. The global plan 2011-2016 has as main initiatives, including flexible programs, strengthen the internationalisation and interdisciplinary, service, personal development and related skills (HKUST, 2015).

Problem-based learning and its variations are methodologies that truly responds to these needs change. The main characteristic can be found in Graaff and Kolmos (2003). It could be an extensive review of the effectiveness of the models of PBL, but these are outside the scope of this study. For historical reasons of implementation, there are numerous review papers in the area of medicine and health, so there are contradictory conclusions. For instance, there are reviewed papers such as Colliver (2000), Norman and Schmidt (2010)), and other with a more center position as Wilder (2015) indicating that there is not strong evidence of effectiveness in changing this model, but interestingly, these same studies also fail to demonstrate that traditional methods are better than PBL. Also, in contrast, other authors like Enarson & Cariaga-Lo (2001), Sungur & Tekkaya (2006); Polyzois et al. (2010) have found advantages in the use of these methods.

However, in the case of engineering, there are many study cases about courses, research, and reports indicate that despite, the difficulties of implementing this student-centered methodology, there are advantages that justify it. For instance, Galand et al. (2012) report about the promotion of soft skills. For Prince and Felder (2006) inductive methods such as PBL, have a cumulative evidence in favour and these are supported by theories of learning, cognitive and social constructivism, Neuro-medicine and empirical findings. Also, help raise intellectual development, thoughts, analysis and learning skills for engineering and science. For De Graaff and Kolmos (2007) with PBL students achieve cognitive skills such as metacognition, critical thinking and problem solving. The effectiveness of PBL also indirectly demonstrated by the decrease in desertion rates, the motivation given, in accentuating the institutional profile and help with the development of competencies (Kolmos & Graaff, 2007).

To move from traditional to PBL, this kind of research results aren't enough to argument changing to PBL. It needs to have complementary studies about PBL effectiveness. Changing to PBL implies some strategies, from the staff level or the low level (Kolmos & Graaff, 2007). In this sense, and to become to empower people, the faculty of engineering design and open a course for training graduate students in PBL.

The initiative was planned during the first half of 2015 and implemented a course for teaching PBL for master and Ph.D. students of postgraduate engineering programs. This course had four credits and was called "Introduction to Problem-Based Learning in Engineering and Technology". The program can be consulted in Daza (2015). The course was an excellent opportunity to capture thoughts about PBL from graduates. So the feedback from the course includes a particular aspect about the PBL as a method for engineering courses.

3 Research question

One of the key aspects to improve educational changes is to think about the course content and understand PBL relevance to fill out the lack of skills in graduate students. Graduate student can be reflective about how their learning was, in relationship with their self-experiences in work. It is because all of the students in this course were working and studying at the same time. After learning how PBL operates, their opinions receive higher importance because necessary they compare the old tradition with the new one. In this sense, the research question is What is the graduate student's views about problem-based learning?

The course was an excellent opportunity to capture thoughts about PBL from graduates. So the feedback from the course includes a special aspect about the PBL as a method for engineering courses.

4 Course description

Detail of this past two months course for interdisciplinary master students is shown in Table 1. The course name is "Problem-based Learning for engineering and technology" and was given at Bogota Campus.

Table 1 Course description

Issue	Description
Teachers	A teacher expert in pedagogy, as course coordinator . A consultant teacher for educational theories and philosophy. An engineering teacher, with knowledge about education. An engineering teacher with PBL knowledge. Some lecturers in specific issues.
PBL Approach	Lecture on the first part and PBL on the second.
Facilitation on PBL part	As a consultant in group management, writing and reading skills.
Group strategy	We try to make up the following groups the Felder & Silverman (1988)
PBL Assessment	Sharing traditional grades by homework and group performances and a final essay
Credits	4
Week hours	8
Total course hours	64, two parts, 32 for each.
Course part 1	Education in Colombia and Latin America, philosophy of education, paradigms and philosophical trends; Pedagogy, technological tools, sustainable engineering and constructivism. At this stage, numerous activities were performed on extra class time, including reading and writing. Each of the lecturers was autonomous but they followed the topic. They were asked to prepare some specific topics and load the material on Moodle.
Course part 2	PBL model, group work, facilitation and assessment in four weekly sessions. This part of the PBL model is working. It was used an average of three problems by session and worked in groups of one to five students. The groups were defined at the beginning of the semester. The Same group in all semesters. When the session started, we spent 15 minutes in a short introduction and trigger talk to beginning the learning process. Students individually did problems and at the end of the semester, they had to do a short reflection in an essay.
Student	24

5 Methodology

We used a qualitative approach. It reflects the views and comments of some of the engineering graduate students. Participants are male and female students from various programs and different professions. In this qualitative part, no distinction was made with age, sex or curriculum.

The opinion of students was taken in two different ways. The main measure was using an open-ended question: "After taking this course: What are your thoughts? In this sense, the usual bias caused by directing questions about the course development is not present. The second one was an internet questionnaire, which was designed to test the course, teachers and outcomes. We took advantage using it to triangulate some findings and coding words to process and analyse information.

In some cases, qualitative methods have advantages over quantitative methods. Special situations were seen in the case of open questions, which in fact, they could have a greater impact without the bias that other questionnaires have.

The open-ended question was written and had the participation of 20 students, but the questionnaire had only 14. Because students were native Spanish speakers, the open-ended question was made in Spanish and also the analysis. The analysis was made using NVivo 11 (QSR, 2015). All opinions were codified according to the word frequency and focused in classifying it according to with knowledge or skills. It was possible because there were a lot of answers in that sense.

Obviously, the language to write thoughts was informal. Here some extracts in Spanish,

"Entre los aprendizajes logrados se destaca el trabajo en grupo, el modelo de aprendizaje de los adultos, teniendo en cuenta que enseño diferentes conceptos para personas adultas y me es de gran ayuda conocer como motivarlos a aprender..." Student A

Another example, one extract about the importance of work in teams,

"Además, mejorar la manera de escribir y conocer los diferentes textos literarios que se puedan utilizar en la academia. El ABP me ayudó a aprender como conformar grupos de trabajo y la manera óptima de resolver problemas..." Student B

And one more example, with some pedagogical language

"El ABP para mi es un método genial para aplicarlo en diferentes ambientes como laborales, personales, profesionales, educativos; siento que me aportó diferentes herramientas para manejo de grupo, identificar cognición y la metacognición, la humildad, manejo de actividades con grupos interdisciplinarios..." Student C





In the analysis with Nvivo, we discard comments about the behaviour, teaching style or materials given because the main interest is to know the views about PBL from the students.

6 Results

With Nvivo, we have to read all of the comments and code in. After the text was code, we use cloud queries to graph the information. The table below shows some of the figures we obtained in this process. As we said before, the text was kept in Spanish and also the results appear in Spanish. Next to the pictures, we make comments regarding the findings. The Table 2 summarize the results after code and process it.

In spite of the long text and ideas from the students, we can find coherence in the results. They are consistent with the benefits of PBL and it is summarised below. We can't generalise our findings, but we compare it with affirmations from some authors.

Table 2 Results and comments about PBL student views

Graphical result	Comment
	<p>The course was very useful to improve soft skills. Students said they had implemented their capacity to writing to communicate, critical thinking, time management and verbal communication.</p> <p>Agree with (Dolmans & Schmidt, 2006; Graaff & Kolmos, 2003; Neville, 2009)</p>
	<p>Students received a foundation in education. They were sensitised on the importance of learning theories and training for teaching. It is necessary to improve pedagogical skills in engineering education (Irby, 1996; Kupriyanov & Gorodetskaya, 2015)</p> <p>Some of this group the student working given adult training so they think PBL is useful to train adults.</p> <p>There is a high potential to encourage teamwork. The subject demands too much time. A semester is not enough to achieve the objectives and complete the program.</p> <p>Agree with (Graaff, 2000)</p>
	<p>About PBL, students understand its usefulness especially in professional life and the relevance of the work over traditional methods. They feel PBL strengthens professional performance. They also believe that PBL is suitable for learning. They said very few about the difficulty to implement it but said that demand too long.</p> <p>Core skills for engineering work are recognised in PBL. They are co-operation, project management, communication, etc. (Kolmos & Kofoed, 2002)</p>
	<p>Students found useful PBL to encourage work in groups. Probably, it was the main aspect to considered with PBL. They were agreeing about PBL gives skills to management time and organising projects.</p> <p>Specific group skills are mention in (Woods, 2014). There are many authors agree with this aspect.</p>

Graduates of engineering think PBL useful to enhance knowledge and skills like interdisciplinary communication and writing. In that sense, it is better than traditional lectures. However, students believe that demands lots of time and excessive reading. Also, there is a consensus about training needs in this kind of methods to be more effective in teaching.

Many “tools” could be given for training or instructional proposes to students. The students had the opportunity to learn from the lectures at the beginning of the course when they taught learning theories and pedagogy. For the students, there were lots of tools to teach, but without enough time to prove it.

Students were convinced about new educational foundations. They also recognised in this course formation aspects to improve in their class. Many of the students were assistant teachers in their master studies, and they could take the value of teaching improvements and its importance.

Regarding other aspects of the course, students mentioned having learned from PBL and have met the goals and objectives of the course. However, there were comments about the lack of time in class. Extra time was needed to do too much work left in class as the main problem. It is accord with some authors because PBL and similar learning methodologies demand more time than the usual one (Bédard, Lison, Dalle, & Boutin, 2010)

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There is a high potential to encourage teamwork. The subject requires too long and a semester is not enough to achieve the objectives and to complete the program (Graaff, 2000).

7 Conclusion

We have shown enough illustration about the need for change academic systems. Like many educational institutions, there is a growing interest at the Universidad Nacional de Colombia to improve learning outcomes for its graduates. There are many initiatives to promote innovation, training and new courses.

In spite, this is not a representative group for generalising; this experience is useful to do some changes and begin to create awareness about the importance on alternative methodologies like PBL. Its importance arises because it was not a simple survey or question for some graduates about their reflexions about education. They were part of a group graduates, who were immersed in a PBL course combining pedagogical theories and PBL. So the mental perspective about education is changed in comparison with current undergraduate students. Additionally, taking into account that they recently had graduated and that they have some experience in the industry, their opinion is very important because it gathers in just one question the opinion of both students and graduates.

The collect comments showing that this experience has been crucial to outline and begin doing some changes, and the idea is to create sensitivity about the existence of alternative teaching technologies such as PBL.

Regarding the course program, it is necessary to make some changes in its contents. It is important to reduce the amount of working programs and the work left for home and also, the need program adjustment to a PBL focus. In this sense, it is necessary to split into two parts this course. It was shown that one semester is not enough to prepare students for PBL with such amount of learning themes.

Regarding the relevant importance that the PBL methodology has, we confirmed that as happen worldwide, graduate students (professionals) think that PBL improved a lot of skills and it can raise their awareness about the importance of these learning tools.

8 References

- Aalto. (2015). Aalto University. Recuperado a partir de <http://www.aalto.fi/en/about/>
Adams, S. (2012). The World's Best New Universities. *Forbes.com*.

- Bédard, D. ., Lison, C. ., Dalle, D. ., & Boutin, N. . (2010). Predictors of student's engagement and persistence in an innovative PBL curriculum: Applications for engineering education. *International Journal of Engineering Education*, 26(3), 511-522.
- Bellah, R. (1999). Freedom Coercion and Authority. *Academe*, 85(1), 16-21.
- CE. (2015a). El Consejo de la Unión Europea. Recuperado a partir de <http://www.consilium.europa.eu/es/council-eu/>
- CE. (2015b). El Consejo de la Unión Europea. Fomentar la educación en favor del crecimiento económico y el empleo. Recuperado a partir de <http://www.consilium.europa.eu/es/policies/education-economic-growth/>
- Colliver, J. A. (2000). Effectiveness of problem-based learning curricula: Research and theory. *Academic Medicine*, 75(3), 259-266.
- CPC, E. C. P. de C. (2014). *INFORME NACIONAL DE COMPETITIVIDAD 2014-2015*. Zetta Comunicadore .
- Daza, C. E. (2015). *Aprendizaje Basado en Problemas e n Ingeniería y Tecnología: El laboratorio en la Enseñanza y Aprendizaje de la Ingeniería y la Tecnología*. Universidad Nacional de Colombia. Facultad de Ingeniería. Bogotá.
- Dolmans, D. H. J. M., & Schmidt, H. G. (2006). What do we know about cognitive and motivational effects of small group tutorials in problem-based learning? *Advances in Health Sciences Education*, 11(4), 321-336.
- Enarson, C., & Cariaga-Lo, L. (2001). Influence of curriculum type on student performance in the United States Medical Licensing Examination Step 1 and Step 2 exams: problem-based learning vs. lecture-based curriculum. *Medical Education*, 35(11), 1050-1055.
- ET-2020. (2013). Council Conclusions on investing in education and training - a response to «Rethinking Education: Investing in skills for better socio-economic outcomes» and the «2013 Annual Growth Survey». *Official Journal of the European Union*, 56(2013/C 64/06).
- Galand, B., Frenay, M., & Raucent, B. (2012). Effectiveness of Problem-Based Learning In Engineering Education: A Comparative Study on Three Levels of Knowledge Structure. *International Journal of Engineering Education*, 28(4, SI), 939-947.
- Graaff, E. De. (2000). *Assessment and Educational Development* (Vol. Aalborg Un). Aalborg Universitet.: Aalborg: Videncenter for Læreprocesser:
- Graaff, E. De, & Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International journal of engineering education*, 19(5), 657-662.
- Graaff, E. De, & Kolmos, A. (2007). History of Problem-Based and Project-Based Learning . (E. de Graaff & A. Kolmos, Eds.). Rotterdam: Sense Publishers.
- HILT. (2014). {*Harvard Initiative for Learning and Teaching*}. *Transforming education from the inside out: Three years of hilt grants to seed experimental teaching and learning at harvard*.
- HKUST. (2015). Hong Kong University of Science and Technology. Recuperado a partir de http://strategicplan.ust.hk/eng/six_areas.html
- Hoidn, S., & Kärkkäinen, K. (2014). Promoting Skills for Innovation in Higher Education: A Literature Review on the Effectiveness of Problem-based Learning and of Teaching Behaviours. *OECD Education Working Papers*, (100), 64.
- Irby, D. M. (1996). Models of faculty development for problem-based learning. *Advances in Health Sciences Education*, 1(1), 69-81.
- Kolmos, A., & Graaff, E. De. (2007). Management of change-Implementation of Problem-based and Project-base Learning in Engineering . (E. de Graaff & A. Kolmos, Eds.). Rotterdam: Sense Publishers.
- Kolmos, A., & Kofoed, L. (2002). *Developing process competencies in co-operation, learning and project management*.
- Kupriyanov, R. V, & Gorodetskaya, I. M. (2015). Global trends in higher education and thier impact on engineering training in Russia. En *Proceedings of 2015 International Conference on Interactive Collaborative Learning (ICL)* . Florence, Italy.
- Levine, D. N. (2000). The idea of the university, take one: on the genius of this place .
- Manpowergorup, C. (2014). *Diversidad y Talento: Bases de la innovación y la sostenibilidad para Colombia*. Manpowergorup Colombia .
- MEM. (2013). *Reformas a la Educación Superior en América Latina: Ecuador, Chile, México, Perú y Colombia. Memorias del encuentro Bogotá, 23 de octubre de 2013* .
- MIT. (2014). Institute-wide Task Force on the Future of MIT Education: Final Report.
- Mourshed, M., Farrell, D., & Barton, D. (2012). *Education to employment: Designing a system that works* .
- Neville, A. J. (2009). Problem-based learning and medical education forty years on: A review of its effects on knowledge and clinical performance. *Medical Principles and Practice*, 18(1), 1-9.
- Olin College of Engineering. (2015). About Olin. Recuperado a partir de <http://www.olin.edu/about/>
- Polyzois, I., Claffey, N., & Mattheos, N. (2010). Problem-based learning in academic health education. A systematic literature review. *European Journal of Dental Education*, 14(1), 55-64.
- POSTECH. (2015). Pohang University of Science and Technology. Recuperado a partir de <http://www.postech.ac.kr/>
- Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *JOURNAL OF ENGINEERING EDUCATION*, 95(2), 123-138.

- Pritchard, R. (2004). Humboldtian Values in a Changing World: Staff and Students in German Universities. *Oxford Review of Education*, 30(4), pp. 509-528-528.
- Schmidt, H. (2010). A review of the evidence: Effects of problem-based learning on students and graduates of Maastricht medical school. En *Lessons from Problem-Based Learning*. Erasmus University, Department of Psychology Rotterdam, Netherlands: Oxford University Press. doi:10.1093/acprof:oso/9780199583447.003.0024
- Stanford Business School. (2006). Stanford Graduate School of Business Adopts New Curriculum Model. Recuperado a partir de <https://www.gsb.stanford.edu/stanford-gsb-experience/news-history/stanford-graduate-school-business-adopts-new-curriculum-model>
- Sungur, S., & Tekkaya, C. (2006). Effects of problem-based learning and traditional instruction on self-regulated learning. *JOURNAL OF EDUCATIONAL RESEARCH*, 99(5), 307-317.
- UCLA. (2015). University of California Berkeley. Instructional Improvement Grants. Recuperado a partir de <https://teaching.berkeley.edu/instructional-improvement-grants>
- University of Cambridge. (2015). Teaching and Learning at Cambridge. Recuperado a partir de <http://www.teachingsupport.cam.ac.uk/teaching-and-learning-innovation-fund-0>
- Walsh, C. (2011). Harvard Gazette: Education and innovation.
- Wilder, S. (2015). Impact of problem-based learning on academic achievement in high school: a systematic review. *EDUCATIONAL REVIEW*, 67(4), 414-435.
- Woods, D. R. (2014). Problem-oriented learning, problem-based learning, problem-based synthesis, process oriented guided inquiry learning, Peer-Led team learning, model-eliciting activities, and project-based learning: What is best for you? *Industrial and Engineering Chemistry Research*, 53(13), 5337-5354.