Changing an Engineering curriculum through a co-construction process: a case study in a Brazilian Higher Education School

Octavio Mattasoglio Neto[1], Rui M. Lima[2], Diana Mesquita[3]

[1] Mauá Institute of Technology, São Caetano do Sul, 09580-900, Brazil
[2] Department of Production and Systems, School of Engineering, University of Minho, Campus of Azurém, 4800-058 Guimarães, Portugal
[3] Research Centre on Child Studies, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal

Email: omattasoglio@maua.br; rml@dps.uminho.pt; diana@dps.uminho.pt

Abstract

The objective of this work is to present a co-construction process of a curriculum which has used different active learning approaches in its engineering programs, with the purpose of motivating students, addressing realistic problems that an engineer would face, right from the beginning of the program. Idealized by the rectory of school, in a top-down decision, the new curriculum establishes some guidelines for these new approaches. In a bottom-up contribution, teachers had to devise activities to be implemented and conducted by them, in the new curriculum. At an early stage, these activities were classified in three type: Projects, Engineering Practices, and Workshops. To analyze the implementation of this new curriculum, a qualitative approach was carried out during one and a half academic year, in which data was collected through interviews, focus groups, and questionnaires. The results indicate the teachers who devised the activities had an important role determining several aspects to formalize the new curriculum in a co-construction collaboration, giving accuracy to the ideas presented at the idealization phase. Despite the benefits of these experiences, the results suggest that not all potential of new curriculum was fulfilled at this initial phase, such as the development of soft skills. There is therefore a need for adjustments to take full advantage of its changes.

Keywords: Curricular change. Project-Based Learning. Engineering Education. Active Learning. Curriculum development.

1 Introduction

Active approaches to promote the learning (Christie & Graaff, 2017) can be introduced in engineering curricula in different configurations (Frenay et al, 2007; Oliveira, 2007, Terrón-López et al, 2016). In some cases, it is an individual teacher's effort or, in others, it comes from a small group of teachers, that introduces strategies such as peer instruction (Mazur, 1997) or Flipped Classroom (Bergmann & Sans, 2016) or even Team Based Learning (Najdanovic-Visak, 2017), amongst others. There are also schools that make an institutional option to implement active strategies widely in the program, as the experiences reported by Frenay et al (2007), Oliveira (2007), Fernandes et al (2009), and Lima et al. (2017a), all of them involving curricular changes.

Powell and Weenk (2003) argue that shifting to strategies based on Project Based Learning (PBL) is motivated by vision, consensus, or faith. Rarely this change is voluntary and may be motivated by government agencies or by universities themselves. According to these authors, six factors influence the politics of higher education in engineering:

- Employers: by establishing market directives.
- Professional bodies: group of professional engineers and academics who, in associations, influence the training of engineers, such as ABET (Accreditation Board for Engineering and Technology).
- International influences: posed by the market or by the engineering education community, serving as a beacon, inspiration and support for local decisions, as well as cooperating to bring ideas of educational innovation initiatives.
- Students: can be seen as "the eyes of consumers", who give feedback about the teaching and learning process, and act as sensors of the labor market.
- Universities: in the case of engineering, bringing influences of external and internal validation to the country, through connection with other schools, their deans and professionals.

- Governments: which in addition to influencing the previous items through government policies are responsible for enabling, organizing, evaluating and / or certifying the infrastructure supporting the engineering programs.

In Brazil, the engineering programs are oriented by the National Curricular Guidelines (MEC, 2002), which guide undergraduate courses in engineering with flexibility to attend different contexts. They allow the continuous improvement and the introduction of innovations as, for example, new technologies and strategies. These guidelines indicate that engineer training aims to provide the future professional of the following general competences: I - applying mathematical, scientific, technological and instrumental knowledge to engineering. II - designing and conducting experiments, and interpreting results. III - conceiving, designing, and analyzing systems, products and processes. IV - planning, supervising, designing, and coordinating engineering projects and services. V - identifying, formulating, and solving engineering problems. VI - developing and / or using new tools and techniques. VII - supervising the operation and maintenance of systems. VIII - critically evaluating the operation and maintenance of systems. IX - communicating effectively in written, oral and graphic forms. X - working in multidisciplinary teams. XI - understanding and applying professional ethics and responsibility. XII - evaluating the impact of engineering activities in the social and environmental context. XIII - evaluating economic feasibility of engineering projects. XIV - becoming responsible for their own professional updating.

Considering the openness stated in the National Curricular Guidelines for the engineering courses, the Mauá Institute of Technology, a Brazilian school, started a process of curricular change aiming to promote the development of transversal competences, preparing students to meet the needs of the market, from the early courses. The new curriculum foresees the replacement of classroom hours in the traditional model by projects and workshops, aiming the development of both technical and transversal competences, increasing student's ability to approach engineering problems. Another motivation to curricular change was a visit of the pro-rector to an American university, with similar characteristics, where the extra-curricular activities carried out by the students have great importance in the curriculum.

Up to that time, the school had a traditional structure, with a large volume of work done in traditional lectures followed by exercises and lab. The principle was that the student could feel more motivated for learning if, since the beginning of the program, had the opportunity of getting involved in projects, workshops, and work in engineering laboratories. Beyond the motivation, the use of several pedagogical approaches would promote the development of transversal competences aligned with the professional needs. These were beliefs, or faith as said Powell and Wink (2003), that started the change.

The introduction of active learning approaches is not an easy task, and some difficulties can arise, as teacher's resistance, non-existence of adequate infrastructure or a lack of support from school management (Goldberg & Somerville, 2014). The commitment of the faculty team is a key point, because they interact with students and face difficulty regarding infrastructure. Convincing them to work together towards the promotion of the curricular change can be seen as one of the main challenges in curriculum change. A curricula change is not a linear process, which begins with an idea and has a ready result as consequence. It is a co-construction, in which teachers have part of the responsibility in the idealization of the new curriculum, as well as other stakeholders (Barnett & Coate, 2005; Wolf, 2007).

This article aims to analyze and evaluate the way a curricular change is constructed during the first year of its implementation in an engineering school in Brazil. This curricular change aimed to put the student in the center of the learning process. The start to change was driven by the provost of the school and was presented to faculty, which started working to formalize and put the new curriculum in operation. The implementation was not linear, but it had different interpretations from the participants of the process, issues which will be discussed in this work. The analysis considered the central elements of the curriculum, such as the different pedagogical approaches used to put students active in the process, students and teachers' role, and, the students' learning achievement. The evaluation considered the perspectives of teachers, managers and students, involved in the changes implemented in the school, during one and a half academic year, since the beginning of the implementation.

2 Research background

The curriculum development involves three stages: preparation, implementation and evaluation. It is a collective process, which includes people and procedures, is under interpersonal, political and social dimensions, as well as under collaboration and cooperation of people. It is not just a rational scientific process, due to the subjectivity involved, nor indeed a linear or systematized process. The subjective guidelines and its flexible feature give a curricular design an open characteristic, different from the design of a mechanism or a prototype (Pacheco, 2005).

From the conception up to its complete implementation, the curriculum goes through different levels. Goodlad (1979) indicates the starting point of a curriculum is an "ideal curriculum". Following this initial step, there is the "formal curriculum", which is revealed in the curriculum documents, such as manuals and textbooks, and translates the official curriculum. In a third step, the "operational curriculum" appears, programmed by a group or individually, translating to the daily practice the ideas and formalism defined before. Finally, there is the "perceived curriculum", experienced day-to-day in the classroom. There is also the "evaluated curriculum", which includes, besides the assessment of students, curricular plans, programs, guidelines, manuals and textbooks, teachers, school, administration, etc.

In addressing the difficulties in training new engineers, the Problem and Project-Based Learning (PBL) strategies are alternatives to traditional approaches in engineering curriculum (Lima et al., 2017a), which can be used to meet requirements posed by professional contexts (Mesquita et al, 2013). These requirements integrate simultaneously technical and transversal competences order to solve engineering problems. The current requirements for the engineering profession asks engineers to increasingly demonstrate competences that go beyond the technical know-how of their profession (Engineer2020, 2004). Some of the transversal competences required are leadership, ability to work in teams, communication skills, entrepreneurship, among others (Pascail, 2006; Passow, 2012; Mason, Williams and Cranmer, 2009; Lima et al., 2017b). These competences are not learned from lectures, in which the teacher just lectures students with steps that must be taken to carry them out. A competence is developed with meaningful learning experiences (Christie & Graaff, 2017), which allow student to develop and mobilize them before effectively being put to test it in a professional environment (Le Boterf, 1997; Zarifian, 2001).

Project-Based Learning (PBL), among several active learning strategies, arises as one of the most studied and important strategies (Lima, Andersson & Saalman, 2017) to promote learning in engineering schools. Being design one of the most distinguished characteristics of Engineering, PBL and its variants have been largely used in engineering curricula. Team students cooperate in an interdisciplinary frame in PBL, developing competences required in the labor market (Mesquita et al., 2013). Many experiences show the use of these strategies in classroom (Kolmos, 1996; Lima, 2017a), involving students, stimulating motivation for learning and assuring the development of new competences (Kolmos and De Graaff, 2007). The main principle of PBL is the student engagement, to solve open problems in an interdisciplinary configuration, in an active way interacting with the object of learning, generally in teams (Kolmos, 1996; Aquere et al., 2012). A problem is the starting point of a project and is the responsibility of students to engage in the search for its solution. Sometimes, there are predefined milestones in which students need to carry out tasks and show the learning improvement. In PBL, teachers also have to develop communication skills and teaching strategies different from those of a traditional classroom. They need to take up other roles, as tutor, mentor, supervisor, among others, helping students to build their knowledge. Kolmos (1996) classifies different types of PBL: Assignment-based project - project based in a part of a discipline; Subject Project - project based on a complete discipline; Problem project - design by open problem - characterized by a problem and development of the learning process that goes beyond disciplinary boundaries. Kolmos, De Graaff and Du (2009) present a model for detailed analysis of PBL approaches with seven dimensions: goals and knowledge; types of problem, projects and classes; progression, amplitude and duration; students learning; academic staff and facilities; physical space and organization; student assessment and evaluation process.

The shift to PBL happens under some expectations (Kolmos and De Graaff, 2007; Guerra et al., 2017): decrease dropout rates; stimulate motivation for learning; enhance the institutional profile; support the development of new skills. The authors inform the extent of this change sometimes happens in a single discipline or, in a more complex way, involving several courses in an interdisciplinary context. Powell and Weenk (2003) also listed three conditions to support and achieve success when changing to PBL: infrastructure, authority and consensus. The "infrastructure" dimension involves facilities, training teachers and communication. The latter ensures a common basis about the perception and the need to change. Authority is needed to ensure adequate planning, guidance and progression in an implementation accepted and institutionalized. Sharing information of experiences and the commitment and vision of teachers focusing on students learning give a bottom-up characteristic to the curricular project. Finally, consensus facilitates the identification of crucial problems for the success of PBL and the inclusion of stakeholders in the innovation process. The "cooperation between the teachers involved in PBL is just as essential as cooperation between students in their team" (Powell and Weenk, 2003, p. 124).

The faculty team, the school management team, and limitations of the school infrastructure determine the solution adopted to each curriculum proposal, what constitutes the context and input as discussed by Fernandes et al (2009). Besterfield-Sacre et al (2014), analyzing data from a widespread survey with faculty, chairs, and deans about change in engineering education, notice "many of the strategies and values of engineering faculty and administrators" converge into some of categories summarized by Henderson et al. (2011) who support the change. These are:

- Curriculum and pedagogy, which inform individuals about new teaching concepts and practices encouraging their use.
- Policy to develop new environmental features that are required or encourage new teaching concepts and practices.
- Reflective teachers who encourage and support individuals to develop new teaching concepts and practices.
- Shared vision, which empowers and supports stakeholders to collectively develop environmental features that foster new teaching concepts and practices.

Still in this research, (Besterfield-Sacre et al., 2014) teachers said they are aware of the learning opportunities they achieve using workshops and teaching and learning centers. They will be able to promote better use of new teaching skills to work with new curricular proposals and better promote student's learning.

3 Methodology

This is a longitudinal exploratory study with data collected before, during and at the end of implementation of a curricular change, using data from participants of this process: teachers, managers and students, to triangulate outcomes. The aim of this study is to analyze and evaluate the construction a curricular change during the first year of its implementation. Specifically the objective was to understand the influence of proponents of curricular change and of the proponents of different pedagogical approaches, managers and teachers respectively, on this change and their influence from the idealized curriculum up to the formalized curriculum.

A curricular change study needs to be accompanied during an extended period. The option was for a case study with qualitative approach, developed during the first year of implementation of the curricular change, using data collected before the implementation too. Considering the objective of understanding the way the curriculum was constructed were the need to listen to several involved stakeholders, managers, teachers and students, in order to get a deep view of their perceptions about this curricular change.

The research questions defined in the scope of this study are: What types of approaches were proposed and carried out with students? What was the role of proponents of specific activities in the change of the idealized curriculum? About teachers and student's role in the process of learning, what changes happen from the idealized to formalized curriculum? What was the contribution of the specific activities to the students' learning? Was there consensus among teachers and, among teachers and proponents of curricular change on specific points of the new proposal? Have the proposed aims effectively achieved the formalized curriculum?

The data was collected using individual interviews, focus groups, and questionnaires in four steps. The first step happened before the announcement of the curricular change, aiming to know the teachers' conceptions about

PBL. The second focused the managers who proposed the curricular change; the aim was to know the motivation and expectation of the curricular change. The third step was a focus group with teachers who proposed the specific activities included in the curricular change to know the aims of these activities, their relation with the elements of the curriculum, and their global perception on the curricular change. Finally, the fourth step involved students and teachers to know their perceptions about the implementation of the specific activities in the program. The specific activities included in the curricular change from now on, in this work, will be named "Projects and Special Activities", represented by the acronym PAE (in Portuguese "Projetos e Atividades Especiais"). More details about PAE will be given in the next section.

The data collection happened during one and half year, from July to December of the next year, represented in this paper as Month 1 (M1) to Month 18 (M18). The M9 was the initial month of implementation of the curricular change for students, and was the beginning of the first semester of the academic year. The interviews were audio recorded with the consent of the interviewees and transcribed to provide an accurate analysis of the information. The students answered the questionnaires in the school labs, with a total of 694 and 626 in the first and second semester, respectively. All steps of research are synthetized in the Table 1.

Table 1 – Steps of research defined by time where dates were collected

	Step 1	Step 2	Step 3	Step 4
Who?	Teachers of school	Provost and coordinator – Proponents of curricular change - who start the ideas, and implement the new curriculum, respectively.	Teachers proponents of new pedagogical approaches - PAE	Teachers and students along and after the 1st year of new curriculum
When?	Before the new curriculum	During curriculum idealization	At the beginning of implementation of new curriculum	In the middle and the end of one year of new curriculum
	July (M1)	November (M5) and February (M8)	April (M10)	August (M14), November (M17) and December (M18)
How was it done?	Individual interviews with semi-structured tool	Individual interviews with semi-structured tool	Focus group with semi-structured tool	Teachers: Focus group, individual interviews Students: questionnaires
How many participants?	7 teachers	2 managers	8 teachers proponents of PAE in two focus Group - four participants in each	12 teachers - interviewed 694 students - end of 1st sem. 626 students - end of 2nd sem.
What to know?	Perception and knowledge from teachers about PBL	Motivation and point of view of proponents of curricular change	Objective, expectation, motivation and point of view of proponents of PAE	Perception of student and teachers after each semester
	What is PBL? Is it possible to use it in the school programs?	Why changing it? How to change? Which improvements could the new approaches bring to the course? Is extra infrastructure needed?	What does PAE bring new to curriculum? What to expect from students and teachers?	What about PAE implementation process: objectives, role of students, role of teachers, evaluation of learning, its contribution?

4 Structure of the new Curriculum

The Mauá Institute of Technology is a traditional engineering school in Brazil, which has been offering traditional and teacher-centered approach courses for more than 55 years. At the time of the study, nine different engineering courses were offered, with annual academic periods. Students complete the program in five academic years, being the two initial years a basic cycle to all programs, and the three final dedicated to a specific engineering. Since its foundation, this may be considered the deepest curricular change ever developed at school, specifically by introducing PAE in parallel the curriculum.

The motivation to the current curriculum change is that students should have **contact with content and practice of engineering right from the beginning of the program**, using the **large number of laboratories available in the school**. This finds support in the National Curricular Guidelines (MEC, 2002) which pointed the need to promote learning in different learning spaces, beyond the classroom. Another option was to **improve the development of projects, putting students in contact with some engineering challenges since the beginning** of program as revealed by an interviewed [Step 2], who said that the cultural change is the most important fact in this experience, replacing the traditional classroom hours by other types of learning work linked with the engineering practice. The international experiences in some engineering schools visited by some board members of the school also helped them to realize the effectiveness of this conception. All these ideas support the idealization of the curricular change (Goodlad, 1979), composing the guidelines of the curricular change.

To introduce these ideas, some hours of traditional classes were replaced by PAE, which were designed by school's teachers who could propose freely, the most varied subjects and with varied pedagogical strategies. To meet the need of curricular organization all PAE set were grouped in a course. By enrolling in this course, the students found a menu in which they could select the specific Projects, Engineering Practices and Workshops they wanted to wanted to participate from a list of 38 options. **Error! Reference source not found.** shows the oldest and the new curricular matrix for the first academic year, with the inclusion of PAE.

Table 2 - Organization of hours in the oldest and new curriculum, in the first academic year of each program.

Curriculum	Physics	Chemistry	Calculus	Vectors & Analytic Geometry	Algorithms and Programing	Technical Drawing	Introduction to Engineering	Total (classes + labs) / week	PAE Meetings/ week
Previous	4 C + 2 L	2 C + 2 L	6 C	4 C	2 L	2 L	4 L	28	0
New	4 C + 2 L	2 C + 2 L	4 C	2 C	2 L	2 L	2 L	22	6

C = Classes hours; L = Laboratory hours

At the formalization of the curriculum (Goodlad, 1979) PAE were classified into three different types: Projects, Engineering Practices and Workshops, due to different pedagogical approach and period. Table 3 shows the initial criteria to classify the Projects, Engineering Practices and Workshops, and the period to each type of pedagogical approach. The proponent teacher was responsible to indicate the period of a PAE.

Table 3 - Initial criteria for classification of PAE

Pedagogical approach	Initial classification	Period
Projects	Directly related to engineering	one academic period – 8 months
Engineering Practices	Directly related to engineering.	half academic period – 4 months
Workshops	Not directly related to engineering. To develop skills and knowledge, or still, to promote a general background of content of other knowledge areas	half academic period – 4 months

At the beginning of the first academic year, all students enrolled had to choose which PAE to perform. The weekly workload to any PAE was 2 hours, organized in a schedule that tried to match the interest of students and the availability of the teachers. During an academic year, the student needs to sign up for at least one Project and a total of three Engineering Practices and Workshops: one or two Workshops, and complementary Engineering Practices. As a rule, the maximum number of students per group in a PAE was 30 but the proponent teacher could decide the exact number of participants.

All PAE were designed following the same general guidelines, established at formalization level: **should have activities developed in the school and active participation of students; not necessarily linked with any course of the program; and no formal assessment of students' learning**. On the one hand, these guidelines show some enforcement, on the other hand, the opportunity and flexibility to teachers to design varied projects freely and an opportunity to encourage creativity. Approximately sixty teachers of school from different academic years and different areas submitted almost a hundred proposals of PAEs. Thirty-eight of these proposals were chosen to compose the list of PAEs offered to students of the first academic year (Table 4), considered the following criteria: interest and feasibility to the engineering program.

Table 4 - Projects, Engineering Practices and Workshops offered to students in the first year

Projects - Period of 8 months	Engineering Practices – Period of 4 months	Workshops – Period of 4 months
PRO 101 – Jam Manufacturing	PRO 701 – Fuel injection	PRO 401 – Mathematical bases
PRO 102 – Autonomous robot	PRO 702 – Spaghetti Bridge	PRO 402 - Graphics
PRO 103 – Flying over the campus	PRO 703 – Aerodynamics of buildings	PRO 403 – Competitive Brazil
PRO 104 – Water treatment	PRO 704 – Lean production	PRO 404 – Entering by cone
PRO 105 – Industrial shed	PRO 705 – Sustainable City	PRO 405 – The Logic of games
PRO 106 – Electronic games	PRO 706 – Chips Fruits	PRO 406 – Knowing LINUX
PRO 107 – Soap manufacturing	PRO 707 – "Houston, we have ...	PRO 407 – The art of solving problems
PRO 108 – Weather station	PRO 708 – Mobile applications	PRO 409 – Modern physics
PRO 109 – Waterway	PRO 709 – Rocket Science	PRO 410 – Creating problems
PRO 110 – Skateboards factory	PRO 711 – Master user	PRO 411 – Negotiation
PRO 111 – Combustion engine	PRO 712 – Engineer Stirling	PRO 412 – Excel-VBA
	PRO 713 – Corrosion	PRO 413 - Python
	PRO 714 – Tensile/Compression	PRO 415 – Newton in equilibrium
	PRO 715 – Arduino	

5 Top-down and bottom-up co-construction of the curricular change

The curricular change was decided in an institutional top-down process, which guarantees the authority that supports it (Powell and Wink, 2003). Nevertheless, along the formalization and operationalization of the new curriculum, there was a great deal of freedom for defining pedagogical details, giving opportunity for teachers to influence, in a bottom-up contribution to their implementation. This section aims to show how teachers influenced this construction as agents of that change.

The data analysis from proponents of curricular change, proponents of PAE and students brought four relevant dimensions used to discuss the implementation of new curriculum. These dimensions are: construction of new curricular structures and clarification of this structure, what means the features of the three different pedagogical approaches; role of the agents (both teachers and students) and; contribution of PAE to students learning.

5.1 Constructing the meaning of the alternative curricular structures

From the interview with teachers who proposed PAE [Step 3], it was possible to realize different meanings for these different pedagogical approaches. Projects, Engineering Practices and Workshops are thus defined:

Projects - Divided into stages and related to an open and multidisciplinary problem, which agree with Kolmos (1996). To these teachers, open problems are understood as those with a variety of ways to be solved, or the use of a variety of tools as a solution. As said one interviewed:

> *"[Project] ... is something bigger, in which I need more resources, different types of knowledge of specific engineering areas, in my case, control automation ... have to do research, I have to see how it works (the software, the mechanism) ..." [FG2P4 - Focus Group 2, teacher 4].*

To interviewed, Projects require a work strategy, which imply in team organization, definition of roles of participants, identification of the problem and definition of steps to solve them. They include the content presentation by teacher to support the work of teams. Students need to research to: support the problem solving process, to search for a solution, to develop and test a prototype, and, finally, to make an oral or written presentation of the results.

Engineering Practices – For some interviewed the Engineering Practices, unlike the Projects, do not need the initial stage of research to define and find the solution to a problem. Teacher directly presents the content and the problem, and students working to solution it, directly too.

> *"The student will make the practical implementation of a proposal that is already half set by the teacher. The specific objective is set by the teacher" [FG2T1].*

> *"... the student can give his solution, but it's very controlled, that is, with restrictions placed by the teacher and with a specific goal also set by the teacher" [FG2T2].*

There are still those who identify Engineering Practices as open mini-projects, only because they have a shorter period to develop and a 'slight' initial research in technical articles [FG2T3].

It is possible to conclude that in Engineering Practices the goal is to develop engineering competences like in a laboratory, focusing on implementing a process or building a product directly, with reduced autonomy to fully develop student's creativity.

Workshops - The aim is essentially to have students develop competences in workshops structured in two stages, first a theoretical presentation by the teacher of some content and, second, the proposition of an oriented work done by student. Generally, it starts and finish in a single class [Focus group 2, teachers 1, 2 and 4] and may have a playful feature, with handling of parts, equipment or tools to promote handling's skill, as to install or build a prototype. It may still be used to promote the development of competences in pencil and paper activities. An example is "Mathematics bases", which aims to develop mathematical skills in which the students have difficulty, or "Negotiation techniques", which promotes skills on negotiation process and management of conflicts.

> *"I think a workshop has a content to be addressed, but without the intention of creating a product as a project, but just building knowledge of some content" [FG1T2 - Focus Group 1, teacher 2].*

Summarizing, Engineering Practices are associated with the application of an engineering tool without manipulating many variables and without ensuring conditions to design large complex projects. In this case, problems are not an open problem. In turn, Projects are associated with open and multidisciplinary problems with unknown solution, developed in stages. Workshops are associated with the development of specific competences, technical, scientific or transversal, to support the engineering background and to broaden the horizons of knowledge.

At end of academic year [step 4], it was possible to realize that some teachers still assign different meaning to these pedagogical approaches. For example, Engineering Practices and Projects are perceived with same features. That is, after one academic year there are still no consensus about the features of these pedagogical approaches and different teachers assign different objectives to the same type of pedagogical approaches. According Powell and Weenk (2003), consensus is a basic condition to implement changes to PBL and, the lack of consensus about the role of each PAE certainly hinders a uniform work.

To students [Step 4] each different pedagogical approaches types or different PAE use different pedagogical strategies represented in **Error! Reference source not found.**. During the Workshops, meetings for resolution of exercises predominate, followed by lectures. In Engineering Practices. Laboratories classes and projects are more frequent. In the Projects, as expected, the students identify the predominance of projects, followed by Laboratories and Lectures. It is interesting to notice the meetings solve exercises in the Engineering Practices is not a significant option.

Table 5 – Different pedagogical strategies used in the PAE (In %) from the students view

	Lecture	Resolution of exercises	Laboratories	Seminars of students	Case study	Games	Projects
Workshops	22	**36**	9	3	14	**2**	14
Practice engineering	18	**5**	**24**	12	10	8	**23**
Projects	21	2	**24**	12	6	**1**	**34**

The predominance of two pedagogical approaches for the Engineering Practices, Laboratories and Projects, confirm the mixed view the teacher also has about this type of PAE. The results of students' perceptions show they can be working on a project or developing lab sessions. From the analysis of teachers' perceptions [Step 4], it is possible to conclude that the small number of students in the groups, defined by teacher, simplified the process of putting into practice active learning strategies, giving conditions for a more individualized work of attendance to the students. It is interesting to notice that Lectures appear in all approaches, that is, teachers continue giving classes traditionally.

In the stage of idealization of the new curriculum, the desire to include practical projects in the curriculum was mentioned. The concept of Projects, Engineering Practices and Workshops appeared in the formalization phase, when these different pedagogical strategies were originally defined. Only in the operationalization stage, these approaches were better defined from the proponents' teachers, who play an important role in this characterization.

5.2 The Teachers' roles

An advantage concerning teachers in the context of curricular change is to accept the challenge to development the PAEs and the willingness to learn [Teacher 4; Step 4]. "*Developing PAE was pretty cool. The teacher devotes time because those are subjects he likes*". This statement meets the expectation of the proponents of the curricular reform [Step 2], as referred "*the curricular reform aims at broadening the teacher's exercise of his competences*". It shows a convergence between the school board's intention and teacher's action, who has the opportunity of putting in practice his competence.

At previous stage of the curricular change, when talking about PBL [Step 1], teachers assigned for themselves different roles that can be classified as a facilitator of the learning process (Mattasoglio Neto, Lima and Mesquita, 2015).

> "... (teacher) *tries to make student questions himself and searches solutions for the problem*." [Teacher 1].
> "...*because of the greater proximity of the student who is responsible for learning*." [Teacher 2].
> "...*to say the work did not end as soon as the student gets the result in the calculator and then asks 'what is that? Is it important? Why are you going to use it?' He must have an orientation*" [Teacher 3].

These teachers' role was confirmed and further detailed by proponents of PAE [Step 3]. They indicated a refinement of conceptions regarding the role of the teacher. According to them, teachers' roles are: advisor, tutor, model, content provider, and team coach, ever promoting the student autonomy. As curriculum reform progresses, this means teachers become aware of new competences that must be set in motion at work with students.

Teachers' roles were defined differently to each pedagogical approach of PAE. In the Projects, the teachers' role was viewed predominantly as team **coach**, helping students to assume their roles, developing the tasks, and performing with a good interpersonal relationship. In the Engineering Practices, the teacher was perceived predominantly as a **role model**, an example to be followed by students. At the Workshops, as **tutor**, someone that supports study work, respecting the different students' profiles. In all these roles, there is the idea of granting the autonomy to the student.

It is possible to notice two different dimensions associated with the teachers' role. One of them is operational, related to operation of PAE, making it happen. Another, related to the pedagogical dimension, determined by the different demands of each approach of PAE.

5.3 The Students' roles

The reason to implement a new curriculum and the PAE, revealed by proponents of curricular change [Step 2], was to help students becoming better "*prepared to accept challenges*", involved in the "*solution of open problems and projects*" and to "*practice engineering working in teams*". In addition, PAE should bring students closer to laboratories and companies, right from the beginning of the first academic period of the engineering program. There was no specific indication about which transversal competences should be developed with PAE.

At the initial phase of the curriculum change implementation, it was possible to gain a perspective on students' role, from the teachers' point of view [Step 3]. Students should be able to "*make choices*", "*take decisions*", "*solve problems*", "*conduct research*", "*carry out the practices proposed by the teacher,*" and "*have a proactive attitude*". This is a more specific contribution that PAE should have to enhance the students' competences.

At the end of the academic year, the evaluation of student's involvement, made by teachers [step 4], brought contrasting perceptions. Some teachers indicated a negative point of view, arguing that, while the teacher accepted the challenge of creating something new, the students did not embrace the opportunity to face the challenge. For these teachers, students understood the work proposed more as a task to be fulfilled, to earn the credits, instead of an opportunity to develop further competences. "*PAE was very nice, but students showed little interest. Most of the students chose PAE because of the schedule. Sometimes it seems some teams are completely lost.*" [Teacher 10, step 4].

In contrast, there are some positive indications about the involvement of autonomous and motivated students. "*In the laboratory tasks, the students stayed long periods, even beyond traditional working hours, without complaints.*" [Teacher 8, step 4]. According to teacher 11 [Step 4], the students, at times "*were excited, surprised, and admired about their achievement, their own abilities. They worked at their own pace*".

Developing new competences and broadening experiences to bring students closer to engineering practice was envisioned during curriculum idealization, but it was not clear how it could be performed at curriculum formalization.

Proponents of the curriculum change focused on the structural curriculum change: the focus was to "set the program in motion". In turn, teachers who proposed PAE were the ones to define the competences students should develop more exactly. The interviews [Step 3] indicated PAE could help students develop transversal competences.

The development of transversal competences has been perceived as the principal contribution of PAE. Instead, the organizational issues to put the project of new curriculum into practice seems more important, which could restrict all its learning potential during implementation.

5.4 Contribution of Projects, Engineering Practices, and Workshops - Results

The proponents of the new curriculum [Step 2] expected PAE to make students more active, committed, dedicated and effective team players. For teachers' proponents of PAE [Step 3], the greatest merit was to stress the engineering function during the learning process, to use course's content in problem-solving and to encourage students to take responsibility for their own learning in a scenario of freedom.

At the end of the academic year [Step 4], teachers perceived the students' participation in PAE differently. As pointed out by teachers "*the cultural gain was beyond engineering, for example astronomy*" [Teacher 4, step 4]. Regarding the development of competences, teacher 8 referred some gains in teamwork and critical judgement: "*teamwork, the attitudes in the presentations of results, and the ability to compare results between teams. They also noticed limited Internet information due to low technical content*" [Teacher 8, step 4].

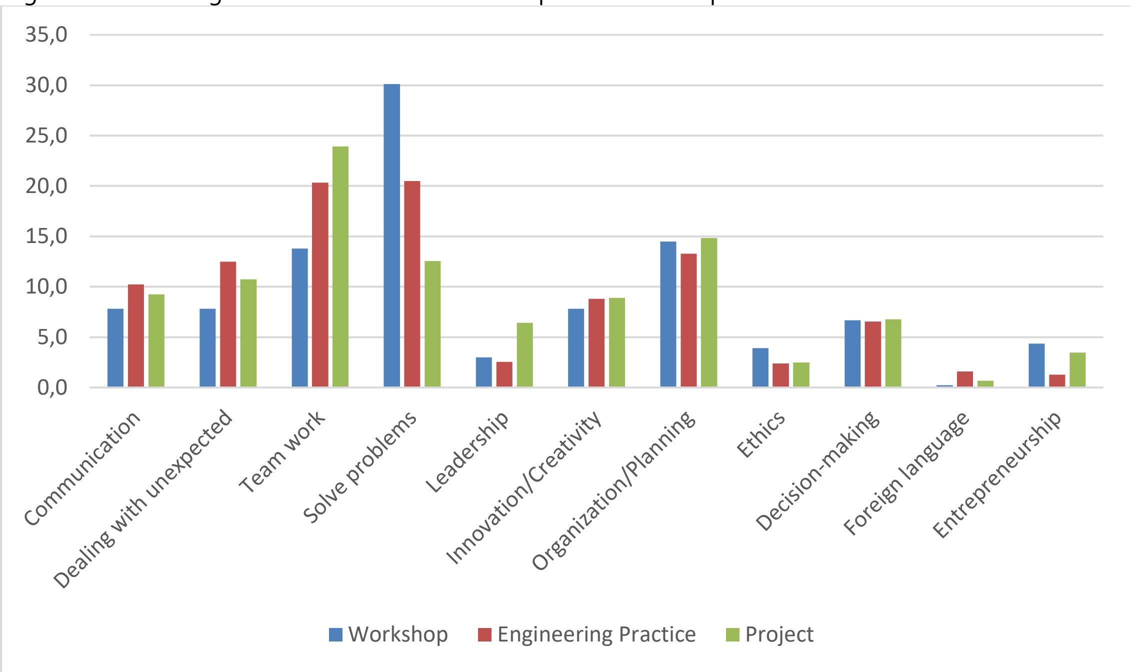
Some teachers claim PAE should have had a stronger and explicitly connection with the courses addressing contents such as physics, mathematics, and others, reinforcing their importance [Teacher 6, step 4]. "*The gap between PAE and the courses ended up generating more difficulty, contrary to what an interdisciplinary project could provide. PAE and the curricular courses have become two separate things*" [Teacher 7, step 4]. The analysis of the teachers' interviews showed an evident contribution of PAE to develop transversal competences, but it lacks a connection with the courses of the program.

Results demonstrate PAE's objective diverge. While the proponents of curricular change require transversal competences, some teachers [Step 4] show the need to link PAE with the courses.

Students share the same point of view, pointing course content should be a strong point of PAE. "Knowing, practicing and having contact", with engineering knowledge is the most valued aspect by the students. They attribute less importance to learning transversal competences. In addition, points out that the involvement with PAE takes time and represent an extra student's workload [Step 4].

Despite these statements, students indicate some transversal competences developed in PAE, especially in Projects: "*Teamwork*", "*Organization and planning*", "*Problem solving ability*", "*Ability to innovate*" and "*Ability to deal with the unexpected*". Figure 1 presents student's development of several transversal competences.

Figure 1 – Percentage of student's transversal competences development in PAE



Note: Students could chose more than one option.

In general, the student's behavior could meet PAE's requirements and thus to be approved, but in general teachers felt that there was not enough perception about the importance of PAE for their development.

The analysis of the results shows the need to improve the connection between PAE and the courses that run in parallel. This connection could increase the sense of meaning for both, courses and PAE, and in that way to increase the motivation and engagement of the students.

6 Conclusions

The top-down decision from the school board represented the authority to ensure the implementation of the proposal. A bottom-up action from proponents of PAE, defining its structure and detailing the role of teachers and students, guaranteed the co-construction of curriculum. The top-down action supported the change and led the involvement of teachers, and the bottom-up action built the curriculum.

To achieve consensus a more effective space for sharing needs to be built of: point of view, presentation and discussion of results and the indication of tools that could help to define hit better routes, and overcome difficulties, ensuring a good performance of the new curriculum. It could be possible, for example, with a more effective meetings organized by the leaders of PAE.

As the curricular change was delineated in a not directive way, it was possible to open space for the contribution and influence of teachers in the phase of formal curriculum. The three types of approaches, Projects, Engineering Practices and Workshops, initially defined in an open way, was over time been defined in a more specific way by teachers work, showing the commitment that they have taken on this challenge, and placing their mark on the construction of the curriculum.

Although all the potential for the development of transversal competences was not been fully used at this first year, teachers became aware of the role they should play in guiding and supporting students' work. The transmission of content overlaps with the development of competences, although soft skills are recognized by teachers as important in the training of students.

From teachers' point of view, the students did not have the desired level of awareness of the importance of the new approaches in their development, considering the PAE as tasks that should be fulfilled in order to reach approval, instead of being perceived as learning spaces of competences. Both teachers and students said that the PAE should have more close connections with course subjects. This discourse indicates that the idealized curriculum has not yet found an identity in its operationalization. If there is the claim for the link with the content of the courses, on the other hand there is a low awareness about need development of soft skills.

A better communication about the objectives of PAE, their contribution to training students and the development of competences with these strategies is required. Beyond the authority, infrastructure and consensus in between teachers, it is need sensitize students about the importance of to catch more than contents at scholar environment.

It can be said that the curriculum is process resulting from a co-construction with alignment and contribution of all stakeholders involved: leaders, teachers, and students. This co-construction is an ongoing process and it is important to encourage it to achieve an innovative engineering curriculum.

7 Acknowledgments

The authors thank all teachers and students who kindly participated in this research.

This work was partially supported by projects COMPETE-POCI-01-0145-FEDER-007043 and FCT-UID-CEC-00319-2013, from Portugal.

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