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Reflecting on 21 years of running full PBL programs

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The technological programs offered at the Higher Education Polytechnic School of Águeda, one of the Departments of the University of Aveiro, have been organized, since 2001, around the Project Based Learning paradigm. This paper will briefly set the scene for the educational development and will then proceed to give an historical perspective on the curriculum developments that took place along the last 21 years, reflecting the experience grown on the field. Finally, the author will offer his personal perspective on the difficulties and benefits of the development and its implementation, as an engaged agent in the process. Preliminary results of a study aiming at understanding the impact of the program in its graduate's careers will also be mentioned.

KEYWORDS

project-based learning, curriculum development (education), engineering education, electronics engineering education, mechanical engineering (education)

1. Introduction

Over the last two decades, higher education systems have been urged to change their learning environments because of pressure from students, employers, and society at large, in demand of adequate answers to the challenges of a rapidly changing world. Mass education, diversity of student profiles, as well as cultural, sociological, and economic changes have all contributed to this scenario. In such a context, an emphasis has been put on the shift from teacher-centered to student-centered systems, in which the development of transversal capabilities gains relevance, the demand being that the opportunities for their development should be made explicit in the learning experience (Cowan, 1987; Fallows and Steven, 2000; Larson et al., 2021). In Europe, these changes have been further fueled by the Bologna process, despite the many different interpretations and implementations that the various national political systems have found appropriate to establish in their realities.

Considering this scenario, also for institutional reasons, the Higher Education Polytechnic School of Águeda - University of Aveiro (ESTGA) has decided to move toward the Project-Based Learning (PBL) paradigm in its three-year technological degrees. The process started in 1999 and developed into an overall educational paradigm change. After 3 years of internal discussion and curriculum development, in October 2001 the move took place on the field. The process of change is thoroughly described by Alarcão (2006) and Oliveira (2006), and will therefore only be briefly mentioned in this article.

After 21 years of running these programs, adjusting the curricula to the ever-evolving reality, in response to evaluation processes and the now substantial evidence of the benefits of PBL environments that can be found in the literature (Gijbels et al., 2005; Strobel and Van Barneveld, 2009; Hamoush et al., 2011; Chan, 2016; Mitchell and Rogers, 2019; Guo et al., 2020), it is possible to look back and critically reflect on the overall experience. The need to continuously reflect and adjust the implementations and pedagogical stances in response to societal needs and evaluation are also at the core of Kolmos et al. (2013) and Visscher-Voerman and Muller (2017), which address evolutions of the Aalborg model and of the Twente Model, two cases of full program implementations of PBL which are references in the field of engineering, and whose early implementation models inspired the development discussed in the present article.

This article follows a previous one (Oliveira, 2011), in which such a reflection was also the goal, after 9 years of the first implementation. Since some of the points made in that article are still valid, they will be summarized in the present paper, for the sake of readability. However, much has changed since, and a new reflection is therefore due. Also, although one can find in the literature numerous descriptions of PBL implementations and their evaluations, reports of those developments over the years are rare - exceptions can be found in, e.g., Askehave et al. (2015), Lima et al. (2017) and Visscher-Voerman and Muller (2017). This article tries to help fill that gap, reflecting on a development that has endured over two decades. Also, fully PBL organized curricula within the engineering field are not the norm, which adds to the relevance of the reflections offered throughout the text.

The article will set out to discuss the overall conceptual curricular structure of ESTGA's implementation and will then proceed to give a brief historical perspective on the evolution of the curriculum, and the reasons informing those changes. Finally, the author will offer a personal perspective on the development, reflecting on the accumulated experience as an engaged agent in the process, discussing the challenges of running a PBL curriculum on a daily basis. Since the author's experience has been mostly related to the Electronics and Mechanics degree, this program will serve as the basis for the overall discussion.

2. ESTGA's PBL curricular framework

In inquiry-based learning environments, learning is triggered by real-life problems, which are usually complex, multidisciplinary and open-ended, in the sense that there may be more than one possible solution (Savin Baden and Howell, 2004). The learning process unfolds while students attempt to solve those problems, in a self-directed effort, which is necessarily different from a path pre-defined by the teacher. Students assume responsibility for their learning, thus defining their own learning needs, at their own pace (Boud and Feletti, 2014). This type of setting also creates the necessary environment for the development of personal and professional capabilities: students work in small groups, plan their own tasks, search for information autonomously, in a context which is close to the requirements of the job market, and promotes long-life learning capabilities. A focus on self and peer-assessment opportunities to promote reflection on the students' learning experience is also an important feature of inquiry-based learning strategies. When navigating the literature on these topics, one is often confronted with the difficulty in distinguishing between approaches, namely Problem-Based Learning, Project-Based learning, and more recently, Challenge-Based Learning. Further insights into these approaches can be found in Sukacke et al. (2022), which provides a comprehensive review of the literature. In accordance with this reference, and for the rest of this article, ESTGA's development shall be considered a Project-Based Learning implementation, since it focuses on the engineering design process of concrete projects, providing a product as the final solution to the problems.

For the sake of the understanding of some of the remarks made in posterior sections, it is important to describe the curricular structure of ESTGA's PBL development. This description is available in previous articles (e.g., Oliveira, 2006; Oliveira and Estima de Oliveira, 2009; Oliveira, 2011), but the need for coherence and readability calls for a condensed version.

The curriculum is organized around thematic modules (TM), a form of aggregate curricular units, which consist of a project and a set of supporting courses. As the name indicates, each TM corresponds to one important theme to be addressed by the program. The idea behind these modules is to concentrate the delivery for the goal themes in the same semester, instead of spreading them out along the program, as is usual in more traditionally organized degrees. This structure is inspired by the Aalborg model (Kjersdam and Enemark,

TABLE 1 Industrial Electronics and Mechanics curricular plan.

Semester		Curricular Unit	ECTS Partial	ECTS Total
1st semester	Thematic Module	PROJECT - APLLIED PROGRAMMING	6	12
	Thematic Module	ALGORITHMS & COMPUTER PROGRAMMING	3	
	Thematic Module	ELECTRICAL CIRCUITS	3	
		GENERAL PHYSICS		6
		TECHNICAL DRAWING		6
		MATHEMATICS I		6
2nd semester	Thematic Module	PROJECT - AUTOMATION SYSTEMS	6	14
	Thematic Module	PROCESS AUTOMATION	4	
	Thematic Module	APPLIED ELECTROTECHNICS	4	
		APPLIED ELECTROMAGNETISM		6
		3D MODULATION		4
		MATHEMATICS II		6
3rd semester	Thematic Module	PROJECT - ELECTRONICS & INSTRUMENTATION	9	18
	Thematic Module	DIGITAL SYSTEMS & MICROCONTROLLERS	3	
	Thematic Module	INSTRUMENTATION & CONTROL	3	
	Thematic Module	ELECTRONICS	3	
		MATERIALS SCIENCE		6
		NUMERICAL & STATISTICAL METHODS		6
4th semester	Thematic Module	PROJECT - COMPUTER ASSISTED PRODUCTION & MECHANICAL SYSTEMS' CONCEI	9	18
	Thematic Module	MATERIALS RESISTANCE	3	
	Thematic Module	MANUFACTURING PROCESSES	3	
	Thematic Module	COMPUTER ASSISTED MANUFACTURING	3	
		THERMAL SYSTEMS		6
		ELECTIVE COURSE		6
5th semester	Thematic Module	PROJECT - INDUSTRIAL ELECTROTECHNICS	9	18
	Thematic Module	INDUSTRIAL ELECTRONICS	3	
	Thematic Module	INDUSTRIAL ELECTRICAL INSTALLATIONS	3	
	Thematic Module	CONTROL OF ELECTRICAL MACHINES	3	
		ELEMENTS OF MECHANICAL SYSTEMS		6
		OPERATION AND PROCESS MANAGEMENT		6
6th semester	Thematic Module	PROJECT - INDUSTRIAL AUTOMATION	9	18
	Thematic Module	AUTOMATION & ROBOTICS	3	
	Thematic Module	HYDRAULIC & PNEUMATIC SYSTEMS	3	
	Thematic Module	INDUSTRIAL NETWORKS	3	
		INTERNSHIP		12

1994; Kolmos et al., 2006; Askehave et al., 2015) and allows for closer to reality projects, which are the core and the driving force of the learning process. Supporting courses address basic, fundamental concepts, thus providing for an integrated learning experience. In the next section, a current curricular plan is presented in Table 1, in which the shaded areas represent TMs; courses not included in those areas are dedicated to general complementary subjects, not directly related to any of the themes: these are called autonomous courses. All courses are taught in 4-h blocks that can be organized according to the course and the learning needs at any stage of the process. The flexibility is thus enhanced, with the 4 h-blocks allowing for an easy reorganization of the provision for teaching according to students' needs, usually in close articulation with the thematic projects. These 4 h periods also allow for the introduction of diverse active learning strategies across the curriculum, discouraging the temptation to use more traditional magistral lecture-oriented practices.

Projects are developed in small groups of students (four to five members), which are granted extended access to laboratories, evenings and weekends included, and thus have no timetabled hours. Groups are assigned a supervisor for every project being carried out. The supervisor's role is to facilitate students' progression, to guide without disclosing solutions, and to help the learning process by asking meaningful, directing questions.

At the end of each semester, groups are required to deliver a written report and a public presentation of the project, before a jury – one of the members being the project supervisor. The presentation is followed by a period of discussion, in which students may be individually requested to answer different questions. It is common practice to invite individuals from other HE institutions or from industry to sit as members of the jury, allowing students to gain different perspectives on their work. Complementarily, self and peer assessment strategies are strongly advised and have become common practice for most projects.

Unlike the early Aalborg model, all courses are assessed individually, making use of diverse strategies. The "re-constructed" Aalborg model (Kolmos et al., 2013) has also moved in this direction. In fact, ESTGA's development can easily be viewed as one of the possible implementations of both the redesigned Aalborg and Twente (Visscher-Voerman and Muller, 2017) models.

Conceptually, and according to the framework proposed by Chen et al. (2021), in which four levels of PBL practice are suggested, namely Course Level, Cross-Course Level, Curriculum Level and Project Level, the implementation described in this article falls into the Curriculum Level. This means that the implementation is "Inside the professional training design," organized within the university, and may use "A combination of one discipline and multidisciplinary projects/problems." The framework described in the previous paragraphs is in accordance with all these requirements. Furthermore, and according to Kolmos (2017), it can also be considered within the scope of "a re-building strategy which involves re-thinking of the role of the university in society and re-thinking the curriculum toward much more flexibility" and is therefore systemic in essence.

3. An historical perspective of the development

This section is dedicated to a brief historical perspective of the evolution of the educational development and respective curriculum plans for the degrees within the Electrical and Mechanical engineering subject areas. Some of these plans have already been published elsewhere and, therefore, the reader will be referred to those publications for further details.

The process of change took 3 years (1998–2001) to prepare and, given ESTGA's small dimension at the time, it involved every member of the staff. This process, which is thoroughly described in Alarcão (2006) and Oliveira (2006), involved staff training workshops and it was itself run in a PBL environment, with the project consisting of the curriculum development of the degrees offered by ESTGA at the time: Electromechanical Engineering (EME), Surveying Engineering, and later, Electrical Engineering (EE).

The first curriculum plans that were implemented on the field in October 2001 (Oliveira, 2006), did not have projects in the first year, as a result of long-lasting internal discussions, which reflected the insecurities of the staff at the time, some of which were still coming to grips on how the program would be run in practice. A first evaluation of this implementation is also offered in Oliveira (2006). Nevertheless, all courses used the four-hour long format to stimulate the implementation of active learning strategies. In this implementation, students attended two parallel TMs from the second year on, one dedicated to Electronics' themes, and one dedicated to Mechanical Engineering themes (in the case of EME) or Industrial Electrical Installations (in the case of EE).

In 2006, because of a directive of the Portuguese Ministry for Higher Education (MHE) regarding the way students accessed HE at the time, the Electrical and Electromechanical Engineering programs were merged, resulting in a single Electrical Engineering degree with two branches: Mechatronics and Industrial Electrical Installations. The two programs already had the 1st year and 50% of the TMs in common (those regarding Electronics) and therefore, the merge was made a lot easier by the structure described in the previous section.

The opportunity was taken, in response to the result of internal evaluations, to introduce TMs right from semester one, to involve students in a full PBL environment as soon as possible, and develop project-work transversal capabilities, that they lacked when moving on to the second year in the original development. In the third-year students had to choose between one of the branches. This transition is described in detail in Oliveira and Estima de Oliveira (2009). It is worthy of mention that the Bologna process, which took place in all Portuguese HE institutions in 2007, by imposition of the MHE, had no impact whatsoever in the ESTGA's PBL development, because all the conditions of the process, both conceptual and political, were already met since the 2001 implementation.

A few years later, in 2012, the program underwent the first accreditation review process, by the Portuguese Accreditation Agency. In the self-evaluation report required by this agency, it was possible to suggest curricular changes to the program. As a result of internal discussions and evaluations, ESTGA suggested a few alterations, the most important one being that the separation between the two branches started in the 4th semester instead of the 5th. This alteration allowed for a more even balance between the number of TMs dedicated to each major subject area of the program. A few other minor alterations were suggested by the accreditation review panel, but none of them induced a major change in the curriculum plan nor in the overall PBL development.

It should be noted that the iterations mentioned so far involved other minor changes in terms of contact hours or the inclusion or exclusion of certain courses. Apart from the fact that these have been discussed in some of the references provided so far, the author does not believe that they are worthy of mentioning in a paper dedicated to an overall reflection on the development.

Finally, in 2018, when a second iteration of the accreditation review process was approaching, the staff involved in the program, recognizing that it was time for a major change, worked as group to propose a new program in response to the ever-changing landscape of the industry, on one hand, and of the students' profiles and the attractiveness of the degree to new emerging publics, on the other. The overall framework discussed in Section 2 was not altered in any substantial way, but four major changes took place:

- The evolution of the industrial landscape, with the advent of the Industry 4.0 conceptual framework (and its future evolutions) requires professional profiles capable of integrating in a more interdisciplinary way areas of knowledge involving Electronics, Mechanics and Industrial Informatics, not to mention an array of ever more demanding transversal capabilities, which were already the focus (and a successful product) of ESTGA's PBL development. To address these changes, the branches disappeared, and students are now required to address a single project per semester. These projects are granted a larger workload and became much more transversal, interdisciplinary, and ambitious. In the author's opinion, this change also reflects a much-increased pedagogical maturity of the staff involved, and engagement with the PBL paradigm and its challenges.
- In alignment with the previous point, the first year's TMs, without forgetting the need for developing students' project-work capabilities, became much more technology centered, which enhances student integration in PBL and allows to start addressing, at the first-year level, themes like Automation, which can later be integrated in every other project.
- Another important change has to do with the inclusion, in the final semester, of an internship in actual companies, a feature that has become more popular over the past few years and in which ESTGA, as a whole (nowadays offering seven first-cycle programs and five second-cycle programs) has been developing a wealth of accumulated experience.
- Finally, a change of the program name, from "Electrical Engineering" to "Industrial Electronics and Mechanics," which appeals to a larger audience and a wider range of publics coming from the Portuguese secondary education system. Although the program has always been able to captivate many students, it did not perform very well with the young students coming directly out of the regular secondary system. The change in the name has proven, in the last 2 years, to be a success.

This new program, which obtained an "approval without conditions" grade from the Portuguese Accreditation Agency (which means that no alterations to the proposed curriculum were required by the accreditation pannel), has been on the field since 2020. Naturally, it will be the subject of future evaluation processes. Table 1 shows a detailed curricular plan of the new program. Further details on the learning outcomes for each TM and each specific courses, as well as assessment strategies, can be found on the institutional website.[1]

1 https://www.ua.pt/en/curso/465 (last accessed on December 14, 2022).

4. On the challenges of running a PBL environment: A personal perspective

The author has been involved with the ESTGA's PBL development from the beginning, first just as a member of staff, and later as the informal coordinator of the change process and further development. After 21 years, he is still an involved member of staff, and one that is engaged with project supervision and facilitation of associate courses, which allows him to have an overall perspective of the development.

As stated in Oliveira (2011), the first conclusion to be taken out of whole development is, again, that it is, at least, as hard to keep it running than to set it up. Such an ambitious development cannot be regarded as a time-limited experiment, but rather as an on-going process. Attitudinal changes take time and reflection, a statement that is still true to this day.

As in the previous article, the following sub-sections will address three dimensions in turn: one concerning the teachers involved; one concerning the students' attitudes toward learning and the institution; and finally, the institutional culture dimension. For the sake of readability, and for each subsection, a summary of the points that are still valid at the time of writing will be provided, followed by the added value reflection on the 12 years that followed the previous article.

4.1. The teachers' dimension

In Oliveira (2011), the following main points regarding this dimension were made:

- The teachers' attitudinal change is probably the most difficult to achieve since their personal beliefs and attitudes toward the learning process are an important barrier to overcome. Usually, academics have been educated in quite traditional environments and tend to reproduce their own educational experience. Breaking that barrier requires proper training. The contribution of experienced staff developers with an engineering background creates empathy with the audience more easily.
- In active learning environments, students are engaged in learning activities involving discussion, presentations, and brainstorming. Teachers are much more easily confronted with the lack of knowledge some students exhibit, especially when it comes to the pre-requisites. It is more comfortable to resort to traditional lectures than to address those difficulties and purposely help students to overcome them. Establishing a culture of group work and group discussion among teachers may be a way to overcome this tendency.
- The role of top management is crucial in creating adequate conditions for staff teamwork and nudge staff members to participate, yet without being too imposing.
- In a PBL environment, a closer relationship between teachers and students happens naturally, due to the nature of the learning activities, but teachers are not always prepared for the related implications. Teachers need to be more available for students, both for informal, out of class, student-teacher interactions, and in terms of the schedule for those interactions, given its spontaneous and unforeseeable nature.
- Dealing with dimensions of students' lives such as group work problems, inter-student relationships dilemmas, time management difficulties, and even their emotional problems

> when going about the learning process is very hard and stressful for teachers. Given that students' affective needs are almost as important as their cognitive needs, if they are to be successful in their learning, these situations should be viewed as opportunities to help students move forward.

These points are still valid nowadays. Teacher training, which in 2011's Portugal, for HE professionals, was not readily available, has evolved immensely over the past few years. The pressing need for innovative pedagogical change, boosted by the Bologna process and other international trends, fueled the need for training workshops as part of intended developments in institutions across the country. These workshops have been run either by invited international guests or by national guests who, like the author, had an accumulated experience of being involved with established innovative developments in the country, that were part of international networks and therefore recognized for their experience. In some of these workshops, apart from the curriculum development aspects, the other aspects mentioned earlier were also addressed, which meant, in the author's opinion, a major step forward.

More recently, the University of Aveiro (along with some other institutions, like the University of Minho) has launched an internal and ambitious teacher training program that includes regularly available workshops, experience exchanging events and even an yearly event[2] in which a group of interested teachers from several institutions meet for a few days, away from their regular obligations, to attend workshops, discuss difficulties and develop ideas on how they can change their own courses/programs, and so forth. In parallel, several Communities of Practice have been established to disseminate and discuss experiences among its members.

For ESTGA, this program represents a very important step, since newly hired staff, who had not undergone the initial change process, had little access to specific training. The way in which ESTGA dealt with this issue was to, whenever possible, pair up a newly hired member of staff with more experienced ones, taking advantage of peer-learning to acculturate the incoming staff member. Also, regular meetings of staff involved in a particular program are incentivized, which provides both for internal discussion and monitoring of the process. These meetings are also a safe place to discuss difficulties and ask colleagues for advice, thus furthering the establishment of a more profound institutional culture.

As a reflection, staff meetings are an extremely helpful tool to maintain the status quo of a PBL environment. It is also worthy of notice that all the developments mentioned in Section 3 involved all members of staff within the related subject areas, even when smaller groups oversaw the filling in of the necessary bureaucratic documents. The author believes that the teamwork and discussions about the strategic directions of the overall development have been instrumental to its cohesion. After all, if one expects students to work in groups, why should not the teachers be able to do at least as much?

Naturally, the COVID-19 pandemic also played a crucial role in the way that the past few years were impacted by the move to distance learning. In a PBL environment., the resource to simulation tools was unavoidable, and ESTGA made the effort to send some equipment to at least one member of each group. Even so, the peer learning that takes place by the close contact between students was severely impaired.

4.2. The students' dimension

In Oliveira (2011), the following main points regarding this dimension were made:

- Usually, students get to Higher Education with limited experience of self-directed learning. Introducing students to a PBL environment, in which they need to take responsibility for the learning process is a challenge, and one which requires an attitudinal change on the students' behalf.
- It is extremely important to explain to the students what PBL is about and the reasons why the institution is committed to pursue that pedagogical approach. This can prove to be a powerful way of getting students on board. Supporting students during their journey, both cognitively and affectively is also very important.
- Self- and peer-assessment activities play an important role in engaging students in the overall process. In the author's experience, illuminative formative assessment (George and Cowan, 1999) activities can be a valuable tool in promoting students' involvement and pushing them to reflect on the learning experience.
- In more traditional environments, students tend to regard programs as mere collections of courses, which they are required to pass, one by one, to obtain a diploma. Changing this conception to one in which they view the program as an overall learning experience is the goal. Overcoming that conceptual barrier is a major challenge, and one that is crucial for the development of a PBL environment.

Although all the points just presented are still valid, and ESTGA has been able to address those aspects consistently over the years, through in-class discussions and promoting contact between students from different years (taking advantage of peer learning and the exchange of experiences, once again), one cannot avoid the effect of the COVID-19 pandemic in the students' profiles of the past few years. The impact was first felt by our students, due to the lack of interaction and the reduced opportunities of hands-on experience, which had an effect on their learning. However, one must admire their resilience and that of the staff involved during the lockdowns. Nevertheless, in a learning environment which relies so much in group work, peer-learning and hands-on experience, the toll was hard to overcome in the next year.

Over the last year, a new impact of the lockdowns hit all HE institutions: the profile of the new incoming students, which were put through their final secondary education years in distance learning environments. These students exhibit lack of focus, difficulties in establishing meaningful relationships with their fellow group members and a general apathy toward self-directed learning. These aspects are challenges that need to be addressed with a fair amount of strength and support to the students. The establishment of clear

2 Docência+: https://www.ua.pt/en/inovacaopedagogica/page/26714, (last accessed on December 14, 2022).

milestones throughout the semester, including preliminary project presentations, may be instrumental in the response to these challenges.

4.3. The institutional dimension

In Oliveira (2011), the following main points regarding this dimension were made:

- Maintaining a PBL environment requires an institutional culture which regards the teachers, the students, and the available resources in a significantly different way than in most traditional environments.
- The way in which the institution deals with the teaching staff is crucial. Proper training and support should be made available for the staff involved, not only during the implementation phase, but also on a regular basis. It needs to be clear that the institution regards PBL as an important feature of its strategy. As mentioned earlier, the institution plays an essential role in the fostering of a team-work climate, which is essential to the congruence of the curriculum.
- Running a PBL environment can be extremely absorbing for teachers, which will have an impact in the time that they can dedicate to other activities, such as research activities. It is crucial that the institutional culture develops, starting to regard teaching activities as an important factor for career progression, and strategic for the institution development. Creating schemes in which teachers get free time for research activities on a regular basis is of the utmost importance.
- Monitoring the process serves the purpose of informing whether the goals are being met, so that measures can be taken in accordance. An effective monitoring system exerts a healthy amount of pressure on all the involved agents to show that they are aligned with the development; it also creates the opportunity to discuss blockages within the structure and examples of good practice. Establishing a well-designed monitoring system becomes part of the new institutional culture.
- When it comes to resources and their management, the institution must rethink its usual procedures. Apart from the need to provide appropriate resources for the projects being developed, broader access to laboratories and equipment should be granted to the students. This requires new ways of managing the working spaces. For instance, at ESTGA, common-use laboratories and students' rooms are open on a 24 h/day, 7 days/week basis, allowing students to manage their own schedule.
- Traditional lecture halls no longer make much sense and should give way to more flexible, smaller spaces, in which chairs and tables can be rearranged to meet the needs of the learning activities. A significant change in the working space setting and the way it is accessed is, in itself, a factor of change in the institutional culture: it influences the way students and teachers interact with the structure and among themselves.

All the points just made are, again, still valid nowadays. It should be stated, though, that ESTGA has developed a now mature institutional culture that addresses all those points satisfactorily, although only technological programs are PBL organized. This requires a flexibility and institutional maturity that needs to be recognized. It also results from the fact that, as stated in Oliveira (2006), two movements have to be present in any institutional change: one from the bottom up (meaning that the staff are on board and believe that this is the right way to go), and one from the top down, in which senior management recognizes the change as strategic and is willing to adjust and to provide the necessary means, without being too imposing.

5. Final remarks

Internal evaluation strategies have been put in place over the years and their results have informed most of the developments described in previous sections. An important aspect to consider is the impact of going through a PBL program in the graduates "after" life, either in the working place, or if they decide to pursue further education in more traditional environments. An investigation on this latter aspect (Oliveira, 2014) found that the impact is quite positive and that although students do struggle with the change in the learning environment, they become even more aware of the advantage of the transferable competencies developed during their first-cycle program.

Preliminary results of an ongoing study that tries to look at the career paths of alumni, and their impressions on the importance of having been exposed to a PBL environment, also show positive results. Alumni recognize the importance of their learning experience, especially in the early years of their careers. These results also point to career paths that value their problem-solving skills, attributed largely to their exposure to a project-based organized curriculum. This seems to translate into rapid evolutions toward the product development units of the companies they work for, and then lead to managing positions in those units.

Finally, in this article, a PBL implementation has been described and reflected upon after 21 years of accumulated experience. The author's personal perspective on the challenges that need to be addressed in establishing a project-based learning environment has been discussed and some suggestions for addressing those challenges have been offered. No matter how overwhelming these challenges may seem, after reading the paper, it should be noted that it is the author's deep belief that it really is worth the effort and that moving towards a student-centered, project-based learning environment may represent an answer to the challenges of our globalized, fast changing world and society. The world has changed dramatically over the past few decades, and higher education systems should change accordingly, becoming a part of an adequate response to that change.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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