Teacher collaboration in PBL: setting the example for the students

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Abstract

This paper discusses collaboration between teachers in project-based learning (PBL) environments in the engineering context. PBL is a challenging active learning methodology, not only for students but also for teachers. Challenges for teachers include, for example, the need to search for new knowledge demanded by the PBL project theme and the difficulty of aligning their own disciplinary area with interdisciplinary areas in a project. PBL compromises common assumptions of teachers, such as the considerable control over the classroom, reliance on their expert knowledge, predictable programmes to teach, the course assessment, the individual work, among others, whereas, probably, the most challenging aspect of PBL from a teacher perspective is teamwork of the teaching team. Teacher may well feel uncomfortable with sharing knowledge and being exposed and/or assessed by their students and peers. At the same time, PBL requires teachers to think about student achievement and success in first place instead of using more mono-disciplinary course based approach. In this paper, the authors will present evidence through literature review and experience in PBL contexts that such collaboration is highly recommended, if not mandatory, for the PBL success. The paper will also advocate that teacher collaboration is important as an example for students to engage in collaboration.

Keywords: Engineering Education; teachers' collaboration; Project-Based Learning (PBL).

1 Introduction

Collaboration, teamwork and the development of shared tasks has always been a common practice amongst higher education teachers. With the grown interest and implementation of student-centred learning approaches (Gaebel et al., 2018) and multidisciplinary project approaches, especially within the Engineering Education field (Guerra et al., 2017), the opportunity for greater teacher collaboration also arises.

Research on teacher collaboration in Engineering Education reveals a great number of different concepts which refer to this same idea, for example, team teaching, co-teaching and collaborative teaching (Vesikivi et al., 2019). According to these authors, team teaching can be defined as two or more teachers planning, instructing and evaluating the learning of a single group of students; co-teaching refers to two or more teachers instructing a multidisciplinary student team in the same classroom; and, collaborative teaching emphasising teacher collaboration and co-operative teaching is used. However, despite the number of teachers involved and their role in the teaching and learning process, these authors argue that "the definition of team teaching should be based on the pedagogical approach and grounded in learning theory" (Vesikivi et al., 2019).

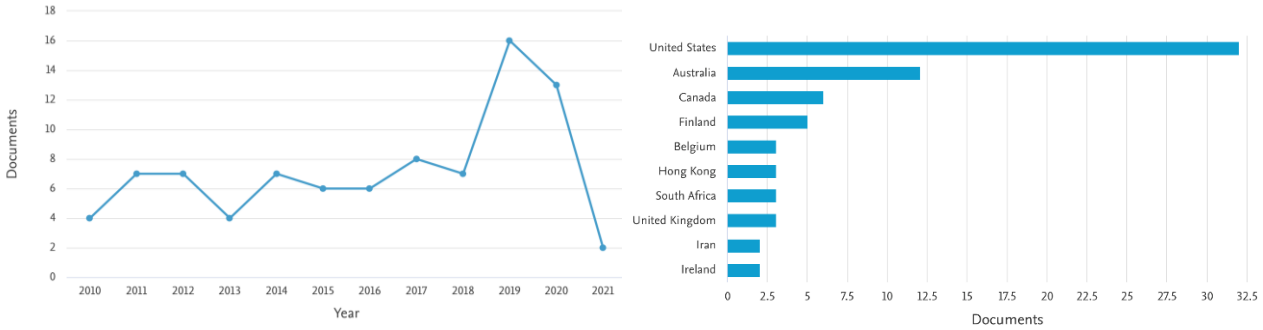
The active learning methodology known as Project-Based Learning (PBL) involves students actively in their own learning. In this context, students, working in teams, must carry out a project to solve a large-scale complex open-ended problem, through a long period of time (Powell & Weenk, 2003). To support this development, teams have the support of their teachers and the knowledge and skills acquired from the courses. This means teachers must plan, work and collaborate with each other and discuss about education issues across boundaries to help teams in this endeavour (Powell, 1999). According to this same author, PBL requires teamwork for tutors, teachers, administrators and integration over the traditional subject boundaries, what could be considered a disadvantage of the PBL.

Having higher education teachers work together seems to have many advantages, but could be rather challenging, if they are not used to do so. The objective of this paper is to explore the difficulties that teachers face by presenting a literature review about the importance of teacher collaboration, its benefits and difficulties on this. Also, the authors illustrate the findings from the literature with experiences from their own learning process as teachers working in teams.

After this brief introduction, section two presents a brief literature review about team teaching in Higher Education. Section three describes the research methodology followed to achieve results. The results are presented and discussed on section four, which is organized based on the overall results and evidence from PBL practitioners' experience. The last section of the paper presents the conclusions and final remarks.

2 Team Teaching in Higher Education

Team teaching is not a phenomenon that is exclusive for engineering education. When analysing 177 publications on team teaching in SCOPUS, of which 117 (66.7%) are articles, 33 (18.6%) are conference papers and 22 are book chapters (12.4%) using ALL ("higher education") AND TITLE-ABS-KEY ("team teaching")) PUBYEAR > 2009 AND (LIMIT-TO (LANGUAGE ,"English")) most are actually from the social sciences, 52.6%, followed by computer science (9.3%) and engineering (9.0%). Figure 1 presents some graphs retrieved from Scopus with number of documents by year and country/territory.



a) b)

Figure 1. Documents found in the search classified by: a) year; b) country/territory

Of the articles, conference papers and book chapters, 87 are focused on team teaching whereas the others have a focus on approaches to teaching, forms of students learning or educational innovation in a broader sense and do not focus specifically on team teaching. When looking at these in more detail, at the 87 papers, the relative number of engineering papers is even lower, 6.1% (Figure 2).

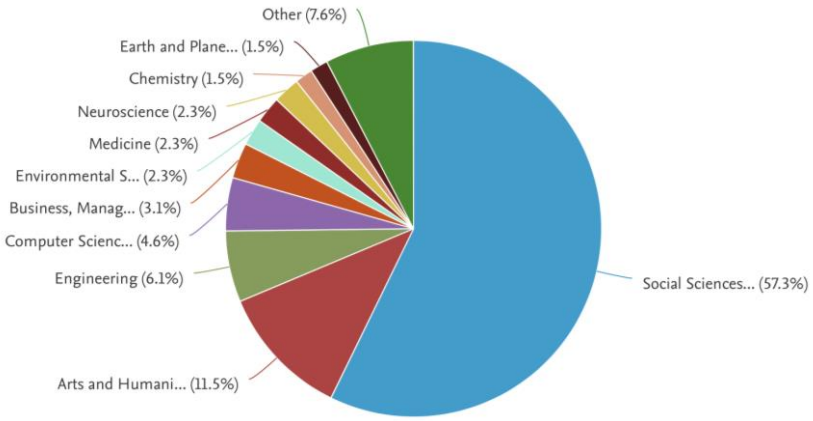


Figure 2. Documents by subject area

A single definition of team teaching was not found, but various authors refer to characteristics of team teaching like Minett-Smith and Davis (2020) who refer to the involvement of two or more teachers, the degree of interaction between the teachers, the resources they share and the interdependence between the teachers.

Liebel, Burden and Heldal (2017) do not provide a single definition either, but refer to the purpose of team teaching, especially in an interdisciplinary context, where team teaching can be used for alignment of course objectives. Their study shows the benefits of team teaching, like providing multiple explanations of the same concepts which can be beneficial for student learning. Benefits are also acknowledged by Jones and Harris (2012), who found that team teaching can be positive for both students and teachers, especially when having uniform purposes and expectations and really working as a team. They also acknowledge the reflection on teaching and assessment that team teaching can encourage, especially when mixing teaching assistants and more experienced teachers. The authors have identified a number of requirements for team teaching to be successful, like continuity in the team, a great deal of mutual trust and the absence of hierarchical relationships within the team.

Vesikivia, Lakkalac, Holvikivid and Muukkonene (2019) also refer to team teaching as the effort of, at least, two teachers and identify a number of challenges to overcome in their study at a Finnish university of applied sciences. Teachers may fear a loss of autonomy when shifting to team teaching and face a lack of time when planning and preparing team teaching efforts. The authors point out that this requires leadership that answers the teacher concern. Team teaching is not always welcomed by every single team member, so institutional support can help to overcome the challenges. Money and Coughlan (2016) show that benefits from a teacher point of view do not necessarily coincide with the benefits as identified by students. The joint effort that can result in a decreased workload for teachers may also result in duplicated and conflicting content for students. In order to find out what the characteristics of team teaching mean for project-based learning, especially in an engineering education context, the publications given above are explored more in detail.

3 Research methodology

This study uses a literature review (Miles & Huberman, 1994), to answer the following questions:

- What does the scientific literature say about teacher collaboration in Project-Based Learning (PBL) in the context of Engineering Education?
- What are the reported benefits and difficulties of its use?
- What does evidence from the experience of PBL practitioners in Engineering Education reveal?

To answer the first two research question, a literature review was developed using the Scopus database. As the theme is the teachers' collaboration in PBL in an Engineering context, the keywords used were related to Engineering education, Team teaching, Teacher collaboration and experience and Project-based Learning and its acronym. The time-frame considered was last decade (since 2010) and sources chosen were journals, conference papers and book chapters. The string used was:

- (ALL ("Engineering education") AND TITLE-ABS-KEY ("Team teaching") OR TITLE-ABS-KEY ("Teachers collaboration") OR TITLE-ABS-KEY ("Teachers experience") AND TITLE-ABS-KEY ("PBL") OR TITLE-ABS-KEY ("Project based learning")) AND PUBYEAR > 2009

The last research question focuses on evidence based on a literature review of publications of a team of PBL practitioners connected to the first year of the Industrial Engineering and Management (IEM) degree program of the University of Minho, Portugal.

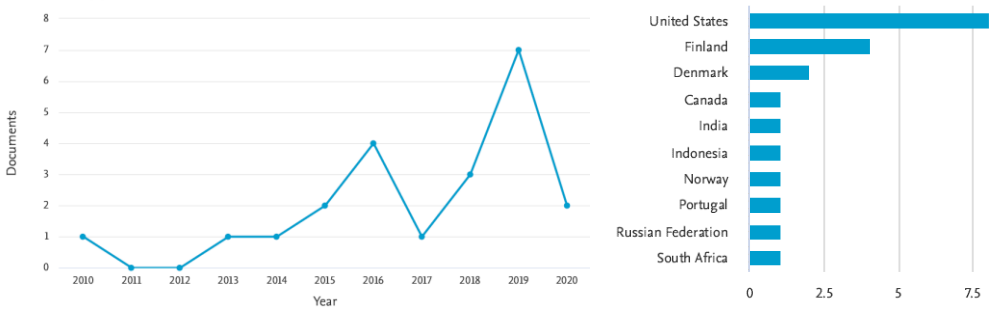
4 Results and discussion

The results of the literature review are presented in two subsections: the first section presents an overall analysis of the bibliometric results retrieved from the Scopus database search, supported by a summary of the main findings based on the studies analysed; the second section, reports on findings based on the literature on the PBL practitioners' own experience.

4.1 Overall results

The search in Scopus database produced 22 results, according to the criteria mentioned previously in the methodology section. The main descriptive statistics are reflected in the graphs of Figure 3a) and Figure 3b),

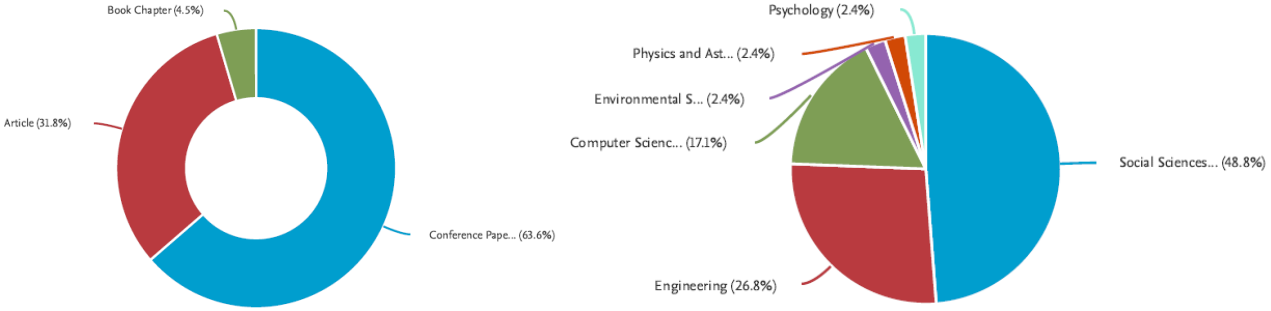
that present, respectively, the documents by year and country. The year 2016 and 2019 are the years with more publications. The United Stated and Finland are the countries that lead the publications in this research topic.



a) b)

Figure 3. Documents found in the search classified by: a) year; b) country/territory

Other descriptive statistics are the documents by year and country reflected in the graphs of Figure 4a) and Figure 4b), respectively. Regarding the type of documents published, the majority are part of conference proceedings (63.6%), followed by articles (31.8%) and very few are book chapters (4.5%). The main three subject areas of the publications are Social Sciences (48.8%), Engineering (26.8%) and Computer Sciences (17.1%).



a) b)

Figure 4. Documents founded in the search classified by: a) type; b) subject area

Four papers were excluded from the analysis as one paper was not in English and the full text of three papers was not accessible to the authors, leaving a total of 18 papers to be analysed in detail of which content wise only 9 papers were considered relevant for this study and its research questions. The identification of these papers is provided in Table 1, as well as a short description of the main benefits and difficulties or requests or recommendations of/for teachers' collaboration in PBL context.

Table 1. Benefits and challenges of team teaching according to teachers in PBL experiences

Reference	Features of PBL	
	Benefits	Challenges
(Singh-Pillay, 2020)	• catalyst for pre-service teachers' awareness of their role as agents of change; • collaborative reciprocal learning; • promotes deep thinking about actions; • helps to break stereotypes and allows teachers to belief in the good of others; • positive feelings toward group members and developed collegial relationships; • provided teachers with the skills needed to successfully manage life tasks such as identifying anxieties, labelling emotions, learning in groups, teamwork, awareness of themselves and others	• need for kindness and respect for others, forming relationships, care about others, make good decisions, behave ethically, avoid negative behaviour and overcoming biases; • powerful and transformative nature of PBL, in terms of shifting existing frames of references; • need to be conscious of their roles as agents of change in the communities they worked in.
(Vesikivi et al., 2019)	• opportunity to develop their teaching skills • helps teachers in forming a holistic understanding of subject matters and their relations.	• expense of losing at least some of the teacher autonomy; • requires development of teamwork skills; • loss of autonomy and getting enough time and resources for planning the courses;

	• sharing positive experiences with more reluctant colleagues hopefully encourages the sceptics to try out the new practices and start applying them • when teachers feel the new pedagogical approach and team teaching as rewarding experiences, they feel less concerned or apprehensive towards the educational reform.	• all levels of management are fully behind the idea and actively drive the implementation.
(Baligar et al., 2018)	• learning facilitated by a group of teachers engaged in team teaching; • shared experiences of collaborative approach at various stages of the course evolution, the need for it, the methodologies used and their benefits; • opportunity to explore beyond the disciplinary boundaries and innovate in multi-disciplinary space; • using the experience gained in this course in designing and delivering their courses in their respective departments; • means for providing students with the skills they need; • way to enhance the teacher's own professional development. • getting an opportunity to acquire knowledge from their colleagues belonging to different engineering disciplines and • students receiving feedback from multi-disciplinary perspectives that has led to improvements in their course projects.	• team of faculty members from diverse engineering disciplines; • team of course instructors with different disciplinary background; • practise of team review is followed in all course project reviews; • multi-disciplinary skills in the delivery team of instructors; • team members brought disciplinary knowledge to the team, however, none of the team members had all the competencies and skills required to deliver the course; faculty members needed common understanding of few of the engineering concepts.
(Lutsenko & Lucenko, 2018)	• collaboration with the colleagues from the departments; • provide opportunities for generating ideas for projects of senior engineering students; • teachers from different departments could act as co-facilitators of teams of students or as "customers"; • selection of practically oriented projects, which simultaneously helps to solve pedagogical tasks as contextualisation of the learning process; • encouragement of students to participate in applied design and scientific research; • urgent university organisational tasks, namely, updating and upgrading of laboratory equipment; • use of advanced software allowing to smooth over the lag of technical equipment of Ukrainian engineering departments and, in future, will lead to the full-grown using of emerging technologies.	• teachers need to be ready to be facilitators of student teams; • need to be ready to collaborate with colleagues from other departments as co-facilitators of student projects regardless of project themes; • academic staff must be open to new educational initiatives fostering the implementation of student projects; • difficulties was related to administrative and organisational issues; • workload of teachers from different departments.
(Kodkanon & Pinit, 2018)	• interdisciplinary aspect may be achieved through engagement in project-based learning (PBL); • shared purpose and a framework and guidelines to support teachers' planning; • value of shared decision-making and leadership.	• need for supportive relationships that take into consideration professional and personal issues; • need for open forms of communication that reflect trust, support and respect; • use of social media to support communication and collaboration; • guidelines and rules established in advance by team members.
(Pastor-Mendoza et al., 2018)	• collaboration has helped to students in their Final Degree Projects completion, which has also established a solid collaboration among teachers involved; • collaboration helps the teachers involved to consider modifications in the subjects which they teach to find a better relationship between them within the curricula; • better understand the internal functioning of each one; • useful to involve more professors of other subjects in future projects; • greater the number of teachers involved, the greater the teaching capacity will be for future students who become involved in large-scale projects. • relationship between professors from different areas can also help to reorient some contents of the subjects, to make them more practical and to relate them among themselves; • more attractive and reduce the workload of the students involvement of a larger number of teachers will facilitate the	

	fundraising of the departments, the school and the university.	
(Angelva et al., 2017)	• better learning results and enlarge teachers' know-how. • team-teaching and project based learning (PBL) give • more opportunities to develop industrial cooperation and • student satisfaction factor has raised • total number of credit points students have completed annually. • working together is nice and fun; • makes easier for students to get a professional job after graduation • very instructive; • not bored; • evaluation is worth to complete together in the teacher team if possible; • problem solving together makes it easier; • better completion percentage; • continuous learning;	• developing new curriculum based on PBL and piloting it with different student groups and organizing learning by teacher teams • meaning of the preplanning phase is significant • first time very challenging, repetition makes it easier • everything to the master time table; • planning phase should be started as early as possible • the joint assessment will support your own decisions; • reviews takes some time from the "ancient" one-way; • lectures in resource planning; • the project team of students carry each other; • suitable and accessible space is required for self-oriented project workshops; • physical location of the teacher team as close to workshops as possible; • teacher team located very close to each other to ensure the open communication; • the beginning is always difficult; • new culture requires change in attitude, others are slower than the others; • project management and teamwork skills are required
(Alves et al., 2016)	• a positive view of PBL as a learning approach • student motivation and engagement • better understanding of the application of concepts in real-life situations, as important outcomes of the project for students • highlight the importance of the development of transversal skills by students throughout the project • higher collaborative work between teachers from different departments and schools • projects enable solutions that involve very specific and complex aspects of courses that cannot be explored in classes; • involves teachers in the reflection of their own practices, promoting changes in course design and planning; • recognition of PBL as a suitable methodology to better prepare engineers.	• higher workload for teachers due to formative activities and milestones to give feedback, beyond the classes; • greater difficulties for students who usually have trouble in finding and selecting proper bibliography and need extra support from teachers; • course could require adjustments every year, according to the project; • instruct and better prepare teachers, to provide more resources (e.g. project rooms); • pedagogical support and training (e.g. educational researchers) for teachers to develop active learning activities; • consumes scarce resources of the department; • important to motivate teachers about these new methodologies in order to all be in synergy and reduce the time it takes to 'convince' the disbelievers.
(Vesikivi et al., 2016)	Teacher collaboration was beneficial for students for several reasons: e.g., • students saw one model of professional collaboration, • students received feedback and guidance from multiple teachers, and the • progress of students' project work was better taken into account in teaching when all teachers were aware of the situation and were able to negotiate next steps together on the fly. Team teaching was evaluated mainly as a • positive experience; • very impressive and rewarding for them to finally see "what engineers really do"; • participate in authentic project work practices; • interesting and useful to see other teachers' teaching methods; • discuss about pedagogical problems and solutions together; • learned also more from the students in this new type of modules than in previous courses, because collaboration with them and presence in the classroom was more comprehensive.	1) Organizational setup related concerns: • all teachers on a shared course should participate in the design process from the very beginning to the very end. • very challenging in practice to deploy multidisciplinary courses that involve teachers and students from majors in different organizational units. • hard to find a single person who would be responsible for the guidance of individual students in the course. 2) Training and motivation related concerns: • team teaching was considered to be a major change in the way teaching is conducted; • change in the teacher's way of working. • time allocation for course planning • having multiple teachers on the same course makes planning challenging as even just finding a common time for a design session may prove out to be almost impossible. • mean more work for the same amount of allocated work hours as it is possible that too few hours are allocated for course design. • deterioration of motivation to develop team teaching. 3) Curriculum design related concerns: • free riders among students are always an issue; • effect of team teaching to accumulated competence and knowledge of graduates.

		• common understanding of pedagogical targets is a prerequisite for a successful course; • adoption of new way of teaching will require considerable amount of time. • integration of topics on a team teaching course should be much tighter than was achieved at present. courses may end up being too patchy. 4) Resources related concerns: • lack of resource hours for planning a team teaching course. • planning of such course would take more time and energy than planning a traditional course with one topic area and a single teacher. • scheduling of topics on a course may be challenging as teachers usually have multiple on-going courses; • allocation of adequate time for planning the courses is important; • should be some best practices for creating and empowering the teacher teams. We • should find ways to ensure the quality of learning as well as ways to make the content integrated courses visible and understandable also outside the university; • how much freedom an individual teacher has on a team teaching course is important; • decide related to decisions together and decisions an individual teacher can make alone.

4.2 Evidence from PBL practitioners experience

The authors of this paper have been involved in the implementation of the PBL learning methodology in the first year of Industrial Engineering and Management (IEM) program at the University of Minho for a more than a decade, more precisely since 2004_2005. The project given to the students involves teachers from different schools and departments, mainly from STEM fields (Calculus, Linear Algebra, General Chemistry, Algorithm and Programming, Introduction to IEM and Integrated Project of IEM). In Alves et al. (2019a) more details of this PBL are given. Teachers collaboration was also subject of some papers, namely: van Hattum-Janssen (2011), Fernandes and Flores (2013), Fernandes et al (2014), Alves et al. (2016a) and Alves et al. (2016b) which corroborates most of the results (benefits and difficulties) founded in the literature review. Main difficulties were mainly related to the workload, deeply discussed in Alves et al. (2009) and Alves et al. (2019b), the assessment model definition and the need to adjust the course contents.

In the 18 cohorts that this PBL was implemented, training more than 800 students, it involved almost 50 persons as teachers (36), tutors (18) and research assistants (8). During the first fifteen cohorts, teachers also performed the tutor role. Almost all of the persons involved are included in the coordination team, having a minimum of 12 members (six teachers, one for each course and six tutors). From year to year, the team members vary, just the IEM team (normally two teachers, responsible for the Introduction to IEM course and Integrated Project) was stable in the 18 cohorts.

This team diversification introduces an additional effort: to introduce the PBL learning methodology to the new members (normally they do not know this methodology or are not accustomed with that). In charge of this introduction is the coordinator that should explain all the process, phases, milestones, assessment model, among others technical aspects. Most important are the soft aspects: to make the new member feel comfortable with this methodology and working in a team. Some reactions were the scepticism at the beginning but after some cohorts they just recognize the value of it. It is interesting to report that in one of the last meetings of the current year, one teacher said: "I like working with this methodology, we are not alone!"

This collaboration is visible for the students that see this way of working as an example. In the current year, due to the COVID-19, the coordinator was not available in the first session with the students (the most important session) to present the PBL and the other IEM teacher had this role. Another visible aspect is when all teachers are present in the oral presentations of the students, giving feedback to teams and providing

opportunities for the reflection on the next steps of the project. Another example of extreme importance is the extended tutorial that teachers participate together with the student teams. As sometimes the feedback of each teacher can be contradictory, the extended tutorial is an exclusive meeting of each student team with all the teachers, in order to listen to the doubts and difficulties that teams could have. Having all teachers in the same room with each student team allows students to hear, understand and discuss teacher feedback.

5 Final remarks

Team teaching in project-based learning experiences in engineering education is a specific form of team teaching in higher education. It shows a number of additional features that go beyond teaching and planning for teaching and learning with two or more teachers. The benefits and challenges of this specific form of team teaching are, therefore, also more elaborate. As can be seen in the first part of the literature review, teachers in PBL need to facilitate learning activities from the start till the end of a project and need to be aware of the learning processes of their students. This requires more communication and agreement within teaching teams than the more traditional forms of instruction. The interdisciplinary nature of projects and the different role that teachers in PBL teams have when supporting students also asks from teachers to be not only informed about the expertise their colleagues have, but also the specific planning of content delivery and the contribution of disciplinary areas to the final solutions proposed by the student teams needs to be in the centre of their joint attention. The practical experiences as described in the second literature review of a specific teaching team confirms this need for close collaboration and the initial resistance that team teaching can provoke. Being part of a teaching team in an intensive method like PBL requires a strong involvement of all team members and attention for the psychological, communication and organisational aspect that team teaching asks in PBL asks from all team members. This extra commitment though, is, according to findings from the literature and the experiences described by the authors' team, compensated by the rewarding learning experiences of both students as well as teachers.

Although the scope of the current study is limited due to the use of SCOPUS as the single database for the literature review, the narrow definition of team teaching in the keywords and the focus on a single team of practitioners for the second literature, this limited exploration already shows that the role of the teacher as a team member in PBL is crucial to make the learning experience successful for students. Further exploration of the literature on specific roles of teachers in team building, team organisation and management and team communication is needed to get a better insight on how to optimise teaching teams for working with student teams. An interesting idea for future work could be to carry out a structured survey on the students' perception regarding the collaborative work of their teachers.

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References

Alves, A. C., Moreira, F., Sousa, R., & Lima, R. M. (2009). Teachers' workload in a project-led engineering education approach. *International Symposium on Innovation and Assessment of Engineering Curricula*, 14.

Alves, A., Sousa, R., Moreira, F., Carvalho, M. A., Cardoso, E., Pimenta, P., Malheiro, T., Brito, I., Fernandes, S., & Mesquita, D. (2016). Managing PBL difficulties in an industrial engineering and management program. *Journal of Industrial Engineering and Management*, *9*(3), 586. https://doi.org/10.3926/jiem.1816

Alves, A.C., Moreira, F., Leão, C. P., Pereira, A. C., Pereira-Lima, S. M. M. A., Malheiro, M. T., Lopes, S. O., & Oliveira, S. (2019). Industrial engineering and management PBL implementation: An effortless experience? In A. K. Lima R.M., Villas-Boas V., Bettaieb L. (Ed.), *11th International Symposium on Project Approaches in Engineering and 16th Active Learning in Engineering Education Workshop, PAEE/ALE 2019; Hammamet; Tunisia; 10 June 2019 through 12 June 2019;* (Vol. 9, pp. 117–127). University of Minho.

Alves, Anabela C., Sousa, R. M., Fernandes, S., Cardoso, E., Carvalho, M. A., Figueiredo, J., & Pereira, R. M. S. (2016). Teacher's experiences in PBL: implications for practice. *European Journal of Engineering Education*, *41*(2), 123–141. https://doi.org/10.1080/03043797.2015.1023782

Alves, Anabela Carvalho, Moreira, F., Carvalho, M. A., Oliveira, S., Malheiro, M. T., Brito, I., Leão, C. P., & Teixeira, S. (2019). Integrating Science, Technology, Engineering and Mathematics contents through PBL in an Industrial Engineering and Management first year program. *Production*, *29*(x), 0–0. https://doi.org/10.1590/0103-6513.20180111

Angelva, J., Tepsa, T., & Mielikäinen, M. (2017). Team teaching experiences in engineering education a project-based learning approach. *Proceedings of the 45th SEFI Annual Conference 2017 - Education Excellence for Sustainability, SEFI 2017*, 1182–1189.

Baligar, P., Kavale, S., M., K., Joshi, G., & Shettar, A. (2018). Engineering Exploration : A Collaborative Experience of Designing and Evolving a Freshman Course. *2018 World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC)*, 1–5. https://doi.org/10.1109/WEEF-GEDC.2018.8629768

Fernandes, S., & Flores, M. A. (2013). Tutors' and students' views of tutoring: A study in higher education. In *Back to the Future: Legacies, Continuities and Changes in Educational Policy, Practice and Research*. https://doi.org/10.1007/978-94-6209-240-2_16

Fernandes, S., Mesquita, D., Flores, M. A., & Lima, R. M. (2014). Engaging students in learning: Findings from a study of project-led education. *European Journal of Engineering Education*, *39*(1). https://doi.org/10.1080/03043797.2013.833170

Gaebel, B. M., Zhang, T., & Bunescu, L. (2018). Learning and teaching in the European Higher Education Area. In *European University Association*.

Guerra, A., Ulseth, R., & Kolmos, A. (2017). *PBL in Engineering Education* (A. Guerra, R. Ulseth, & A. Kolmos (eds.)). SensePublishers. https://doi.org/10.1007/978-94-6300-905-8

Jones, F., & Harris, S. (2012). Benefits and Drawbacks of Using Multiple Instructors to Teach Single Courses. *College Teaching*, *60*(4), 132–139. https://doi.org/10.1080/87567555.2012.654832

Kodkanon, K., & Pinit, P. (2018). High-school teachers' experiences of interdisciplinary team teaching. *Issues in Educational Research*, *28*(4), 967–989.

Liebel, G., Burden, H., & Heldal, R. (2017). For free: continuity and change by team teaching. *Teaching in Higher Education*, *22*(1), 62–77. https://doi.org/10.1080/13562517.2016.1221811

Lutsenko, G. V., & Lucenko, G. V. (2018). Project-based learning in automation engineering curriculum. In V. M. E. Clark R., Hussmann P.M., Jarvinen H.-M., Murphy M. (Ed.), *Proceedings of the 46th SEFI Annual Conference 2018: Creativity, Innovation and Entrepreneurship for Engineering Education Excellence* (pp. 1032–1039). European Society for Engineering Education (SEFI).

Miles, M. B., & Huberman, A. M. (1994). *An Expanded Sourcebook Qualitative Data Analysis*. SAGE Publications, Inc.

Minett-Smith, C., & Davis, C. L. (2020). Widening the discourse on team-teaching in higher education. *Teaching in Higher Education*, *25*(5), 579–594. https://doi.org/10.1080/13562517.2019.1577814

Money, A., & Coughlan, J. (2016). Team-taught versus individually taught undergraduate education: a qualitative study of student experiences and preferences. *Higher Education*, *72*(6), 797–811. https://doi.org/10.1007/s10734-015-9976-5

Pastor-Mendoza, J., Gonzalez, E. P., Tradacete Agreda, M., Rodriguez Martin, G., Gutierrez Moreno, R., Rios Munoz, M., & Barba Magdalena, S. (2018). Students and teachers experiences in the completion of multidisciplinary Final Degree Projects. *2018 XIII Technologies Applied to Electronics Teaching Conference (TAEE)*, 1–8. https://doi.org/10.1109/TAEE.2018.8476003

Powell, P. (1999). From classical to project-led education. In António Sérgio pouzada (Ed.), *Project Based Learning. Project-led Education and Group Learning.* (pp. 11–42). Thematic Network Plastics in Engineering.

Singh-Pillay, A. (2020). Pre-service Technology Teachers' Experiences of Project Based Learning as Pedagogy for Education for Sustainable Development. *Universal Journal of Educational Research*, *8*(5), 1935–1943. https://doi.org/10.13189/ujer.2020.080530

van Hattum-Janssen, N. (2011). O papel dos professores nos projetos. In L. C. de Campos, E. A. T. Dirani, & A. L. Manrique (Eds.), *Educação em Engenharia Novas Abordagens* (pp. 247–269). EDUC - Editora da Pontifícia Universidade Católica de São Paulo.

Vesikivi, P., Holvikivi, J., Lakkala, M., & Bauters, M. (2016). Teacher collaboration in IT project courses: Resistance and success. *44th Annual Conference of the European Society for Engineering Education - Engineering Education on Top of the World: Industry-University Cooperation, SEFI 2016*.

Vesikivi, P., Lakkala, M., Holvikivi, J., & Muukkonen, H. (2019). Team teaching implementation in engineering education: teacher perceptions and experiences. *European Journal of Engineering Education*, *44*(4), 519–534. https://doi.org/10.1080/03043797.2018.1446910