



Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

Preparing engineering students for collaborative project-work: Piloting an online course on PBL and project management

Guerra, Aida Olivia Pereira de Carvalho; Schoefs, Franck

Published in:

Educate for the future: PBL, Sustainability and Digitalisation 2020

Publication date:

2020

Document Version

Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Guerra, A. O. P. D. C., & Schoefs, F. (2020). Preparing engineering students for collaborative project-work: Piloting an online course on PBL and project management. In A. Guerra, A. Kolmos, M. Winther, & J. Chen (Eds.), *Educate for the future: PBL, Sustainability and Digitalisation 2020* (1 ed., pp. 30-42). Aalborg Universitetsforlag.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- ? Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- ? You may not further distribute the material or use it for any profit-making activity or commercial gain
- ? You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

Preparing engineering students for collaborative project-work: Piloting an online course on PBL and project management

Aida Guerra

Aalborg University, Denmark, ag@plan.aau.dk

Franck Schoefs

Université de Nantes, France, franck.schoefs@univ-nantes.fr

Mathilde Chevreuil

Université de Nantes, France, email, mathilde.chevreuil@univ-nantes.fr

Abstract

MAREENE is an international Master programme on *Reliability based structural MAintenance for marine Renewable ENergy*, delivered at Université de Nantes (France). This Master programme is a one-year programme that completes a first year to deliver a Master degree. It is developed in collaboration with Aalborg University (AAU), Norwegian University of Science and Technology (NTNU) and the School of Mechanical & Materials Engineering of the College of Engineering and Architecture of University College Dublin (UCD). The programme curriculum is problem-based and project-organised (PBL), where small groups of students solve real and authentic problems within civil and marine engineering through a project of two ECTS per semester. Besides the project, students also have online courses, which provide technical knowledge and support their project work, namely in PBL and project management. Université de Nantes is running for the first time a Master engineering programme with a PBL curriculum, where both students and staff lack, or have limited, experience on how to manage and organise learning in a PBL environment. Therefore, the MAREENE programme includes a 15 h, fully online course on PBL and project management as part of the project module, the overall goal of which is to provide students the knowledge and tools needed to develop the skills and competences to carry out a problem-based project successfully. The course is student-centred, problem-oriented and focused on students' experiences and needs. This paper describes the framework of the PBL online course, its learning principles and evaluation. The course evaluation targeted students who participate in the course, and their responses were collected through a questionnaire distributed through Moodle. Results indicate that course structure, materials and assignments support student learning and have met their expectations from a moderate to a large extent. In addition, they also consider the course and topics addressed relevant, including for future projects they will be involved in.

Keywords: Online course, PBL and project management, student learning.

Type of contribution: PBL best practice

1 Introduction

The need for a more student-centred curriculum in engineering education is leading to the integration of problem-based, project-organised learning (PBL) and the establishment of new teaching practices focused in student learning and development. The popularity of PBL has been rising around the world and is mainly due to the competences and skills students develop, namely problem-solving skills, communication,

teamwork, critical thinking, self-directed learning and lifelong learning, among others. Social and professional trends, such as digitalisation, automation and sustainability, call for the development of such skills to enable future engineers to perform and operate in a globalised and volatile society and working environments (Motyl, Baronio, Uberti, Speranza, & Filippi, 2017; Richert et al., 2016; United Nations, 2015). This means that traditional, transmissive and teacher-centred curricula and practices are changing by integrating PBL and developing a more student-centred curriculum. However, such transitions require a change in teachers' and students' roles, type of learning outcomes, assessment, learning and teaching activities and learning spaces. The development of resources and activities to support student learning and teachers are central for a successful integration of PBL. Examples of resources and activities to support both academic staff and students are face-to-face training workshops and online courses, which provide them with knowledge and skills to manage and facilitate learning (Cheaney & Ingebritsen, 2005; Kolmos, Graaff, & Du, 2009; Savin-Baden, 2000, 2007).

Furthermore, the future of education is digital, where the use of technology, digital media and social media, namely computers, smart phones, online resources and platforms to collaborate, communicate and access information is part of how 21st century students learn. Furthermore, the combination of continuous emergence and innovation of communication technologies and the need for continuous learning has been contributing to the boom of the digital learning. Digital learning enables autonomous learners to learn anywhere (e.g. distance learning) and anytime (e.g. asynchronous learning). It has also been proved that interaction, one of the most important components of any learning experience, is one of the major constructs of distance learning. However, the "boom" of digital learning does not come without concerns, namely effectiveness of learning settings and opportunities created, alignment between learning intentions, assessment and development of skills (Garrison, 2000; Savin-Baden, 2007; Vrasidas, 2000; Warschauer, 2007).

In summary, as engineering education develops towards more student-centred learning and towards more autonomous and independent learners, digital learning creates new learning spaces and possibilities. For example, it provides the opportunity to develop resources to support academic staff and students integrating and managing learning in a PBL environment, such as online courses. In addition, such courses can be delivered by PBL experts and at international scale. This paper reports the example of a PBL online course, called PBL and Project Management, which is part of MAREENE, an international Master programme. MAREENE is the acronym for Reliability based structural Maintenance for marine Renewable ENERgy, and is delivered at Université de Nantes (France) and developed in collaboration with Aalborg University (AAU), Norwegian University of Science and Technology (NTNU) and the School of Mechanical & Materials Engineering of the College of Engineering and Architecture of University College Dublin (UCD). It is a one-year programme that completes a first year to deliver a Master degree. Its curriculum is problem-based and project-organised (PBL), where small groups of students solve real and authentic problems within civil and marine engineering through a project of two ECTS per semester. Besides the project, students also have online courses, which provide technical knowledge and support to their project work, such as the PBL and Project Management online course. The need for an online course on PBL and project management emerges from Université de Nantes' students and staff lack, or have limited, experience on how to manage and organise learning in a PBL environment. This paper describes an online course and its learning principles, followed by reflections of its implementation and evaluation.

2 Description of online course "*PBL and Project Management*"

The course is student-centred, problem-oriented and focused on students' experiences and needs. Its overall goal is to provide the knowledge and tools students need to develop the skills and competences to carry out a team-based, problem-oriented project successfully. PBL and Project Management is a short, fully online course, with a duration of 15 hours, and is part of a two ECTS project module per semester. The course addresses the topics PBL, collaboration, project management, academic co-writing and

documentation, which are core elements of PBL working processes. Table 1 presents the course learning outcomes.

Table 1. Learning outcomes

<ul style="list-style-type: none"> • Define collaborative, problem-based project work • Define group collaboration, problem formulation and project work, documentation and academic co-writing processes in a PBL environment • Identify challenges in collaboration, problem formulation and project work, documentation and academic co-writing • Develop strategies to manage learning and group working processes, namely collaboration, problem formulation and project work, documentation and academic co-writing • Implement the strategies to improve learning and group working processes, namely collaboration, problem formulation and project work, documentation and academic co-writing • Discuss and reflect on the strategies implemented to improve learning and group working processes • Reflect on group practices and provide critical feedback to peers
--

The course is organised in four online seminars, with assignments in between that are carried out individually and as a group (Table 2).

Table 2. Course activities and respective descriptions

Activity	Description
Online seminar (OS1): Kick-off and introduction	<ul style="list-style-type: none"> - Introduction to the course: schedule, structure, goals and assignments - Brief definition of PBL and its elements, namely collaboration, problem orientation and project work. - Overview of Assignment 1
Assignment 1: Understand PBL principles and practice	<ul style="list-style-type: none"> - PREPARATION: Read the booklet about the Aalborg University (AAU) PBL model, pages 4 to 15. (Booklet available: https://www.aau.dk/digitalAssets/148/148025_pbl-aalborg-model_uk.pdf and in the course Moodle) - INDIVIDUAL TASK(S): After preparation, answer the following questions: <ol style="list-style-type: none"> Define PBL in one word. What are the aspects of PBL you find hard to understand, or that lack concrete examples for/in practice? (max. 20 words) What are the three aspects you find most positive about the AAU PBL model? Why? (max. 30 words) What are the three aspects you find most challenging about the AAU PBL model? Why? (max. 30 words)
Online seminar (OS2): PBL working processes and associated challenges	<ul style="list-style-type: none"> - Summary of understanding and expectations of PBL - Define PBL principles and practice - Define collaboration, problem orientation and project work, documentation and co-writing - Overview of Assignment 2
Assignment 2: Observation of PBL challenge in practice	<ul style="list-style-type: none"> - IDENTIFY YOUR PBL CHALLENGE - GROUP TASK(S) <ol style="list-style-type: none"> Why the challenge is a challenge? Design an agenda, or framework, to describe how your group practises the PBL challenge. (When designing the agenda, or framework, please consider the following: how the challenge is practised in the group; what works and why; and what does not work and why) - INDIVIDUAL TASK(S): <ol style="list-style-type: none"> Observe the group practising the PBL challenge. Write notes of your observations according to the above agenda (or framework)..
Online seminar (OS3): Develop action plans to address PBL challenges	<ul style="list-style-type: none"> - Summary of PBL challenges and group practice - Identify PBL challenges based on Assignment 2 - Identify tools and resources to improve collaboration, problem formulation and project work,

Activity	Description
	documentation and academic co-writing - Overview of Assignment 3
Assignment 3: Plan of action to improve PBL working processes	- PLAN FOR IDENTIFIED CHALLENGE - GROUP TASK(S) 1. Go through the links and resources related with the PBL working process you want to improve (list is in Moodle). 2. Based on examples of tools given in the links and resources, design a plan to improve a PBL working process. Describe your plan here. 3. Implement the plan. - INDIVIDUAL TASK(S) Write down your reflections on how the plan worked in practice, considering the following: 1. What are the main problems the plan aimed to address? 2. What did the plan actually improve and why? 3. What did not work with the plan and why? 4. What can be improved further in your PBL working processes and how?
Online seminar (OS4): Strategies to address PBL challenges and course summary	- Summary of online seminars and assignments - Overview of “toolbox” catalogue to address PBL challenges - Course evaluation

The online seminars comprises three parts: summary of assignments (e.g. main lessons from assignments, peer-feedback), online seminar (e.g. introduction to session topics), and assignment overview. By their turn, the assignments are also composed by three parts: go through materials and resources, carry out the assignment, and submit assignment report. All the submitted reports and feedback notes are compiled and made available to students. Figure 1 illustrates the overall structure of course’s seminars and assignments.

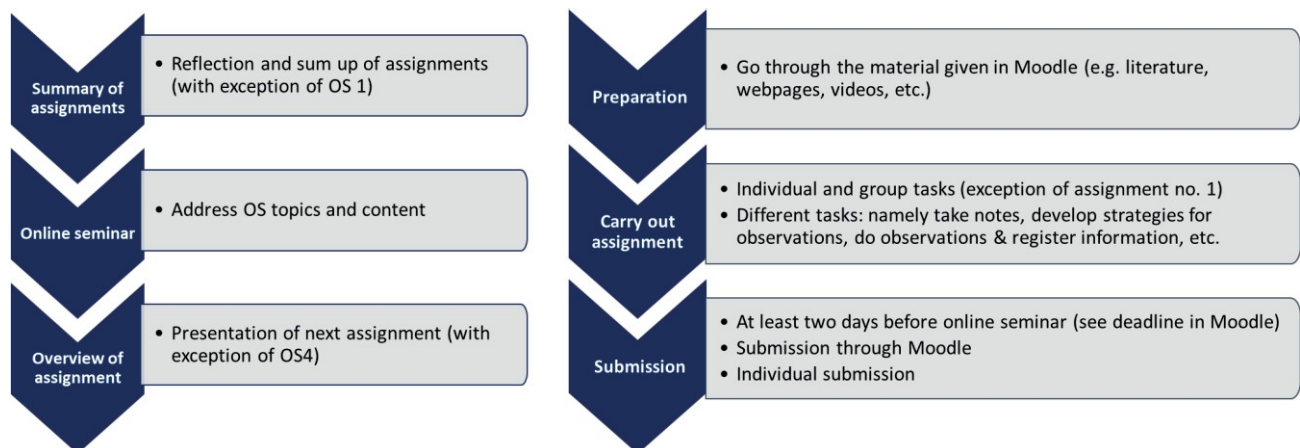


Figure 1. Online seminar and assignment overall structure

3 Guiding principles to design the online course “PBL and Project Management”

Chickering and Gamson’s work “*Seven Principles for Good Practice in Undergraduate Education*” has been one of the main works cited by educational journals and practitioners literature when it comes to the effectiveness of distance learning (Hutchins, 2003). The seven principles are as follows (Chickering & Gamson, 1989, 1999):

1. Encourage student-faculty contact (e.g. frequent contact among teachers and students as core factor for student involvement and motivation. Teachers support student learning by, for example,

- getting through rough times and keep working, foster intellectual commitment, think their own values and plans, i.e. promoter of liminal learning).
2. Encourage cooperation among students (e.g. interaction among peers is a promoter of peer learning. Good learning is collaborative and social; it increases involvement, deep learning and potentiates students' achievements (see for example Zone of Proximal Development, Vygotsky 1978)).
 3. Encourage active learning (e.g. involve students actively in their own learning and carry out activities, relatable with their experiences and applicable in their daily lives).
 4. Give prompt feedback (e.g. students need appropriate feedback on performance to benefit from the course and activities; need chances to reflect on what they have learned, what they still need to know, and how to assess themselves).
 5. Emphasise time on task (e.g. provide opportunities for students to practise good time management by allocating realistic time to activities).
 6. Communicate high expectations (e.g. expecting students to perform well becomes a self-fulfilling prophecy when teachers and institutions hold high expectations of themselves and make extra efforts).
 7. Respect diverse talents and ways of learning (e.g. create variety and diversity of learning activities, materials, resources, presentation formats that create opportunities for students to show their talents and learn in ways that work for them).

The seven principles are set on a constructivist approach to learning, where students are co-constructors and responsible for their own learning, and as a social activity increasing their involvement and development. Furthermore, the teacher is not the "knowledge transmitter" but rather a facilitator who supports student learning. In summary, distance learning can be student-centred, and Chickering & Gamson's seven principles for good practice constitutes a good framework to design student-centred online courses. However, Chickering & Gamson's principles are generic, and it is left to the teacher to develop a pedagogical approach which integrates them. Problem-based, project-organised learning (PBL) is a student-centred learning approach, which ticks off all the principles stated above and provides guidelines to design online courses. Furthermore, the online course integrates a project module of a PBL curriculum; therefore, the most logical step would be to design a course about PBL and project management aligned with PBL principles.

Kolmos et al. (2009, p. 11) define PBL as problem-oriented, contextual, exemplary, experiential, participant-directed, team-based, interdisciplinary, project-organised and relating between theory-practice. The nine PBL learning principles can be clustered in three approaches: cognitive approach, content approach, collaborative approach, as Figure 1 illustrates.

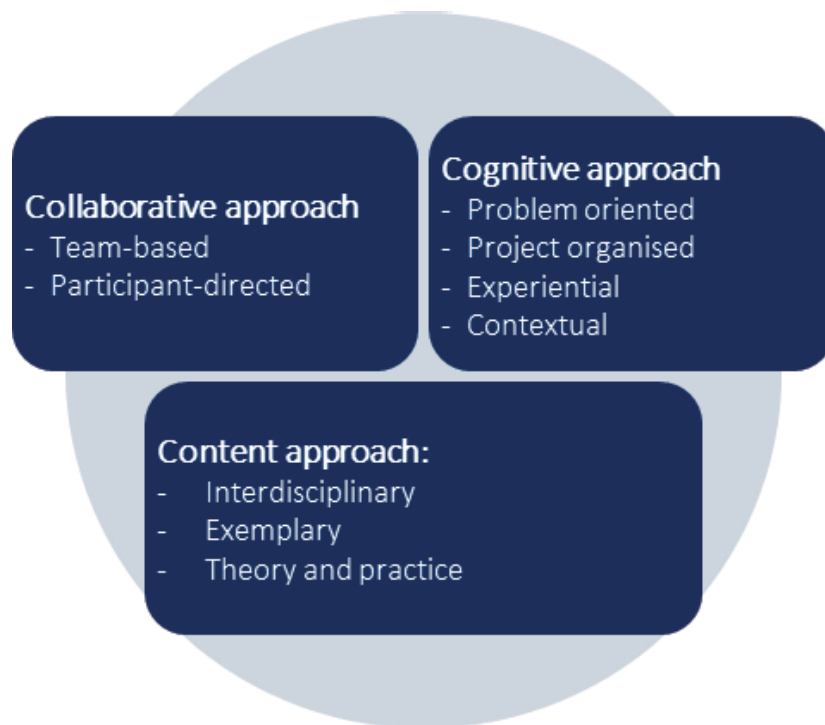


Figure 2. PBL learning principles, based on (2009, p. 11)

In the PBL approach, the learning starts with the formulation of a real problem (problem-orientation), which is solved through projects (project-organisation). Learning takes place in relation to a real context (contextual learning), and it is grounded in the learners' experience (experiential learning). The content approach concerns interdisciplinarity, exemplarity and the relationship between theory and practice. Interdisciplinarity means that the learning process crosses traditional disciplinary boundaries, whilst exemplarity means that the activities students undertake are exemplars of the overall objectives of the curriculum and through reflection and generalisation generate knowledge. The learning process entails an analytical framework in which theoretical knowledge is applied to formulate and solve problems (relation between theory and practice). Collaborative learning refers to team-based and participant-directed learning, namely that it is a social activity undertaken through dialogue and communication in which students learn from each other. Participant-directed refers to students' collective ownership of decision-making and learning processes (Kolmos et al., 2009). Table 3 describes the relation between PBL principles and the course activities.

Table 3. Relation between the online course and PBL principles (Kolmos et al., 2009)

Cognitive approach

- Problem orientation – The point of the departure for student learning is on challenges they want to address.
- Project – Online course is part of a project module and aims that knowledge and tools are applied in the project work.
- Experiential – Several activities are developed and centred on students' experiences, namely the definition of challenges, the observation of the PBL challenge in practice and implementation of action plan, etc.
- Contextual – By using students' challenges in working in a PBL environment as point of departure, learning of PBL and project management are placed in the context of their project.

Content approach:

- Interdisciplinarity – It is mainly addressed at content level.
 - Exemplarity – The goal of the course is to provide knowledge and tools to manage learning in a PBL environment. The assignments include different activities which are illustrative of PBL practice principles (e.g. collaboration, co-writing and documentation, problem design, project management) and how they can be used to develop strategies to improve design in a PBL working process. The assignments are exemplary of the
-

procedures of how to constructively design a plan of actions to improve PBL working processes.

- Theory and practice – The online course includes diverse resources and materials that aim to provide students theoretical knowledge to develop and apply a plan of actions to improve PBL working processes in practice.

Social approach:

- Team-based – It includes group-based activities.
- Participant-directed – Students have ownership over their learning and decide which challenge to address and how.

In sum, the online course on PBL and project management adopts a PBL approach by using its principles as guiding precepts for its design. Furthermore, the organisation of the course and some of its activities can be illustrated using Kolb's learning cycle (Illeris, 2008), as Figure 3 illustrates. The cycle comprises four main stages: concrete experience, reflection and observation, abstract conceptualisation and active experimentation. *Concrete experience* involves carrying out activities such as Assignment 4 (implementation of action plan). *Reflective observation*, the second stage of the cycle, entails participants taking a step back from the "doing", i.e. the group work and implementation of the action plan, and reviewing what has been done, how it went and why. Examples are Assignment 1 (identification of challenges based on previous experiences) and Assignment 2 (observation of challenge in practice). However, it is through *abstract conceptualisation* that students give meaning to these activities by relating them to the "bigger picture", such as content delivered through the online seminars and the tools, which also provide the arguments for their decisions and design of plan of action in Assignment 4. In the final stage of the learning cycle, *active experimentation*, the students considered what it is needed to address a given the challenge, what they have learned and how this will be put into practice. An example of active experimentation is the design of a plan of action in Assignment 4. After this stage, a new cycle takes place.

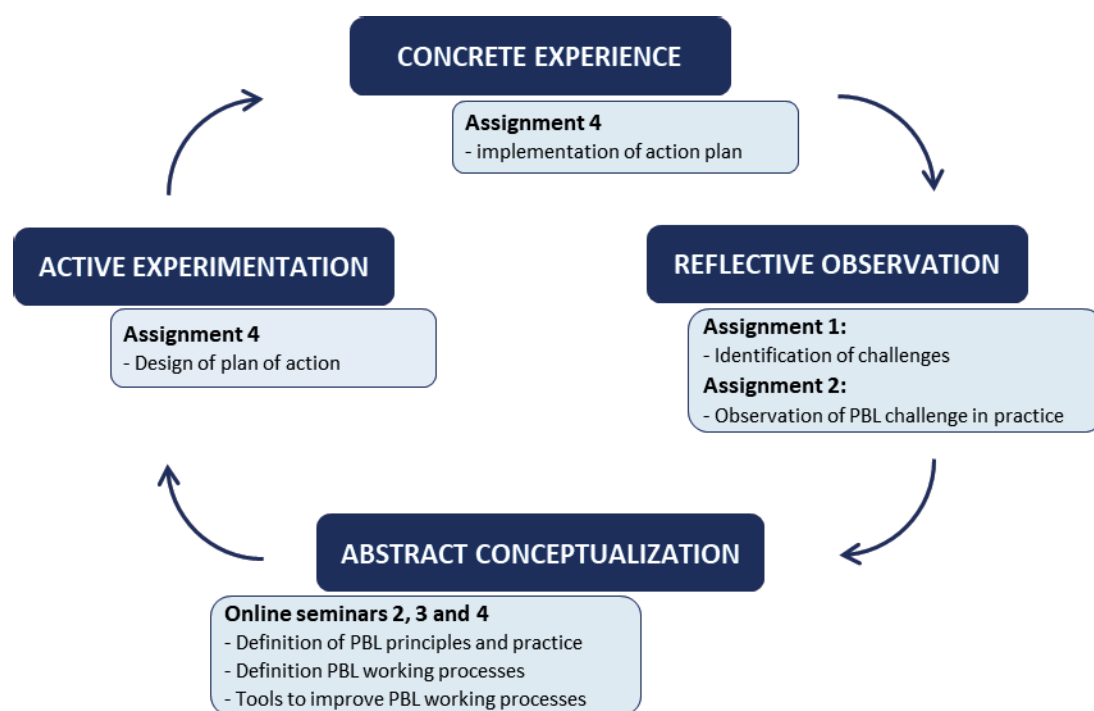


Figure 3. Relationships between Kolb's learning cycle and the online course activities.

4 Implementation and evaluation of online course “PBL and Project Management”

The online course was delivered from 11 September 2019 to 14 October 2019 to six students (i.e. total no. of students enrolled in the Master programme). The course uses Moodle *Extrac doc* (name given by university to the Moodle platform) as the learning management system (LMS) and *Lifesize* as the telecommunication application. *Lifesize* is used for online seminars, whilst *Extrac doc* is used to organise the course and as repository of resources. The online seminars were delivered synchronously, where students were together in a physical space (i.e. classroom at university) and the lecturer was online, using the telecommunication application. Three groups of two students carried the assignments out asynchronously, supported by resources and materials uploaded in the LMS. The communication between students and lecturer was done by email and in the discussion forum of the LMS. The course evaluation was conducted when the course finished.

The literature on PBL and distance learning (see for example, Graham, Cagiltay, & Craner, 2000; Hutchins, 2003; Savin-Baden, 2007) serves as precepts to develop the course evaluation model, which includes three main perspectives (Figure 4):

- Technological perspective (e.g. focus on digital tools and applications used, their functionality and usability),
- Instructional perspective (e.g. focus on structure, organisation, material, online resources and sessions of the course), and
- Learning perspective (focus on students’ expectations as well as relevance and impact, content and assignments of the course).

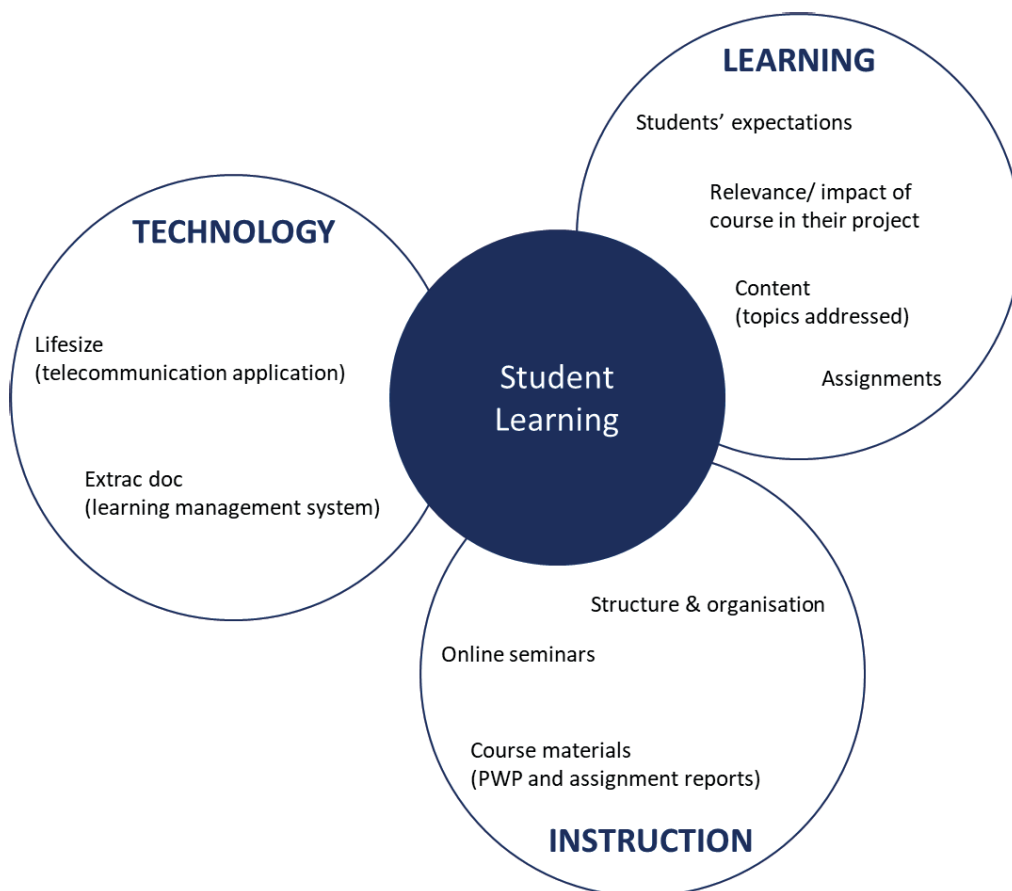


Figure 4. Three focus areas of evaluation and respective items.

Following the evaluation model, a questionnaire is constructed. Ten closed questions, with four-point scale, compose the questionnaire. Each closed question is followed by a text box for further comments. Besides these questions, the questionnaire also includes one last open question to gather students' suggestions for improvement (Table 4). The questionnaire was delivered using the LMS features, and only two out of six students have answered it.

Table 4. Evaluation perspectives and respective questions

Evaluation focus	Questions
Learning (closed questions)	<ul style="list-style-type: none"> • To what extent has the course met your expectations? • How do you evaluate the relevance of the course topics (i.e. problem orientation, collaboration, project management) in your learning and project work? • To what extent has the course structure (i.e. online seminars followed by group assignments) supported your learning. • How appropriate do you find the assignments to supporting your learning and project work? • To what extent do you consider that this course will affect your work in future projects?
Instruction (closed questions)	<ul style="list-style-type: none"> • How do you evaluate the way the online seminars were delivered and conducted? • How do you evaluate the seminars' slides and the assignment reports? • How do you evaluate the no. of sessions, temporal organisation and delivery of the course? • How do you evaluate the tools, links and literature provided in the course?
Technology (closed question)	<ul style="list-style-type: none"> • To what extent the technologies used have impacted your learning during the course?
Other (open question)	<ul style="list-style-type: none"> • What overall suggestions can you give for the improvement of the course?

Students' feedback

Both the number of students attending the course and answering the evaluation questionnaire are very low. For this reason, the evaluation information gathered through the questionnaire does not allow drawing solid conclusions about the course quality and fulfilment. Nevertheless, we have decided to include the evaluation results in this paper because we consider that it triggers reflections and points for further discussion. Table 5 shows students' answers to the questionnaire.

Table 5. Answers from students (n=2)

Evaluation focus	Question	Response
Learning	• To what extent has the course met your expectations?	(3) To a moderate extent; 2 (100%)
	• How do you evaluate the relevance of the course topics (i.e. problem orientation, collaboration, project management) in your learning and project work?	(3) Relevant; 2 (100%)
	• To what extent has the course structure (i.e. online seminars followed by group assignments) supported your learning?	(3) To a moderate extent; 1 (50%) (4) To a large extent; 1 (50%)
	• How appropriate do you find the assignments to supporting your learning and project work?	(2) Somewhat appropriate; 1 (50%) (4) Very appropriate; 1 (50%)
	• To what extent do you consider that this course will affect your work in future projects?	(3) To a moderate extent; 1 (50%) (4) To a large extent; 1 (50%)
Instruction	• How do you evaluate the way the online seminars were delivered and conducted?	(3) Good; 1 (50%) (4) Very good; 1 (50%)
	• How do you evaluate the seminars' slides and the assignment reports?	(2) Somewhat good; 1 (50%) (3) Good; 1 (50%)
	• How do you evaluate the no. of sessions, temporal organisation and delivery of the course?	(2) Somewhat good; 1 (50%) (3) Good; 1 (50%)
	• How do you evaluate the tools, links and literature provided in course?	(4) Very good; 2 (100%)
Technology	• To which extent have the technologies used impacted your learning during the course?	(3) To a moderate extent; 1 (50%) (4) To a large extent; 1 (50%)

Overall, both students evaluate the course as relevant, with appropriate structure and materials from a moderate to large extent (see Table 5). This indicates that the course fulfils its main goal in supporting student learning in a PBL environment, which is also highlighted by following student's statement:

*"I think the course was **really relevant** and it has **planted the seeds in my mind to develop the approach throughout the next projects I will be part of**. It's a shame that we only had few sessions because I feel like **this is something that needs to 'develop' instead of simply 'learn'**."*

The above also refers to the short duration of the course, which means that students might need more than 15 hours to develop competences to manage their project and learning. One possible explanation is that PBL and project management are relatively new topics and out of the expected technical domain that characterises the traditional engineering education. This might mean that students need to adjust to different disciplinary domains and discourse that the innovative and PBL environment requires, namely interdisciplinary knowledge and collaboration. This requires time, which is partly corroborated in the following statement:

*"If I can give you some kind of suggestions it would be to keep the quality of your sessions because you are a big plus to this course but **we need more time and experience to properly assimilate the concepts for years to come**."*

Regarding the instruction perspective, students also consider it good to very good (see Table 5). However, a further comment suggests that more attention should be given to font size and amount of text put in the slides when making online presentations, especially when using a videoconference style. One aspect brought by students in the open question relates with "synchronism" between the course and project work. Note that the course runs in parallel with project work, and it is part of the project module. It started one week after the project starts however; a student considered that the course had a "fast pace" when comparing with the project. The consequence is that the assignments and what is expected to be delivered as part of the course and implemented in project work were not always clear, as the following statement highlighted:

*"The pace of the course was **much faster than the pace of our projects** [...]"*

In addition, the students' focus was in getting hold of what was expected from them and organising their project overall, including the time and physical spaces for group work, as the following statements highlighted:

*“A part of explanation for these different paces is that here **we do not have any room and specific time to set meetings**. We have to organise that according to our different personal free time and we also need to find a place to work in small group (which is impossible in UniNantes)”.*

“I also felt like it was too early in the development of this approach to give us projects that were entirely open because even if the first objective was to make us steer the project in a direction that we found to be the best, we were too much lost instead to do anything without thinking that we would probably waste our time on irrelevant matter”.

Aligning better expectations and “slowing down” (e.g. starting later than the project work starts; or increasing the time between online sessions) the pace of the course are two important points to consider, especially if it is needed to increase students' motivation in engagement in these type of courses.

Nevertheless, the technology used has a moderate to large impact on student learning. However, there was no elaboration on how and why from the students' side. These are two questions that should be further explored and deepened in future evaluations in order to understand the impact of technologies used in student learning with the aim to, for example, design better online learning experiences for students.

5 Final reflections

The paper describes a design and implementation of an online course on PBL and project management in the international engineering Master programme MAREENE. The curriculum is problem-oriented and project-organised. The PBL and Project Management online course integrates a two ECTS project module

per semester, and its overall aim is to equip students with knowledge and skills needed to manage their learning in a PBL curriculum. The online course ran between September 11 and October 14, 2019 for a total of six students. Its evaluation was voluntary, enabling to gather only two responses. Nevertheless, the results gathered show that the course fulfilled its overall goal and was relevant to student learning in a PBL environment. It also planted the seeds for the need for further experience and development for future projects. The evaluation and students' written responses to open questions also provided some more insights and raised aspects for further reflection and discussion when it comes to online courses to support student learning in a PBL environment, namely, the relevance of physical spaces as complementary to online courses (at least in the beginning), course duration and its alignment with project duration and phases, clarification of expectations and the impact of technologies on student learning. These could be also key perspectives for future development of online courses for students that also are part of a curriculum change process, i.e. change from a teacher-centred learning environment towards a more student-centred environment, such as PBL. In addition, the paper also describes the use PBL and distance- learning principles to design online courses (see for example, Table 3 and Figure 3). Independently of the content addressed in the online course, these can constitute guidelines to design student-centred, flexible, exemplary, problem-oriented online courses, where student learning and experiences are at the core.

6 References

- Cheaney, J., & Ingebritsen, T. S. (2005, November). Problem-based learning in an online course: A case study. *International Review of Research in Open and Distance Learning*, 6(3). <https://doi.org/10.19173/irrodl.v6i3.267>
- Chickering, A. W., & Gamson, Z. F. (1989). Seven principles for good practice in undergraduate education. *Biochemical Education*, 17(3), 140–141. [https://doi.org/10.1016/0307-4412\(89\)90094-0](https://doi.org/10.1016/0307-4412(89)90094-0)
- Chickering, A. W., & Gamson, Z. F. (1999). Development and adaptations of the seven principles for good practice in undergraduate education. *New Directions for Teaching and Learning*, 1999(80), 75–81. <https://doi.org/10.1002/tl.8006>
- Garrison, R. (2000, July 1). Theoretical challenges for distance education in the 21st century: A shift from structural to transactional issues. *International Review of Research in Open and Distance Learning*, 1(1) <https://doi.org/10.19173/irrodl.v1i1.2>
- Graham, C., Cagiltay, K., & Craner, J. (2000). *Teaching in a web based distance learning environment: An evaluation summary based on four courses*. Center for Research on Learning and Technology.
- Hutchins, H. (2003). Instructional immediacy and the seven principles: Strategies for facilitating online courses. *Online Journal of Distance Learning Administration*, 6(3). Retrieved from <http://nurs.westga.edu/~distance/ojdla/fall63/hutchins63.pdf>
- Illeris, K. (2008). *How we learn: Learning and non-learning in school and beyond*. Routledge.
- Kolmos, A., Graaff, E. De, & Du, X. (2009). Diversity of PBL — PBL learning principles and models. In X. Du, E. de Graaff, & A. Kolmos (Eds.), *Research on PBL Practice in Engineering Education*, 9–21. https://doi.org/10.1163/9789087909321_003
- Motyl, B., Baronio, G., Uberti, S., Speranza, D., & Filippi, S. (2017). How will change the future engineers' skills in the Industry 4.0 framework? A questionnaire survey. *Procedia Manufacturing*, 11, 1501–1509. <https://doi.org/10.1016/j.promfg.2017.07.282>
- Richert, A., Shehadeh, M., Plumanns, L., Gros, K., Schuster, K., & Jeschke, S. (2016). Educating engineers for Industry 4.0: Virtual worlds and human-robot-teams: Empirical studies towards a new educational age. *2016IEEE Global Engineering Education Conference (EDUCON)*, 142–149. <https://doi.org/10.1109/EDUCON.2016.7474545>
- Savin-Baden, M. (2000). *Problem-based learning in higher education: Untold stories*. Buckingham: SRHE and Open University Press.
- Savin-Baden, M. (2007). *A practical guide to problem-based learning online*. Routledge.
- United Nations. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. Retrieved February 4, 2019, from Transforming our world: the 2030 Agenda for Sustainable Development website: <https://sustainabledevelopment.un.org/post2015/transformingourworld>
- Vrasidas, C. (2000). Constructivism versus objectivism: Implications for interaction, course design, and evaluation in distance education. *International Journal of Educational Telecommunications*, 6(4), 339–362. Retrieved from <https://www.vrasidas.com/wp-content/uploads/2007/07/continuum.pdf>
- Warschauer, M. (2007). The paradoxical future of digital learning. *Learning Inquiry*, 1(1), 41–49. <https://doi.org/10.1007/s11519-007-0001-5>

