The Lecturer as a Program Manager: Lessons Learned from Continuously Improving a Project Management Master's Course for Engineers

Marcus Vinicius Pereira Pessoa and Linlin Pei

Introduction

Engineering education must help learners develop a complex skillset that includes analysis, communication, independent learning and teamwork capabilities while also meeting ever-increasing content demands for solving typical problems in engineering (Jonassen, 2015). Engineering learning and practice have three distinguishing characteristics (Johri et al., 2011): (1) the use of tools that help create representations (graphs, charts, visuals) to support the engineering work; (2) alignment with professional practices from the engineering community to work in groups and teams; (3) an emphasis on design, where design has a unique

M. V. Pereira Pessoa (✉) · L. Pei
University of Twente, Enschede, The Netherlands
e-mail: m.v.pereirapessoa@utwente.nl

L. Pei
e-mail: pei.l@utwente.nl

L. Chechurin (ed.), *Digital Teaching and Learning in Higher Education*,
https://doi.org/10.1007/978-3-031-00801-6_5

way of developing cognitive and situated skill requirements. Design is probably the most common kind of problem regularly solved by engineers and is widely considered to be one of the core or distinguishing engineering activities (Mills & Treagust, 2003; Simon, 1996). Design problems are normally solved through projects. The term 'project' is universally used in engineering practice as a 'unit of work', and almost every task undertaken in an engineer's professional practice is in relation to a project (Mills & Treagust, 2003).

One of the current most-favoured pedagogical models for teaching design is project-based learning (PBL) (Kolmos et al., 2020). Teaching design and design project management call for PBL that resembles reality, which normally relates to solving open problems and using multidisciplinary approaches (Polman, 1998), which is a challenge for PBL (Dym et al., 2005).

This chapter describes the development of the Engineering Project Management (EPM) master's course from 2018 to 2021. PBL is the course's core pedagogical approach, and its evolution followed a yearly improvement process intending to make the PBL dynamic closer to engineering project practice reality, where the learning process occurs as a natural consequence of the group's project execution. To achieve this objective, the pedagogical approaches of individual assessment in PBL, flipped classroom, socially shared regulation of learning (SSRL) and peer feedback were gradually introduced. The choice of these pedagogical approaches, although supported by promising results in the literature, was mainly based on the author's previous knowledge, preferences and the capability of receiving support from the university's infrastructure. Therefore, this research focuses more on investigating the extent to which the chosen approaches are appropriate for the proposed objective rather than on justifying or guaranteeing that these approaches are optimal choices.

The research followed the principles of the educational design research model as described by McKenney and Reeves (2018), which requires iterative cycles of design, evaluation and redesign. The research methodology followed a four-step continuous improvement cycle:

Analysis and Exploration Phase

1. Define the problem or improvement need based on the scenario and/or the students' feedback.
2. Define the intervention approach based on the literature and according to the university's supporting infrastructure.

Design and Construction Phase

3. Design/redesign the course according to the chosen intervention approach.

Evaluation and Reflection Phase

4. Gather qualitative and/or quantitative feedback from the course attendees. The measurements help determine if the set objectives were met and support the next improvement cycle's problem definition.

The EPM Course

EPM is worth five ECTS[1] and is a nine-week master's course that combines theory from project management and systems engineering with a group project. During the course, each group of students must create a project management plan for a product design and development (PDD) project. Project management theory supports project planning, where each group's team member is responsible for different knowledge areas (Table 2); systems engineering theory supports the integration (identification of the subsystems' interfaces) of the scopes from the different group projects as each of the teams is responsible for planning the development of a different subsystem from the same system.

[1] European Credit Transfer and Accumulation System (ECTS); 1 ECTS equals 28 h of study load.

The course was introduced in 2018, filling the gap in project management knowledge in the University of Twente (UT) mechanical engineering (ME) master's programme. From 2018 to 2021, course attendance ranged from 75 to 105, with most attendees coming from mechanical engineering and industrial design engineering (on average, 85%). Table 1 shows the course's learning objectives and related assessment approaches. The project has three assignments in its scope where each group develops: (1) project initiation material; (2) a project management plan; (3) performance indicators for controlling the project's execution.

EPM 2018: Initial Course Design

The creation of the EPM master's course was motivated by the importance of project management to engineering practice (McKinsey Capital Projects & Infrastructure Practice, 2017). The EPM uses PBL to solve ill-structured problems (Mills & Treagust, 2003; Williams & Williams, 1997) that are typical of design engineering. PBL begins with an assignment to carry out one or more tasks that lead to the creation of a final product or result (a design, model, etc.), which normally results in a report summarising the performed procedure and a presentation of the outcome (Prince & Felder, 2006).

In PBL, when dealing with ill-structured problems, one cannot assume that learners have enough skills to solve them (Jonassen, 1997); therefore, support is needed while still guaranteeing autonomous work (García-Martín & Pérez-Martínez, 2017). The level of support needs to be balanced because, on the one hand, scarce support hinders problem-solving and results in demotivation, and on the other hand, excessive support negatively affects self-learning. According to García-Martín and Pérez-Martínez (2017), support is particularly needed during tasks or phases that students find more difficult as well as in the project's cornerstone points. At these points, three types of support are proposed: providing temporary frameworks by scaffolding, giving a model or example of desired performance and coaching the students.

Therefore, the EPM course included a course-long project with the students working in groups to create a project management plan for

Table 1 Learning objectives and related assessment approach

Learning objective (LO)	Assessment		
	2018	2019	2020, 2021
LO1. Identify and differentiate the concepts related to project management, strategic management, operations management and crisis management	Test (summative)	Quizzes (formative) Test (summative)	Quizzes (summative)
LO2. Identify and differentiate the concepts related to portfolio, program, project and subproject	Test (summative)	Quizzes (formative) Test (summative)	Quizzes (summative)
LO3. Create a project management plan according to the five project management process groups: Initiating, Planning, Executing, Monitoring & Controlling and Closing	Project (summative)	Project (summative)	Peer feedback (formative) Project (summative)
LO4. Reflect on the strengths, weaknesses and applications of traditional and agile project management	Test (summative)	Exercise (formative)	Quizzes (summative)
LO5. Apply, by exercising during a practical project, tools and techniques from the project management knowledge areas (integration, scope, schedule, cost, quality, resource, communication, risk, procurement and stakeholder management)	Project (summative)	Project (summative)	Peer feedback (formative) Project (summative)
LO6. Apply, by exercising during a practical project, the Team Canvas, Project Management Canvas, Agile Management and Value Function Development	Project (summative)	Project (summative)	Peer feedback (formative) Project (summative)

(continued)

Table 1 (continued)

Learning objective (LO)	Assessment		
	2018	2019	2020, 2021
LO7. Integrate, by exercising during a practical project, aspects from lean product development, systems engineering, system modularisation and the function-behaviour-structure (FBS) ontology during project planning and execution	Project (summative)	Project (summative)	Peer feedback (formative) Project (summative)

a product development project. The lecture time was split into 60% theory and 40% group discussion with the lecturer. Qualitative student feedback suggested that the lecture time was insufficient to (1) cover the theory in the necessary depth; (2) deliver project feedback in the necessary amount and quality. Another complaint was that the project assessment did not grade actual student effort as the whole group received the same result regardless of how much work each student contributed.

EPM 2019: Better Accommodating the Content and Interaction

Considering the problem of solving the three issues identified during the course evaluation, blended learning and, in particular, the flipped classroom, were chosen to tackle items 1 and 2. To solve item 3, the selected approach was to individually assess group members.

Blended learning combines online and traditional learning environments, technology and media to create a more efficient and balanced learning environment (Osguthorpe & Graham, 2003). Blended learning also incorporates different teaching and learning methods (both online and traditional), group and individual learning activities and synchronous and asynchronous interactions (Garrison & Vaughan, 2012). The aim is to choose a combination that will highly motivate

Table 2 Project team's roles

2018	2019–2021	Role's responsibilities
Project manager	Project manager	Guarantees that the group works together and the deliverables produced by all team members are integrated
Project team	Scope specialist	Defines the project scope, which includes both engineering and managerial activities
	Scheduling specialist	Defines the project schedule that leads to scope delivery and risk mitigation
	Budget specialist	Estimates the project budget for executing all the project activities with the defined resources
	Stakeholders and communication specialist	Identifies and prioritises the stakeholders and defines how the team members and stakeholders communicate
	Quality specialist	Identifies the quality criteria and assures the project's quality
	Systems engineer	Conceives a system architecture capable of delivering the product's scope
	Risk specialist	Identifies, assesses and plans managerial and technical risk mitigation
	Resources and procurement risk specialist	Plans the resources (including human resources) and defines the project's procurement needs

the students and assist them in successfully mastering the course (Alonso et al., 2005; Thorne, 2003). The flipped classroom (Bergmann & Sams, 2014; Zainuddin & Halili, 2016) is one blended learning pedagogical approach where direct instruction moves from a synchronous group learning space to an individual learning space, and the resulting

group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. This is the reverse of the more common practice of introducing new content in the synchronous group space (class) then assigning homework and projects for the students to complete independently at home.

Blended learning and the flipped classroom have increasingly been used to change classroom dynamics and better engage students in the learning process (Bergmann & Sams, 2014; Zainuddin & Halili, 2016). One of the biggest advantages mentioned by students is that they had the option to watch each video lecture as many times as required to be prepared for class or for executing an assignment. Mok (2014) also observed that students were more engaged and empowered to take on more ownership of their learning. Finally, Lou et al. (2012) achieved positive results by using the flipped classroom to support self-directed learning when solving ill-structured problems.

The flipped classroom was implemented as part of the EPM redesign, where the theoretical content was covered by micro-lectures (7–10 min), and synchronous class time was used for group work and project feedback. The flipped classroom dynamic included the learning activities to be executed:

- Before class (out-of-class activities): Watching videos (micro-lectures) that presented the theory, answering the related online quizzes and exercises with the support of the reading material and elaborating on the project deliverables.
- In class (face-to-face or virtual class): The students discuss, interact, debate and solve problems together with guidance and immediate feedback given by the lecturer.
- After class (out-of-class activities): The students reflect on the feedback and upload revised versions of the project's deliverables.

Prince (2004) states that PBL courses do not need to be entirely team-based, nor must individual responsibility be absent, as seen by the emphasis on individual accountability in cooperative learning. Indeed, once PBL encompasses group work, special attention must be given to

fairly assessing the work so that the final grade reflects each student's effort in producing quality project results (Fernandes, 2014).

To implement this individual evaluation in a meaningful way and mimic practice, the class was divided into project teams composed of nine students where each student played a different role and was expected to produce individual but interdependent deliverables. Table 2 shows the role changes from 2018 to 2019 onwards. The students changed roles in each assignment, except for the project manager. In a reality-inspired scenario, the teams were part of the same company and each of them was responsible for planning the development of one specific product.

Couse evaluation highlighted that the flipped learning approach could accommodate the course's theoretical content and improve the effectiveness of lecturer feedback. The main issue was that 36% of the students thought that the assignment goals were unclear. The identified causes were:

1. Unclearly defined/written assignment tasks that require higher feedback frequency;
2. Open project goals that require higher feedback frequency;
3. Reduced feedback amount and quality, particularly due to the ratio of the available time and the number of student groups.

EPM 2020: Ambiguity Reduction

As identified in the 2019 course evaluation, bringing the course closer to engineering project practice reality also brought more ambiguity to the challenge imposed by the course project. Real-world design problems are complex, multifaceted, ill-structured and interact with existing contextual elements (Johri et al., 2011; Jonassen, 1997). Although well-structured problems have well-defined initial and goal states, clear constraints and a solution path, an ill-structured problem is often open-ended with uncertain or ambiguous goals and/or means to pursue the goals (Jonassen, 1997). This means that they could involve several acceptable solutions with multiple solution approaches, or there could be no solution at all (Kitchener, 1983). In this context, uncertainty

relates to a lack of information, and ambiguity is defined as a lack of clarity regarding the relevant variables and their functional relationships (Martin & Meyerson, 1988). Solving ambiguous and/or uncertain problems depends on the mental models the solvers choose to use, the resources available and the organisational context (Schrader et al., 1993), whereas a mental model represents how someone understands how something works in the real world; the mental model is then reused in situations deemed similar (Johnson-Laird, 1983).

Jonassen (1997) argues that ill-structured problem-solving is a design process based on decision-making and model building, instead of a goal-achieving process typical of solving well-structured problems. Ill-structured problem-solving requires solving its intrinsic ambiguity, where the problem-solvers must reconcile conflicting conceptualisations of the problem and construct arguments to defend their selection of problem space and solutions, which involves identifying alternative views or perspectives about the problem (Ge et al., 2016; Jonassen, 1997). Therefore, reducing ambiguity requires learners to acquire further knowledge, create new mental models, evaluate those models and select the best fit for further use (Kitchener, 1983). The challenge is selecting the skills and resources that fit the problem at hand (Schrader et al., 1993), which requires critical thinking to avoid quickly converging on sub-optimal solutions due to personal biases (Ge et al., 2016; Jonassen, 1997; Kitchener, 1983).

Researchers seem unanimous that one of the most effective types of learners is the self-regulated learner (Butler & Winne, 1995). Self-regulation of learning (SRL) is characterised by a recursive flow of information: the learners engage in academic tasks and draw on knowledge and beliefs to construct an interpretation of a task's properties and requirements. Based on their interpretation, they set goals that are approached by applying tactics and strategies that generate products. Monitoring these processes of engagement and the progressively updated products, they create internal feedback. This information provides ground for monitoring and reinterpreting the tasks and objectives and direct future engagement. External feedback is provided to confirm, add to or conflict with the learner's interpretation of the task and path for

learning (Kuhl & Goschke, 1994). In this way, encountered obstacles might require the adjustment or even abandonment of initial goals.

SRL helps learners navigate uncertain problem states, fuzzy situations and unclear goals in search of solutions; the process also reflects how the proposed solution might alleviate the causes of the problem, what should be done when a challenge arises and what values apply if alternative solutions are selected (Jonassen, 1997). Therefore, SRL plays an active role in ill-structured problem-solving (Ge et al., 2016).

When groups co-construct plans or align monitoring perceptions to establish a shared evaluation of progress, they are engaged in shared regulation. The concept of SSRL extends SRL from individuals to groups. The group regulates as a collective, where its members collaborate to construct shared task perceptions or shared goals. SSRL involves interdependent or collectively shared regulatory processes, beliefs and knowledge that are orchestrated in the service of a co-constructed or shared outcome (Panadero & Järvelä, 2015).

As part of SSRL, feedback allows progressive updates and the construction of mental models (Butler & Winne, 1995). Feedback allows a learner to confirm, add to, overwrite, tune or restructure information in memory. Feedback can be internal from peers in collaborating groups or the teacher.

Consequently, the 2020–2021 course redesign incorporated SSRL and peer feedback to support the student groups in dealing with ambiguity during project execution, where:

1. A partially filled rubric was provided when starting each assignment, listing each role's deliverable assessment criteria but omitting the grading rating.
2. The students worked in functional groups comprising students that performed the same role across the teams (i.e., scope specialists). Students from the same functional group worked together to define the rating. For instance, one criterion could include the expression 'clearly defined', but the understanding of its meaning and rating must emerge as a consensus in the functional group. The result from this step was a co-created assessment rubric.

3. In parallel to step 2 and benefiting from its results, the groups produced assignment version 1.
4. Assignment version 1 was then peer-reviewed by another group using the co-created assessment rubric for reference. To guarantee feedback quality, these peer reviews received a quality check from the lecturer to see if the ambiguity was removed and if the target values were too simplistic or unfeasible/unrealistic.
5. By considering the learning from giving and receiving feedback, a final version of the assignment was produced.
6. The lecturer then used the co-created assessment rubric to summatively assess the final version of the assignment.

Although the students positively evaluated SSRL and peer feedback support during the ambiguity reduction process, improvement opportunities were also identified. The students pointed out that the project could add more technical challenges and that the lecturer's feedback should cover detailed issues and include a discussion about general integration issues, which were still somewhat ambiguous. They also suggested valuing their effort by summatively assessing the quizzes.

EPM 2021: The Lecturer as a Program Manager

The students' feedback is in line with Jonassen (1997) who stated that the right balance between self-direction and direct instructions, particularly in the case of ill-structured and open problems, must be achieved to guarantee academic-level achievement.

To accommodate this change, the course was framed as a program. In the practice of project management, a program is defined as a set of projects that must be managed in a coordinated way to obtain the benefits not achieved by managing them individually (Project Management Institute, 2017). In the course scenario, the teams were part of the same company and each of them was responsible for planning the development of one specific subsystem for a new product. This setting required collaboration within and among the groups to guarantee the interfaces between the different subsystems. In this context, the lecturer was the

course's program manager, while the students who were project managers in each group acted as tutors and facilitated the coordination.

The course evaluation pointed to the negative impact of the lack of face-to-face interaction because of the measures against COVID-19.

EPM 2020–2021: Impact of COVID-19

In 2020 and 2021, the restrictions caused by COVID-19 resulted in the synchronous interaction with and among the students being changed from face-to-face to virtual:

- It was impossible to meet face-to-face due to the COVID-19 restrictions and because some students returned to their home countries.
- Meeting face-to-face was impractical when a large number of students could not be accommodated in the same physical environment at a safe distance.
- The need for guaranteeing feedback quality became more difficult when several lecturers and/or tutors were involved.

In a course where quality feedback is paramount, the total lack of face-to-face impacted communication efficiency and was the main source of complaint from the students:

> I really liked the course set-up, but online, it simply didn't work out as the communication with the groups was not easy. If it is onsite again, I would probably enjoy it more!!
>
> I really missed working in person. I think, especially with this subject, it is super important to be able to meet in person. By video conferencing, a lot of information gets lost and the workflow is just not the same.
>
> I feel that the collaboration among team members is lacking a bit. It did not feel like a real work environment. But yes, that could be mostly because we communicate online these days.

EPM Evolution Summary

Table 3 summarises the EPM course's evolution by showing what pedagogical approaches were used in each year, the number of micro-lectures and the roles performed by the lecturer:

- **Lecturer as a content expert**. A content expert provides feedback, answers questions and shares experiences to help guide decision-making. During project execution, the lecturer will react to the questions and requests made by the students and bring their engineering project management knowledge and experience into play. In this way, they act as a project management office (PMO).
- **Lecturer as an assessor**. A learning assessor gauges the extent to which the learning objectives were achieved according to the evidence provided.
- **Lecturer as a coach**. A coach provides specific instructions, telling you what you need to do and how to do it. The lecturer will act as a coach during the virtual classes by suggesting specific topics for group discussion (many times related to the point raised in the discussion

Table 3 EPM evolution summary

	2018	2019	2020	2021
Traditional classroom	×			
Flipped classroom		×	×	×
Project leader and team	×			
Team with specific individual roles		×	×	×
Formative assessment of quizzes		×	×	
Summative assessment of quizzes				×
Lecturer-defined assessment rubric	×	×		
Co-created assessment rubric			×	×
Project groups	×	×	×	×
Functional groups			×	×
Lecturer as a content expert	×	×	×	×
Lecturer as assessor	×	×	×	×
Lecturer as a coach		×	×	×
Lecturer as a program manager				×
Number of videos + quizzes	–	22	24	32

forums) and observe, reflect, model and debrief the students during the activity.

- **Lecturer as a program manager**. A program manager is a strategic project management professional whose job is to help oversee and coordinate the various projects, products and other strategic initiatives across an organisation. In this way, the lecturer will manage the program that brings together all of the product's subsystem projects.

EPM 2020 and 2021 in Numbers and Opinions

In 2020 and 2021, the students were surveyed to assess their appreciation of the course content and organisation (including the individual assessment of the group work), the flipped classroom, SSRL and peer feedback. The survey included closed questions using a 5-point Likert scale (5—highly agreed, 4—agreed, 3—neither agreed nor disagreed, 2—disagreed, 1—highly disagreed) and open questions. There were 106 respondents out of 106 students in 2020 and 84 respondents out of 84 students in 2021. The colour coding used in Table 4 aims solely to facilitate the visualisation of the higher means (greener) and standard deviations (redder) and have no further significance.

EPM 2020 and 2021 in Numbers

To What Extent Did the Course Achieve Its Objectives?

Most of the students agreed that the course is important and both achieved its learning objectives and the students' personal objectives (Table 4). It indicates that the elements included in the course could combine and facilitate learning. Students' comments highlighted the need for further alignment of the content available in different materials and the opportunity for further reflection.

Table 4 EPM 2020 and 2021

		2020			2021		
		Mean	Stdv	Median	Mean	Stdv	Median
	This course is relevant for a future engineer	4.29	0.61	4	4.29	0.48	4
	The course learning objectives were achieved	4.12	0.58	4	3.98	0.69	4
	My personal learning targets were achieved	3.90	0.87	4	4.04	0.81	4
Flipped classroom	1.This approach makes lectures more interesting.	3.90	0.93	4	3.65	0.88	4
Flipped classroom	2. This approach is better than the traditional approaches, in the case of project-based courses.	4.02	0.84	4	3.95	0.87	4
Flipped classroom	3. This approach makes students more motivated and active throughout the course.	3.75	0.91	4	3.64	0.95	4
Flipped classroom	4. This approach motivates students to attend the lectures.	3.47	1.01	4	3.46	1.07	4
Flipped classroom	5. Courses using this approach will be seen positively when choosing a future course.	3.89	0.91	4	3.73	0.88	4
SSRL	1. SSRL within this course was useful.	4.29	0.87	4	3.96	0.87	4
SSRL	2. Being capable of defining assessment criteria is an important skill.	4.41	0.63	4	4.24	0.79	4
SSRL	3. I learned from creating the assessment criteria in cooperation with fellow students.	3.99	0.94	4	3.75	0.96	4
SSRL	4. Through SSRL, I reflected critically on my own work.	4.10	0.86	4	4.05	0.83	4
SSRL	5. SSRL makes me feel responsible for my own learning process.	3.83	0.91	4	3.71	1.10	4
SSRL	6. SSRL ensures an equal relationship between the teacher and the students.	3.57	0.99	4	3.51	1.01	4
Peer feedback	1. Peer feedback within this course is useful.	4.06	0.87	4	3.94	1.06	4
Peer feedback	2. Being capable of giving constructive peer feedback is an important skill.	4.75	0.43	5	4.67	0.47	5
Peer feedback	3, Being capable of dealing with critical peer feedback is an important skill.	4.72	0.45	5	4.70	0.53	5
Peer feedback	4. Being capable of improving one's work based on received peer feedback is an important skill.	4.60	0.51	5	4.49	0.70	5
Peer feedback	5. Peer feedback ensures that I put effort into my assignments.	3.69	0.96	4	3.51	0.94	4
Peer feedback	6. Peer feedback ensures that I am better prepared.	3.97	0.90	4	3.87	0.78	4
Peer feedback	7. Feedback should only be provided by the teaching staff.	2.15	0.95	2	2.11	0.93	2
Peer feedback	8. In general, I am confident that the peer feedback I provide to other students is of good quality.	3.91	0.68	4	3.81	0.70	4
Peer feedback	9. In general, I am confident that the peer feedback I receive from other students is of good quality.	3.26	0.96	3	3.13	0.90	3
Peer feedback	10. I learn from giving peer feedback to fellow students.	4.29	0.58	4	3.99	0.77	4
Peer feedback	11. Through peer feedback, I learn to reflect critically on my own work.	4.14	0.68	4	4.23	0.64	4
Peer feedback	12. Peer feedback makes me more aware of the assessment criteria for this course.	4.28	0.76	4	4.31	0.69	4
Peer feedback	13. Peer feedback ensures an equal relationship between the teacher and the students.	3.45	0.90	4	3.16	0.96	3

To What Extent Did the Flipped Classroom Work in the Course?

In general, the students appreciated the flipped classroom (Table 4). In particular, the answers from question 4 show that work still needs to be done to increase the students' motivation to come to the lectures as the answers indicate that the lectures' value added was not perceived as being high by 45% of the students. If online settings are continued, online

lectures need to be redesigned, but this problem might be solved/reduced by returning to a face-to-face setting.

To What Extent Did Self-Regulation Work in the Course?

The use of SSRL during the course was highly appreciated (Table 4) as 87% of the students agreed or highly agreed that it was useful, and an even higher number (91%) thought the capability of defining assessment criteria was an important skill. Mixed results were given to questions 5 and 6, which related to feeling responsible for their own learning process and the SSRL ensuring an equal relationship between teacher and students. Unfortunately, not all of the criteria in rubrics defined by the students had the expected quality, which required intervention and last-minute adjustments, which might have had a negative impact on question 6.

To What Extent Did Peer Feedback Work in the Course?

The students rated the peer feedback positively (Table 4) and considered themselves capable of giving and receiving feedback. Another finding was that the students rated peer feedback as a positive tool for increasing the awareness of the course's success criteria. The answers also show that the course implementation of peer feedback can be improved. While most of the students were confident in giving good feedback, they were not as confident about the received feedback quality and that peer feedback would ensure they are better prepared. Sometimes low-quality rubric criteria led to conflicting assignment interpretations between the feedback giver and the lecturer.

The Students' Opinions About EPM in 2020 and 2021

The most relevant/recurrent strengths and weaknesses that supported the students' evaluations of the course are listed in sequence.

To What Extent Did the Course Achieve Its Objectives?

⊕ **(2020)** '*The information provided in the course itself is really good and interesting'; 'I think the learning goals are of high importance for an engineer'; 'I really think I will use the techniques I learned in this course!'; 'It is the first time I can actually picture how I would be using this new information a course taught me in future jobs.'*
⊕ **(2020)** '*I expect from a master's course that it motivates me to explore the subject independently and expand my knowledge. I also expect to improve my collaboration skills by working with peers. This course is immersive in the sense it is designed with assignments and quizzes that facilitated the learning and helped me learn from peers'; 'This course is difficult because you really can learn something that is partly theoretical and practical, which is not found often at the university.'*
⊕ **(2020)** '*This course, aside from one other, is the first management course that actually teaches me how to use specific management tools and how to apply management concepts. This is a great relief for me as a pragmatic engineer. Simultaneously, much inspiration is provided by the mentoring aspect of the lecturer's role and the guest lecturers. With anecdotes, experience and a personal approach, I became inspired to pursue this function in my career. In one sentence: This course proved to me the utility of management theory that was previously littered with buzzwords and empty idioms.'*
⊕ **(2021)** '*In general, I found the course very good and useful. It is the first time, although I had so many group projects, that I made such a clear plan beforehand. For me, the course and the assignment objectives were clear.* ⊖ *However, I never knew exactly what I had to deliver at the end. Only after we were given some examples it was clear to me.'*
⊕ **(2021)** *'I never knew about the intricacy of the project plan before this. This course helped me understand the importance and depth it requires even before the start of a project.'*
⊕ **(2020)** '*The videos and quizzes, the books, the lecture notes and the live lectures really helped to keep motivation during the entire course.* ⊖ *The drawback of this is that if the information can be found in four different places, it is hard to find if you need to find specific information later.'*

⊕ **(2021)** *'I thought the whole structure of the course really supported us in experiencing the process instead of just getting a whole lot of information thrown at us.'*
⊕ **(2021)** *'There is a high degree of individuality and self-supported learning, which I think is key for a master's student. Yet, there is a good and clear method of explaining the new theory. By rotating the tasks within a project group, you are forced to perform different kinds of tasks, which I think is something that is limited if it is not forced upon students. In this way, you develop yourself into a multi-available employee for future employers.'*
⊕ **(2020)** '*Even with the project groups being so large, I like that we all had a specific role, so you do not get people who do not contribute anything to the project. Although you work in a group you still get an individual grade, which I like.'*
⊕ **(2021)** *'Regardless of your background in project management, the assignment was still challenging. A lot was going on within the project itself, and then on top of that, you had to collaborate with other project groups. Not only did this significantly increase the level of difficulty of the course, but it was also a new and fun experience. I have never heard of a course within the UT where you have to work together with other project groups.'*
⊕ **(2021)** *'I have learned a lot in this course and with a very broad spectrum. Most master's courses taught only a few tools and had a narrower approach to their end goal and a lot of time was spent writing a report, which was more or less the same most of the time. This course allowed multiple angles on a project, especially since everyone had different roles. I feel like I learned many new things while also going into some depth with other topics I already knew about.'*
⊕ **(2021)** '*The pressure of somewhat vague assignments to think even harder.'*
⊕ **(2020)** '*I believe the recent change to the course, where every member performs several different specialist tasks, is definitely a good decision; I also believe it is better for members of the same specialist group to perform with their fellow specialists (same rubric group), which was a nice improvement*'; '*changing roles allowed broader learning.'*

⊕ **(2020)** '*Even though the requirements were at times confusing, the discussion forums, the rubrics and the Q&A sessions helped a lot.'*
⊖ **(2020)** '*Having information in a lot of places (micro-lectures, lectures, lecture notes, two books, the internet) often made it confusing to know where to look for your information'; 'A lot of resources are available for this course (e.g., quizzes, lectures, PMBOK, slides, communities of practice,* etc.*), which was a bit confusing for me because there was not often a clear direction where to go.'*
⊖ **(2020–2021)** The course material '*did not cover the information required for the different assignments in the same depth'; 'is not as high (difficult) as the other master's courses'.*
⊖ **(2020)** '*Terms and names used in the course were used interchangeably, and no clear definition was mentioned as to what they might be.'*
⊖ **(2020–2021)** '*The methods that we are using could use a more critical evaluation, which is something that I would expect in a master's course.'*
⊖ **(2021)** *'The main point of critique I have for the course is that the purpose and exact deliverables of the assignments were not always clear at first, ⊕ but fortunately, plenty of opportunities were provided for clarification, such as the lectures and Q&A.'*
⊖ **(2020)** '*It depends on the luck you had with choosing your roles, the group you had and the community apparently.'*
⊖ **(2020)** Assignments were still perceived as ambiguous at the beginning (also corroborated by the survey results in sect 5.1.1): '*Assignments' vagueness/ambiguity, which led to spending more time trying to understand WHAT to do than the time effectively doing (understand HOW to do is part of the doing).'*

To What Extent Did the Flipped Classroom Work in the Course?

⊕ **(2020)** '*I think the teaching methods used throughout the course are very effective. The flip classroom method enhances the commitment of students and makes it more relevant for students to prepare themselves before lectures.'*

⊕ **(2020)** '*I had experiences with the flipped classroom approach in the past, and it was terrible. This course did an infinitely better job of using the approach. It was nice to be able to do the studying and lecture-watching on your own time, it helped with having a bit more time to think about the raised points.'*
⊕ **(2020)** '*I really (really really) value the structure of this course. The division of lectures into small chunks followed by quizzes might have brought my first experience with a course during which I did not miss at least 50% of the covered content because I was daydreaming during lectures.'*
⊕ **(2021)** *'The small videos are much better than 1.5-hour-long lectures with bad quality and contain the same if not more information. The quizzes help to retain the information. And the effort from the lecturer to adapt their course with new methods motivates me more to access them.'*
⊕ **(2021)** *'First, I liked the flipped approach because by using videos and quizzes I could study the basic concepts in my own time and at my own pace. In this way, we had more time during lectures to discuss the assignment and get feedback from the professor.'*
⊕ **(2020)** '*The videos provide you with enough information and are concise as opposed to many lectures that give too much unnecessary information.'*
⊕ **(2020)** '*The videos were well-put-together and were the right length to not get distracted but stay focused on the video. It was useful that they could be paused when I would get distracted and rewatched while working on assignments. These aspects are the opposite of the normal lecture approach, but better in my opinion.'*
⊖ **(2020)** The videos and quizzes '*did not cover the information required for the different assignments in the same depth'.*
⊖ **(2020)** '*The micro-lectures could have more practical examples besides the theory, in a way to understand not only the theory but also how to apply it in the right way.'*
⊖ **(2020)** '*The quizzes after the micro-lectures did not always ask questions about the information presented in the micro-lectures or the understanding from the rest of the lectures and reading. Sometimes they were about things we just hadn't learned yet.'*

⊖ **(2020–2021)** Several students pointed out that the lectures need improvement: '*There was quite a difference in energy between the micro-lectures and lectures'; 'lack of case discussion'; 'the lecture's information density could be higher'; 'the content of the conferences every Friday morning is not very helpful for executing the assignments or getting the background knowledge. It sometimes felt like a waste of time as it was a little slow-paced and a lot of the same points were made.'*
⊖ **(2020)** Another point raised regarding the videos and quizzes: '*the student has too much freedom to not look and understand the material'.*
⊖ **(2020)** '*It has the disadvantage of being less interactive. It is less inviting to ask questions based on the course material.'*

SSRL (creation of rubrics in the communities of practice) and peer feedback

⊕ **(2020)** '*I think it* (the rubric creation) *helped with thinking about how to approach the assignment together*.'
⊕ **(2021)** *'The methodology used in the course was very interesting. The course takes students out of their comfort zone and places them in the position of protagonists in the learning process. This was a good experience in active learning.'*
⊕ **(2020)** '*It was very nice to have your project group and your expert group. I very much enjoyed working together with both.'*
⊕ **(2020)** '*I thought it was a great idea to give us the criteria and have us define the criteria assessment for poor/good etc., or even change/add criteria. This way by giving us the initial criteria it becomes clearer what should be done for an assignment and by defining the assessment ourselves, it makes us think better about the quality of the deliverables to get a certain grade.'*
⊕ **(2020)** '*What I really liked about the project is that you also were communicating with the people who had the same role as you. I think I learned the most from this through discussion.'*
⊕ **(2020)** '*It felt good to be part of two communities (group and functional group) because both were somehow able to help whenever I was stuck.'*

⊕ **(2020)** '*Working with the functional groups allowed me to understand the topics relevant for each assignment.'*
⊕ **(2020)** '*Cross team cooperation with our teammates and specialists with the same function was an intense but useful process as there was a lot to learn and teach others.'*
⊕ '*Working together as a team, working with various specialist groups was very interesting. Getting feedback from other students, giving feedback to others' work helped me learn many things.'*
⊕ **(2021)** *'This was my first peer review course. I learned a lot after my peer review feedback. I learned more about critical thinking and owning up to my tasks as each person is responsible for his tasks and also other team members rely on my work. This course helped me in trusting my teammate's work.'*
⊕ **(2020)** '*I think the level of self-steering learning (not everything is prepared but you have to figure out yourself what you are doing) is a very important feature of a master's course.'*
⊕ **(2020)** '*The peer review exercises help to get a better understanding of what was expected during the exercises.'*
⊕ **(2021)** '*What I experienced the most is that what we needed to do for each assignment was always unclear. By discussing it with the other groups, specialisations, Q&A and examples, it was finally clear for me. I think this is partly the intention of this course.'*
⊕ **(2021)** *'I really liked using the rubric criteria because it forces you to think about the aspects that the product must meet. It has certainly contributed to the critical view of my own work because as a student you determine for yourself what requirements your work must meet.'*
⊕ **(2021)** *'Feedback moments were really great!'*
⊖ **(2021)** *'I think giving and receiving feedback is awesome, but how it is done now takes too long, and it forces you to work on the weekends or overtime on Mondays and Tuesdays if there is something actually wrong. Once it is possible, I would rather send the hand-in to another group and physically discuss it in an afternoon session. This gives way more depth as one sentence is sometimes not enough. You have to do something in COVID times, but this is a significant problem in my opinion.'*
⊖ **(2020)** '*Not everyone participated in the functional groups.'*

⊖ **(2020)** '*I think it would be better if the rubric was just there and that the group is used to discuss the best tactic on how to execute the project plan, for example.*'
⊖ **(2020)** '*The communities of practice did not work for me. We had 13 people, and only 4 gave any input during the meetings. The rest did not participate in the creation of the rubric or the discussion at all. When there is no push for students to participate, they apparently don't do it.*'
⊖ **(2020)** '*It might be better to have an individual rubric requirement and deadline so that students can discuss the overall best rubric to take. This, hereafter, should also be evaluated by the professor.*'
⊖ **(2020)** '*I got high scores in the peer review but lots of things have yet to be done.*'
⊖ **(2020)** '*It is self-learning, but you can still actually miss important stuff and you can miss points in the grading because of it.*'
⊖ **(2021)** *'It would be nice if the students were handed an example of how to write peer feedback.'*

Reflection

From 2018, when EPM was included in the master's courses list, until 2021, the EPM master's course has been continuously redesigned to simulate the reality of engineering project practice and let the learning process occur as a natural consequence of the group project execution. The course uses PBL, where the assignments relate to a course-long group project that forms the basis for student assessment. The challenges faced were (1) accommodating both in-depth content and group coaching within the course timeframe; (2) assessing student performance fairly; (3) dealing with the ambiguity and uncertainty intrinsic in open problems; (4) adapting to COVID-19 restrictions and the fully online course setting.

Redesigning the course as a flipped classroom was chosen to accommodate the theoretical content and yet have enough coaching time to guide and give feedback to the project groups. The theoretical content was covered by recorded micro-lectures (7–10 min videos), online public

videos (to show different perspectives about the content) and readings. Theory recall and understanding was assessed by quizzes related to each video as well as additional reading. Theory application, analysis and evaluation were assessed by the project assignments. Coaching took place asynchronously via discussion forums and email and synchronously during the lectures. Classroom time gradually evolved from lecturing to coaching; in 2021, lecturing took place only in the first two lectures after which there were only meetings with each group.

The students gave very positive feedback about the flipped classroom setting and micro-lectures. Regarding lecturing the content in class, student feedback showed that they preferred using class time for richer interaction rather than just consuming theory. Providing richer and more meaningful in-class interaction proved to be a challenge as it not only required developing the necessary material but also changing the lecturer's role from just a content expert. During the richer interaction, the lecturer was challenged by unexpected questions and taken out of their comfort zone. To deal with that, the lecturer changed to a coaching role and then further to a program manager role. In this sense, the lecturer helped the students navigate the theory, find paths to solving problems (coaching role), organise the effort among the groups and communicate to the whole team to guarantee work coherence and even learning (program manager role). As a final remark about the flipped classroom, careful selection must be made to guarantee the coherence among the online course materials, particularly because different sources might use different terminology, which might confuse and frustrate the students.

To perform fair student assessment, the project group became a project team with each team member having a specific role responsible for producing an individual deliverable, while the team deliverable had to be coherent and whole. The challenge here was twofold: (1) to divide the overall work into meaningful chunks with similar workloads and avoid some students working more than others; (2) to avoid limited learning due to over-specialisation as students might maintain the same role and only learn part of the theory and practice. Dividing the work was facilitated because project management is clearly divided into knowledge areas

(Project Management Institute, 2017), but guaranteeing similar workloads was a reason for student complaints, which was only solved in 2021. Avoiding limited learning was achieved by requiring students to change roles in each of the three project assignments.

As mentioned before, planning a development project is an open problem in that different teams might create different but correct plans. Therefore, teaching does not have a unique recipe, but students need to understand the planning process and develop critical thinking to choose the right approaches according to the project's peculiarities. SSRL was chosen to deal with this challenge as it is particularly useful for groups to understand a problem and set strategies for its solution. SSRL was implemented by providing a basic rubric for each of the project's assignments, and students had to reflect on what they considered a good result. This rubric was then used during the assignment creation, peer feedback and summative assessment. In this sense, learning takes place before, during and after the assignment is created. This accomplishment was confirmed by the student survey results, where they positively rated both SSRL and peer feedback. It is important to mention that the produced deliverables were of better quality than previous years, including SSRL and peer feedback.

The course was initially designed to have face-to-face synchronous and/or class meetings. The change to a complete online course directly impacted lecturer feedback and student group interactions, which would also have happened during the face-to-face lectures. The main negative consequence was general communication during group work (both project groups and functional groups). This was a general complaint among the students, and they think they lost out from the lack of face-to-face communication with their peers. The lectures were also negatively affected by the situation. It was a challenge to interact with more than 100 students without seeing any of them. The students highlighted the online lectures' low value in terms of depth and energy.

Conclusion

This work presented the evolution of the Engineering Project Management (EPM) master's course from 2018 to 2021. EPM is a PBL-based course that aims to bring teaching project management closer to engineering project practice reality so that the learning process occurs as a natural consequence of the execution of the group project. To achieve this objective, the pedagogical approaches of individual assessment in PBL, flipped classroom, SSRL and peer feedback were gradually incorporated over the three years. These redesigns also led to changes in the lecturer's role, which evolved from content expert and assessor to include the roles of coach and program manager. The latter guaranteed coherence in the work, communication among the groups, and it also became a live example of project management in practice and was a source of learning in itself.

The evidence gathered from 2018 to 2021 (and particularly in 2020 and 2021) shows that the elements implemented throughout the interventions were appreciated by the students, and the objective of bringing the course closer to real-life practice was achieved. The use of the flipped classroom, SSRL and peer reviews was highly appreciated by the students, which suggests that these approaches helped create a positive learning dynamic. The achieved results align with the literature that recommends the use of SSRL and peer feedback when teaching about open problems to face their intrinsic uncertainty and ambiguity. No contradictions or new findings resulted from this research. The intervention's main theoretical contribution is showing that self-regulation effectively helped reduce ambiguity when the project groups were dealing with open problems/assignments.

The COVID-19 restrictions and shifting to full online lecturing also affected the course. In the initial settings, the in-class time was planned face-to-face, when mostly group work and lecturer feedback would take place. The full online setting reduced communication quality and effectiveness among the group members and with the lecturer.

Even though this research has provided promising results, it is limited by including only one case of application. Most of the students were north European and from the mechanical engineering master's

programme, which creates a group with a similar and specific mindset. Future work could include understanding the difficulties found by minorities and students who are not from northern Europe. Further analysis in other course scenarios is also required.

The EPM redesign effort was partially funded by the European Commission's Erasmus + project, Cooperative e-learning Platform for Higher Education in Industrial Innovation (CEPHEI), Grant Agreement 586081-EPP-1-2017-1-FI-EPPKA2-CBHE-JP.

References

Alonso, F., López, G., Manrique, D., & Viñes, J. M. (2005). An Instructional Model for Web-Based e-learning Education with a Blended Learning Process Approach. *British Journal of Educational Technology*. https://doi.org/10.1111/j.1467-8535.2005.00454.x.

Bergmann, Jonathan; Sams, A. (2014). Flip Your Classroom: Reach Every Student in Every Class Every Day. In *International Society for Technology in Education,* 17(1). https://doi.org/10.1111/teth.12165.

Butler, D. L., & Winne, P. H. (1995). Feedback and Self-Regulated Learning: A Theoretical Synthesis. *Review of Educational Research*. https://doi.org/10.3102/00346543065003245.

Dym, C. L., Agogino, A., Eris, O., Frey, D. D., Leifer, L. J., & College, H. M. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education*, *January*, 103–120. https://doi.org/10.1109/EMR.2006.1679078.

Fernandes, S. R. G. (2014). Preparing Graduates for Professional Practice: Findings from a Case Study of Project-based Learning (PBL). *Procedia—Social and Behavioral Sciences*. https://doi.org/10.1016/j.sbspro.2014.08.064.

García-Martín, J., & Pérez-Martínez, J. E. (2017). Method to Guide the Design of Project Based Learning Activities Based on Educational Theories. *International Journal of Engineering Education*.

Garrison, D. R., & Vaughan, N. D. (2012). Blended Learning in Higher Education: Framework, Principles, and Guidelines. In *Blended Learning in Higher Education: Framework, Principles, and Guidelines*. https://doi.org/10.1002/9781118269558.

Ge, X., Law, V., & Huang, K. (2016). Detangling the interrelationships between self-regulation and ill-structured problem solving in problem-based learning. *Interdisciplinary Journal of Problem-Based Learning*. https://doi.org/10.7771/1541-5015.1622.

Johnson-Laird, P. N. (1983). Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness. *Language*. https://doi.org/10.2307/414498.

Johri, A., Olds, B. M., Esmonde, I., Madhavan, K., Roth, W. M., Schwartz, D. L., Tsang, J., Sørensen, E., & Tabak, I. (2011). Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences. *Journal of Engineering Education*. https://doi.org/10.1002/j.2168-9830.2011.tb00007.x.

Jonassen, D. H. (1997). Instructional Design Models for Well-Structured and Ill-Structured Problem-Solving Learning Outcomes. *Educational Technology Research and Development*. https://doi.org/10.1007/bf02299613.

Jonassen, D. H. (2015). Engineers as Problem Solvers. In *Cambridge Handbook of Engineering Education Research*. https://doi.org/10.1017/CBO9781139013451.009.

Kitchener, K. S. (1983). Cognition, Metacognition, and Epistemic Cognition: A Three-Level Model of Cognitive Processing. *Human Development*.

Kolmos, A., Holgaard, J. E., & Clausen, N. R. (2020). Progression of Student Self-Assessed Learning Outcomes in Systemic PBL. *European Journal of Engineering Education*. https://doi.org/10.1080/03043797.2020.1789070.

Kuhl, J., & Goschke, T. (1994). A Theory of Action Control: Mental Subsystems, Modes of Control, and Volitional Conflict-Resolution Strategies. In J. Kuhl & J. Beckmann (Eds.), *Volition and Personality: Action Versus State Orientation* (pp. 93–124). Hogrefe.

Lou, S.-J., Chung, C.-C., Dzan, W.-Y., & Shih, R.-C. (2012). Construction of A Creative Instructional Design Model Using Blended, Project-Based Learning for College Students. *Creative Education*. https://doi.org/10.4236/ce.2012.37187.

Martin, J., & Meyerson, D. (1988). Org Cultures and the Denial Channeling and Acknowledgement of Ambiguity. In *Managing Ambiguity and Change* (pp. 93–125).

McKenney, S., & Reeves, T. C. (2018). Conducting Educational Design Research. In *Conducting Educational Design Research*. https://doi.org/10.4324/9781315105642.

McKinsey Capital Projects & Infrastructure Practice. (2017). *The Art of Project Leadership: Delivering the World's Largest Projects*.

Mills, J. E., & Treagust, D. (2003). Engineering Education—Is Problem Based or Project-Based Learning the Answer? *Australasian Journal of Engineering Education*, *3*, ISSN 1324–5821. http://www.aaee.com.au/journal/2003/mills_treagust03.pdf.

Mok, H. N. (2014). Teaching Tip: The Flipped Classroom. *Journal of Information Systems Education*.

Osguthorpe, R. T., & Graham, C. R. (2003). Blended Learning Environment: Definitions and Directions. *Quarterly Review of Distance Education*, *4*(3), 227–233. Article.

Panadero, E., & Järvelä, S. (2015). Socially Shared Regulation of Learning: A Review. In *European Psychologist*. https://doi.org/10.1027/1016-9040/a000226.

Polman, J. L. (1998). Activity Structures for Project-Based Teaching & Learning: Design and Adaptation of Cultural Tools. *AERA*.

Prince, M. (2004). Does Active Learning Work? A Review of the Research. In *Journal of Engineering Education,* 93(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x.

Prince, M., & Felder, R. (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education*. https://doi.org/10.1002/j.2168-9830.2006.tb00884.x.

Project Management Institute. (2017). The Standard for Program Management. In *PMI*. https://www.amazon.com/Standard-Program-Management-Fourth-SPANISH/dp/1628255730.

Schrader, S., Riggs, W. M., & Smith, R. P. (1993). Choice Over Uncertainty and Ambiguity in Technical Problem Solving. *Journal of Engineering and Technology Management*, *10*(1–2), 73–99. https://doi.org/10.1016/0923-4748(93)90059-R.

Simon, H. A. (1996). *The sciences of the artificial* (Vol. 1). https://doi.org/10.1016/S0898-1221(97)82941-0.

Thorne, K. (2003). Blended Learning: How to Intergrate Online Learning and Traditional Learning. In *Kogan Page*.

Williams, A., & Williams, P. J. (1997). Problem-Based Learning: An Appropriate Methodology for Technology Education. *International Journal of Phytoremediation*, *15*(1), 91–103. https://doi.org/10.1080/026351497015 0107.

Zainuddin, Z., & Halili, S. H. (2016). Flipped Classroom Research and Trends from Different Fields of Study. *International Review of Research in Open and Distance Learning*, *17*(3), 313–340. https://doi.org/10.19173/irrodl.v17i3.2274.