Does a flipped classroom approach help? – Experiences from a project-based engineering course

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Abstract

Many project-based courses start with theoretical background lectures. However, the application of this knowledge in the students' projects is often limited. This paper explores the research question: Does a flipped classroom approach improve the connection between theoretical lectures and the practical project? The method consists of converting four conventional lectures into a flipped classroom approach and posing surveys to the students. Furthermore, the teachers reflect on the outcomes in comparison to previous years. The results show that the exercises after the pre-recorded flipped lectures are appreciated by the students. However, the quality of their final project reports and observations during supervision meetings do not show clear results. As the project was carried out in 2021 during the pandemic, the results might be overshadowed by the impact of the remote teaching situation. Finally, the continued work on the flipped classroom approach led to high quality reports and improved course evaluations in 2023.

Sammanfattning

Många projektbaserade kurser börjar med teoretiska bakgrundsföreläsningar. Tillämpningen av dessa kunskaper i studenternas projekt är dock ofta begränsad. I den här uppsatsen undersöks forskningsfrågan: Förbättrar en flippad klassrumsmetod kopplingen mellan teoretiska föreläsningar och det praktiska projektet? Metoden består av att omvandla fyra konventionella föreläsningar till en flippad klassrumsmetod. Utvärdering görs med hjälp av enkäter till studenterna. Dessutom reflekterar lärarna över resultaten i jämförelse med tidigare år. Resultaten visar att övningarna efter de förinspelade flippade föreläsningarna uppskattas av studenterna. Kvaliteten på deras slutliga projektrapporter och observationer under handledningsmötena visar dock inga tydliga resultat. Eftersom projektet genomfördes 2021 under pandemin kan resultaten överskuggas av effekterna av den avlägsna undervisningssituationen. Det fortsatta arbetet med flippad klassrumsmetoden ledde till högkvalitativa rapporter och förbättrade kursutvärderingar i 2023.

Keywords: *flipped classroom; project-based learning; life cycle engineering; pedagogical project.*

1 Introduction

Project-based courses have been gaining popularity with the aim to address engineering megatrends, such as education for sustainability (Sukackė et al., 2022). Project work has been an important part in teaching life cycle engineering at many different universities (Viere et al., 2021). The course Life Cycle Engineering (BOM250) at the Department of Architecture and Civil Engineering (ACE) also uses a project-based learning approach. The

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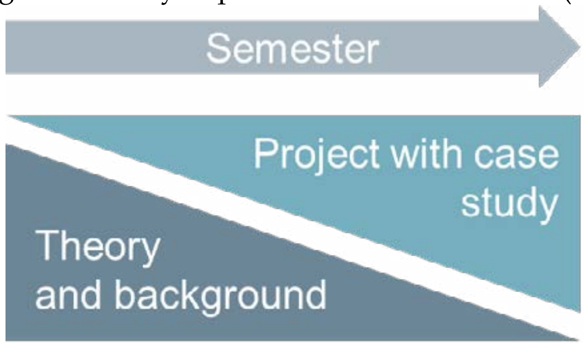
course has been taught for eight years and about 50 civil engineering students on the master level take the course every year. The main task is to calculate the environmental impact of a building or an infrastructure project, e.g. a bridge, using LCA. This project work is conducted in groups of four to five students and the written project report makes up 50% of the final grade. The rest the course consists of lectures on the theory needed for the project, software tutorials, and of small exercises. The exam at the end of the course makes up the other 50% of the grade.

As in most LCA course for engineers (Cosme et al., 2019; Mälkki & Alanne, 2017; Viere et al., 2021), the emphasis slowly shifts from the theoretical background towards the practical case study throughout the semester (see Figure 1). The problem is that not all students are able to apply the theoretical background presented in the lectures during the project. There seems to be a gap, which can be noticed in supervision meetings when teachers are asked to explain basic concepts again. Furthermore, in the written reports misunderstandings of the theories can be noticed.

Figure 1: Shifting from theory to practice over the semester (Cosme et al., 2019)



The aim of this project is to test if the use of a flipped classroom approach for teaching the theoretical background can improve the connection to the project phase. The main research question (RQ) is: Does a flipped classroom approach improve the connection between theoretical lectures and the practical project?

This question can be further divided into:

> RQ1: Does the availability of short videos on specific aspects of LCA support students in using information from the lectures in the project?
>
> RQ2: Which exercises given to the students after watching the videos are suited to support them in remembering and applying the theoretical aspects?

The results presented in this article are based on a pedagogical project carried in the beginning of 2021 during the pandemic. The discussion also reflects on the continued development until 2023.

2 Background

The building and construction sector is responsible for about 40% of global greenhouse gas emissions and 50% of the resource demand. Therefore, future architects and civil engineers have the potential and responsibility to contribute to the environment. Life Cycle Assessment (LCA) is a method of assessing the environmental impacts related to the manufacture and use of a product or a service. According to Burnley et al. (2019), LCA is an effective way of encouraging engineering students to develop and apply a wide range of transferable skills. Mälkki & Alanne (2017) provide an overview of published LCA studies in education including the teaching and learning methods. Most of them include lectures, a project, and group work. In a recent paper, Viere et al. (2021) analyse twenty-eight studies published on the experience on teaching LCA in higher education and conclude that project work is very common and an important element of teaching LCA.

Project-based learning (PjBL) is a systematic teaching and learning method, which engages students in complex, real-world tasks that result in a product or presentation to an audience (Chen & Yang, 2019). The aim of PjBL is to support students in creating knowledge based on a given problem or challenge (Beneroso & Robinson, 2022). As such, it follow a constructivist (Hein, 1991; Yilmaz, 2008) education approach. According to a meta review by Chen & Yang (2019), PjBL has a medium to large positive effect on students' academic achievement compared with traditional lectures. Guo et al. (2020) review the reported results in the literature more specifically for different subjects in higher education and argue that more evaluation studies are needed. Nevertheless, they recommend more educators to adopt PjBL because it promotes students' innovation competence and supporting their autonomy during learning tasks.

When teaching LCA for engineering students, the project is usually to conduct an LCA of a typical product and present the results to a hypothetical client. In the course BOM250, the students can choose between an apartment building and a bridge. The teachers in the course facilitate the project in supervision meetings by asking and answering students' questions. In addition, the lectures at the beginning of the course provide the foundation to start the project group work. Furthermore, software tutorials support students to learn the LCA software needed to carry out the case study in the project. Cosme et al. (2019) describe the benefits of using this three-fold approach of theory, software, and project for teaching LCA. While they describe the case studies and the different software used in detail, the information on the lectures is limited. There is a lack of information on strategies to link the lectures on the theoretical background knowledge with the project.

In a flipped classroom, the traditional in-class instructional time and out-of-class practicing time is switched (Lage et al. 2000). The information transmission component is moved out of class time. Students prepare for class by individually engaging with resources, such as videos or texts that cover the content of the traditional lecture. The intention is to free face-to-face time for creating meaningful learning situations for in-class interaction between students and teachers (Lundin et al. 2018).

Castedo et al. (2019) compared a student group of an engineering bachelor program using a flipped-classroom methodology with a group taught with traditional lectures. According to their results, the flipped-classroom methodology has a direct impact on student learning (or grades), especially for students with a high degree of involvement. One reason could be that from a cognitive load perspective, self-paced preparatory work might better manage working memory than traditional lectures (Clark, Nguyen, & Sweller, 2005).

However, the flipped classroom approach also comes with challenges (Akçayır & Akçayır, 2018), such as additional time for teachers to prepare videos, insufficient video quality or students fail to schedule time for preparation. Furthermore, students tend to prefer in-person lectures to video lectures (Bishop & Verleger, 2013). Abeysekera and Dawson (2015) see potential issues of student motivation as flipped classroom approaches wager the success of in-class activities on the likelihood of students completing their pre-class assigned work. According to the authors, this leads to the perennial problems of student preparation: how do teachers know if students have prepared, what they know and if the preparation was useful?

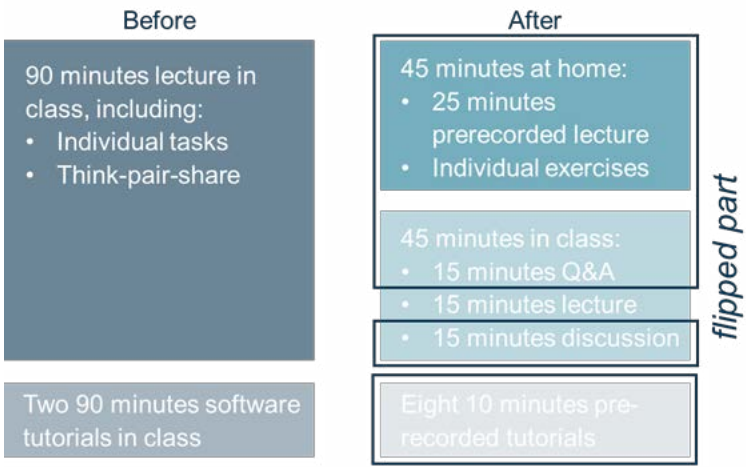
3 Methodology

New course structure

The overall course structure followed the one of the previous years. After two general introductory lectures a lecture on LCA was given online to introduce the four steps of LCA. Each of the steps was covered in detail in four consecutive partially pre-recorded lectures. The original 90 minutes lecture were split in half (see Figure 2). The first half was covered by a pre-recorded video with an average length of 25 minutes and a small exercise afterwards. The exercises were intended to prepare the students to fully benefit from in-class work. The students could choose, if they watched the video and completed the exercise during the scheduled lecture time or beforehand. This was mainly to avoid that the students feel like they had to work more, which is mentioned by Alebrahim and Ku (2020) as one reason to potential students' resistance towards a flipped classroom approach. The pre-recorded lectures were uploaded three days in advance. The second part of the lecture started by answering students' questions and summarizing the results from the exercises. A presentation on the theory not covered in the pre-recorded video followed, which usually took about 15 minutes. In the remaining 15 minutes, the students discussed questions covering both parts of the lecture and the application of the content to their project in breakout rooms. This allowed for social interactions between the students.

In addition, software tutorials that were previously given live in a computer room where pre-recorded. The students were asked to voluntarily upload screenshots of the final results after completing each of the tutorials so that the teachers could check if it was carried out correctly. There were no consequences if students did not complete a tutorial.

Figure 2: Structure before and after introducing a partially flipped classroom



Exercises

For each lecture, small online exercises were developed that allowed the students to repeat and apply the content. Those exercises were voluntary and there were no consequences if they were not completed. To answer RQ2, the form of the exercise varied (see Table 1). Exercises 3 and 4 were based on individual quizzes to be filled out right after the lecture aiming at remembering – the *Knowledge* step of Bloom's taxonomy (Bloom et al., 1956). The students received the feedback about the correct answers immediately afterwards through the computer. As such, a behaviouristic learning theory was followed (Mödritscher, 2006). Exercises 1 and 2 consisted in applying an important aspect of the pre-recorded lecture to another example. As such, they aimed at the *Application* step in Bloom's taxonomy and followed a constructivist learning theory. Exercise 1 had a social component, because students were asked to write their answer in a discussion forum and comment on at least one answer of another student. As such, the students provided and received formative feedback from each other.

Table 1: Overview of lectures and exercises

Lecture	Exercise	Exercise format	Learning theory
1 Goal and scope	Define a functional unit	Discussion in forum	(Social) Constructivism
2 LCI	Draw a flow chart	Apply to another example	Constructivism
3 LCIA	Quiz	Multiple choice quiz for repetition	Behaviourism
4 Interpretation	Quiz	Multiple choice quiz for repetition	Behaviourism

Means of evaluation

According to Abeysekera and Dawson (2015), a difficulty of the flipped classroom is the question how teachers know if students have prepared and if the preparation was useful. To answer RQ1, it was focused at a) comparing the quality of the final reports to previous years and b) observations during the supervision meetings. The level of questions received during the supervision meeting usually provide an indicator for the level of understanding of the students.

To gather data for RQ2, the students were asked to fill out a small anonymous online survey to rate the usefulness of the different exercises during the course on a scale from 0 – not useful to 3 - very useful. In addition, the supervision meetings were used to check if questions are posed that have been answered during the exercises. As the final exam grades are anonymous, it was not possible to use those to compare the grades of students who completed the exercises with those that did not.

4 Results

Online survey on exercises

The results from the online survey are shown in Table 2. On average 89% of the students completed the exercises. However, only 57% of the 49 students were also present in the second part of the lecture and answered the poll. In general, the students seem to have found the exercises useful. The results do not indicate that the exercises using a behaviourist approach (Exercises 3 and 4) were preferred over the constructivist exercises (Exercises 1 and 2) and vice versa.

Table 2: Survey results (response rate refers to the percentage of students that attended the lecture afterwards and answered the poll)

Exercise	Completion rate	Response rate	Not useful (0 points)	Less useful (1 point)	Quite useful (2 points)	Very useful (3 points)	Average points
1 Goal and scope	90%	49%	0%	4%	88%	17%	2.3
2 LCI	88%	65%	3%	9%	63%	25%	2.1
3 LCIA	96%	71%	0%	3%	57%	40%	2.4
4 Interpretation	82%	43%	0%	5%	62%	29%	2.1
Average	**89%**	**57%**	**1%**	**5%**	**67%**	**28%**	

Teachers' observations

Two supervision meetings were held with all student groups by the examiner and me. In general, the questions received during these meetings seemed to be on the same or a lower level than last year. Based on the observations during the first supervising meeting, Exercise 1 did not support in understanding the concept of a functional unit. One reason might be that the formative feedback between the students and the teacher's brief discussion of wrong answers was not sufficient. Direct comments from the teachers in the discussion forum to explain wrong assumptions might have helped. Exercise 2 of drawing a flow chart seemed to have worked better as a support because many groups used them as a basis for the discussions within the group.

Written reports

According to the examiner who has been involved in the course for the last eight years, the written reports had the same quality as the last years on average. No group failed the group work during this year, which has happened before.

5 Discussion and Conclusions

Reflections on the research questions

In general, the students seemed to have appreciated the small exercises. Considering that these were voluntary, an average completion rate of 89% seems to be very high. However, only 57% answered the survey on average. Based on this feedback, the answer to RQ1 can be assumed to be yes. However, the results from the observations and questions received during the supervision meetings and also the quality of the final reports do not give any indications that the availability of short videos did support students in using information from the lectures in their projects.

The survey did not show any clear preference towards one type of exercise and therefore no clear answer to RQ2. The results can be interpreted in such a way that all exercises were equally suited. In the author's opinion, the two exercises following the constructive theory and using examples closely related to the final project supported the application better and are more important than testing memorizing the lecture content in quizzes.

In an attempt to interpret these results, it has to be considered that only flipping parts of the original lecture content (50-80% out of a conventional 90-minute lecture) did not free as much time in class for teacher-student or student-student interaction. A fully flipped approach might have shown different results. Nevertheless, the flipping freed some time for discussions between the students in breakout rooms to increase social interaction. This seems to have been an important aspect in the remote teaching phase during the pandemic. However, it was not reflected in the evaluation for this study.

The response rate to the survey was limited. It could be assumed that the students who in general are more interested in the topic are the once that filled out the survey - therefore leading towards a positive bias in the evaluation. Furthermore, the teachers' observations did not follow a specific method or protocol. The author informally discussed with one other teacher. As such, the evaluation of the reports is subjective.

Finally, the teachers observed that the remote working situation hindered the group work in general. For example, students in one group still did not know all their group members' names two months into the course. This probably had the biggest impact on the quality of the group work making it difficult to compare with previous years.

Reflections three years later

Three years after the first implementation of the flipped classroom approach and back to on-site courses as before the pandemic, the same approach is still used. The more complex constructive exercises were moved to the time in class and replaced by multiple-choice quizzes at home with automatic correction following the behaviourist theory, an approach also recommended by Bishop and Verleger (2013). The students seemed to appreciate the quizzes very much according to the course evaluation done at the end of the semester. In the course evaluation, many students highlighted the value of the pre-recorded lectures for exam preparation while a few mentioned they would prefer conventional lectures in class. The pre-recorded software tutorials provided the biggest benefits in the first year. In a final poll, 92% of the students preferred the pre-recorded tutorials over live tutorials. Since then, the software tutorials were further extended, and they were highly appreciated again in 2023. Compared to the previous years, both the quality of the final reports and also students' rating of the course in the evaluation has increased in 2023. The rating for the overall impression of the course reached an average of 4.3 in 2023 compared to 3.9 in 2022 and 2021. This can be interpreted as indication that working with this course in the pedagogical project and continuing to work on it afterwards has finally improved its quality.

Outlook

With the increasing interest on the industry in LCA, the course Life Cycle Engineering is likely to continue in the future. The number of students can be expected to rise. This will pose challenges in grading written reports but further highlight the benefits of pre-recorded software tutorials and automated quizzes. The plan is to increase the number of quizzes to allow teachers to get more insights into the student preparation in an efficient way, which according to Abeysekera and Dawson (2015) is a core challenge in a flipped classroom approach. After three years, it is time to update and probably re-record the lectures entirely. This provides the opportunity to completely flip the four lectures. Furthermore, the time schedule will be adapted to better fit the flipped classroom approach. The remaining four lectures in the course will remain in the conventional format.

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