Evaluating the flipped classroom approach in engineering education:

Students' attitudes, engagement and performance in an undergraduate sustainability course

E O Sterner[1]*
***Chalmers University of Technology**
Gothenburg, Sweden
E-mail: erik.sterner@chalmers.se

O Hagvall Svensson*

S Toivonen*

J Bill
Semcon Production Information
Gothenburg, Sweden

T Adawi*

ABSTRACT

This paper describes the implementation and evaluation of the flipped classroom approach in a sustainability course for undergraduate engineering students. Using a mixed methods approach, the evaluation focused on student engagement, performance as well as students' attitudes and beliefs about the flipped classroom. A novel aspect of this work compared to previous studies on the flipped classroom is the tracking of student attitudes and engagement during the course. The results indicate that while student attitudes grew more neutral during the middle of the course, student engagement as well as performance on the final written exam increased significantly compared to previous years. Pedagogical implications for instructors wanting to implement the flipped classroom approach are briefly discussed.

Conference Key Areas: Open and Online Engineering Education; Sustainability and Engineering Education; Engineering Education Research

Keywords: flipped classroom, attitudes, engagement, performance

[1] Corresponding Author
E O Sterner
erik.sterner@chalmers.se

INTRODUCTION

It is often argued that teacher-centered approaches, particularly the sole reliance on lectures, give students insufficient opportunity to actively engage in learning activities and reflect on their progress and performance [1]. ICT is increasingly being used in higher education to activate students and move to a more student-centered approach to teaching. One approach that is becoming increasingly popular is *blended learning* [2], which utilizes multimedia in face-to-face and online teaching [3].

As a particular form of blended learning, the *flipped classroom* approach [4] has received substantial attention in recent years. The basic idea of the flipped classroom is that students prepare before class using, for example, video lectures and online quizzes, and are engaged in individual or group-based activities in the classroom. Studies show that the flipped classroom can increase student creativity and facilitate the development of higher-order thinking skills [5]. Moreover, there is emerging evidence of improved student learning compared to traditional teaching [6]. This is in line with previous research, showing that active learning generally increases student performance [7]. However, “flipping” a course requires a change from a *transmission* view to a *constructivist* view on teaching and learning, and it often requires a substantial time investment [3]. Non-traditional teaching methods may involve challenges for the teacher, such as how to support student learning in a format that is new to them and how to face students who may be reluctant to actively engage in class.

This paper contributes to the growing body of research on flipped classroom by describing the implementation and evaluation of the flipped classroom approach in a sustainability course for undergraduate engineering students. A novel aspect of this work compared to previous studies on the flipped classroom is the tracking of student attitudes and engagement during the course. More specifically, the following research questions are addressed in this paper:

1. What attitudes towards and beliefs about the flipped classroom do students have and how do these change during the course?
2. Does flipping a course increase student engagement?
3. Does flipping a course increase student performance?

Consequently, this work should be of interest to teachers who are considering flipping their courses.

1. BACKGROUND AND OVERVIEW OF COURSE REDESIGN

The course studied here, a course on mathematical modelling of environmental issues (7.5 ECTS), is offered to third-year engineering students and about 40 students enroll in this course each year. Prior to the course reform, the course suffered from low attendance (around 30%) and low passing rates (around 60%), which was thought to be related to strong competition from the final half of the bachelor’s thesis course which is given in parallel to the studied course.

To improve student engagement and performance, about half of the course activities were flipped (11 of the 18 lectures). Since the flipped classroom has previously been shown to be popular among students [6], the implementation of this blended learning

format was seen as a way to better compete for the students' attention.The course also consisted of six computer exercises which were adjusted in the course reform by adding reflective discussions about the assignments, to better align with the overall active learning approach. Another change made was that a bonus-point system was introduced to increase engagement. In order for students to give the new teaching format a fair chance, the flipped sessions were made semi-mandatory, where students had to take part in at least eight out of the total eleven sessions. The flipped sessions were designed as follows.

1.1 Pre-class activities

As preparation for the seminars, the students were asked to follow an online "learning sequence" consisting of a combination of videos, texts, quizzes and discussions. On average the learning sequences were assumed to take 1 hour. The learning sequences were made available in the online platform EdX Edge [8]. The videos introduced key concepts, the quizzes were used in order for students to test whether they had understood the key concepts. Occasional open-ended questions and discussion forums were used in order to provide the teachers with various input from the students and for the students to see how other students reason.

1.2 In-class activities

In class, a brief repetition of the key concepts was given. The rest of the time was spent on exercises and discussions to help the students acquire a deeper understanding and develop skills according to the intended learning outcomes. During group exercises the students typically worked for 15-25 minutes on a task or small set of tasks in groups of 2-4 in which they applied and explored the concepts and content knowledge introduced in the preparatory material. Activities were usually wrapped up by inviting students to share their thoughts with the rest of the class.

2. STUDY DESIGN

To evaluate the flipped classroom approach, a mixed methods approach was used. Data was collected through surveys, observations and interviews, both during and after the course (including some data from previous years course versions).

Students' attitudes towards and beliefs about the flipped classroom (RQ 1) were probed using three surveys. The first survey was answered by 32 out of 37 students, while the second and third surveys had 26 and 22 respondents respectively. The surveys were distributed during the first and the fifth week of the course, as well as after the course, to capture the change in attitudes during and after their experience of the course. The decrease in respondents where expected as the attendance is always highest at the course start and completion of course evaluation surveys seldom get high completion rates. In addition to these surveys, ten semi-structured interviews were conducted with volunteering students (convenience sampling). During these interviews the students were asked questions to clarify the reason for their attitude to some of the course components and the flipped classroom format.

Student engagement (RQ 2) was measured in four ways. Firstly, attendance was taken at the course sessions. Secondly, data was collected using the online learning platform on students' preparation before the seminars. Thirdly, teachers were asked

about the students' engagement in the course sessions. Fourthly, an estimate of the fraction of in class time with active student engagement was made by the teachers. All of the measures except the second were compared with observations and estimates from previous years.

Student performance (RQ 3) was assessed by collecting the students' grades on the exam. This data was compared with the grades from previous years.

3. RESULTS

The results are structured following the three main questions of the study.

3.1 Student attitudes and beliefs about the flipped classroom

Only 1 in 32 students reported having previous experience of the flipped classroom. In the initial survey (first week of class), the students were positive with an average value of 3.8 out of 5 (see Figure 1). In the second survey (middle of course), students answered, on average, that they were more neutral towards the flipped classroom (3.4 out of 5). However the fraction of students that reported that they were very positive increased (see Figure 1). The distribution of answers suggests a certain divide between a group of students who were very positive towards the format and the majority of the class which seemed to be normally distributed around the neutral attitude alternative. In the third survey (not shown in the figure), after the course, the students were asked a slightly different question: "When the flipped classroom format worked at its best in the course, what was your attitude towards the format then?". The answers to this question showed a clearly positive attitude towards the format when it worked well, averaging 3.73 with a median value of 4.

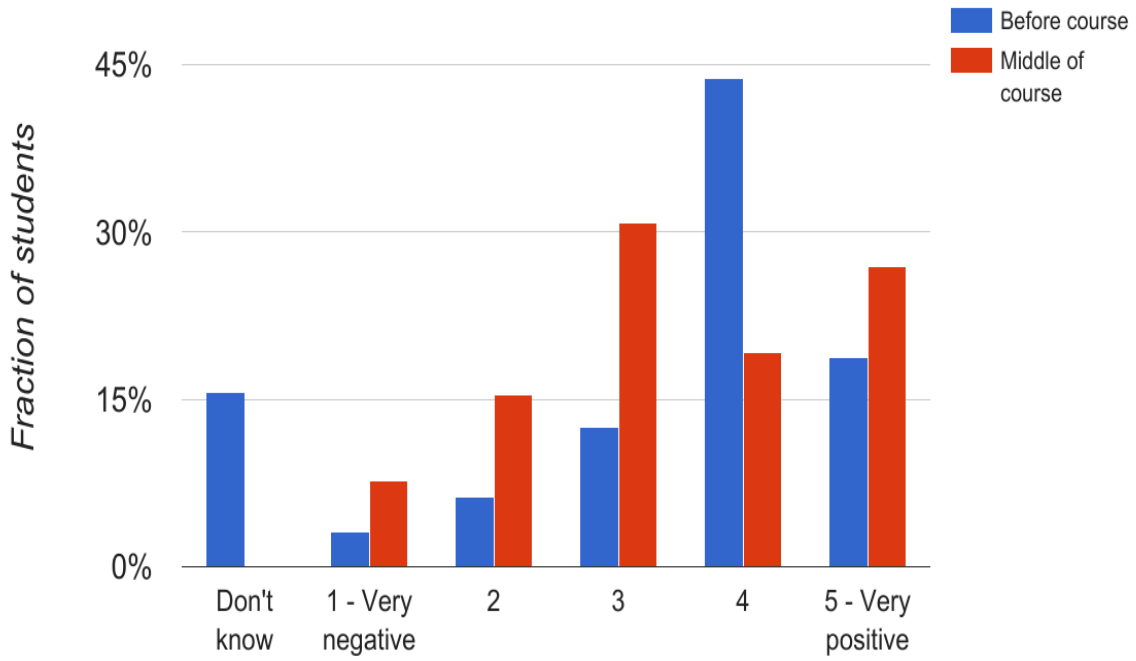

Fig. 1. Attitudes before and in the middle of the course. The question answered was "What is your attitude towards using the flipped classroom in this course?".

Students' perceptions of their relative learning from using the two main components of the flipped classroom format, the videos and collaborative learning activities in class, in contrast to traditional lectures, was studied in the second and third survey. Figure 2 shows the answers to a question regarding whether the students perceived that they learned better by actively participating as opposed to passive listening. The answer to a similar question regarding whether the students learned better by watching videos instead of attending lectures gave similar results. Both of these questions had answers that were fairly inconclusive but there seems to exist an opinion that favors active participation over passive in the classroom sessions. The slightly positive view on active participation and on utilizing videos was more evident from the answers to the survey distributed after the course, when it got an average of 3.5 with more students answering that the learning was "much better".

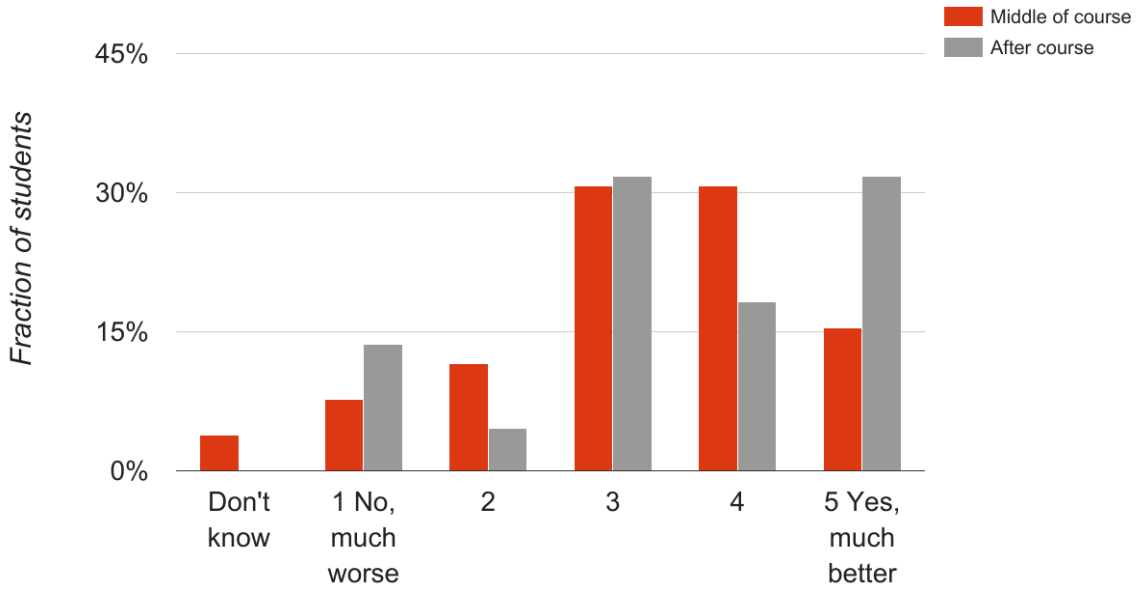

Fig. 2. Attitudes to learning effectiveness in the middle of and after the course. The question answered is "Based on yourself, do you believe active participation is a better way of learning during a lecture rather than (only) listening?".

The Interviews and answers to open questions in the survey during week 5 indicate that students perceived that the flipped classroom format was suitable for this sustainability course (for example in discussing different perspectives, which is typical for the sustainability discourse) and that it supported their learning. As an example, one student answered: "*I have an easier time appreciating material if I get to take part in discussing it and it feels like this is a course that actually can use the flipped classroom".*

It became clear, however, that the students felt that the preparatory material was more rewarding than the seminars. Being able to access preparatory material in video format and using quizzes for automatic feedback was appreciated, however students did not appreciate in-class sessions as much. For example, students stated being uneasy with having to share their thoughts and answers in front of the whole class, and others felt the difficulty level of the seminars was too low. As an example, one students commented on the seminars: *"Remake them* [the seminars] *so that one learns new things, building on the preparatory material, not only repeating them"*.

3.2 Student engagement

On average, student in-class participation doubled in comparison with estimates from previous years (except for the first two weeks which have had high attendance in earlier years as well). This can partly be accredited to the inclusion of semi-mandatory sessions. However, the attendance for all sessions increased dramatically, including all non-mandatory sessions, particularly the computer lab sessions. Both teacher observations and student interviews described the student participation in the seminars to be highly active during the regular smaller group exercises but notably passive in whole class-exercises or during units of lecturing. A couple of students remarked on the positive aspect of getting to know your classmates due to the use of the flipped classroom. When asked to compare with previous years, the teachers experienced the students' engagement to be markedly higher. The course team estimated that the students were active during 75% of the seminar class time and that the degree of preparation before class was increased substantially compared to previous years. Logs from the digital learning platform showed that the majority of the students had looked at the preparatory material before class. The students assessed the course workload to be higher: 3.6 (scale: 1- "too low" 5- "too high") relative to on average 2.8 the two years prior to this.

3.3 Student performance

Student grades on the final exam in 2016, i.e. after flipping the course, were used as an overall assessment of student performance, and student grades on the final exam for 2013-2016 are shown in Figure 3.

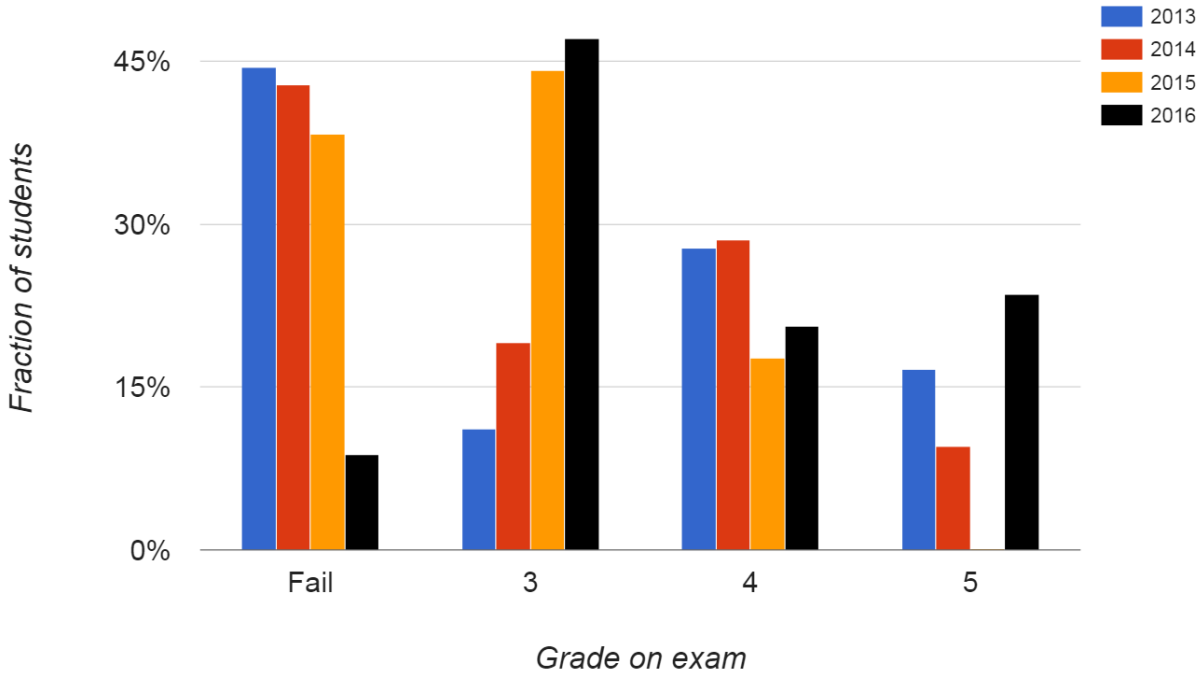

Fig. 3. Grades on the final exam in the time period 2013 to 2016. The total number of students taking the main exam these years were 18, 21, 34 and 34 respectively.

The fraction of students passing the main exam (with grades 3-5) increased from about 60% to more than 90%, for those who took the main exam. The highest grade was also achieved much more frequently, from on average 7% to 24%.

4. DISCUSSION AND CONCLUSIONS

The results regarding student attitudes towards the flipped classroom are in line with previous research, showing that the flipped classroom is appreciated by students [6]. An interesting finding was that student attitudes towards the flipped classroom changed during the course. In the first survey, students were positive towards the introduction of the flipped classroom, which changed to a more neutral stance in the middle, but after the course the attitudes were again positive. An aspect that influenced the students, and most likely their perception of the flipped classroom, was that the course ran in parallel with the second half of the bachelor's thesis course. How this parallel course influences the results should be investigated in a follow-up study.

Relative to previous years, student engagement was significantly higher according to the four different measures studied. A doubling in attendance for most sessions, more class hours spent on active learning and more student preparation before, and participation during, seminars clearly indicate a higher student engagement and effort. The student course evaluation survey also confirmed a higher perceived work load. Besides the introduction of the flipped classroom format the newly introduced bonus-point system in which students were rewarded for doing well on the assignments and presentations, may also have affected the student engagement.

Potentially related to increased engagement during the course, student performance on the final exam also increased significantly. It is difficult from one study to accredit this to the flipped classroom format in itself; however, it seems possible to conclude that the format is suitable for the course studied, as a facilitator of active learning and student engagement. Apart from the exam grades, further analysis of student examination could delve deeper into whether the introduction of the flipped classroom affected student performance in other aspects.

It takes time to adapt teaching to the flipped classroom format and to get comfortable in the new role as a teacher. For example, the seminars suffered from some deficiencies regarding the level of difficulty, and were criticized by many students. This will be fine-tuned for the second iteration of the reformed course and discussions on what learning is and what course activities which promote what type of learning will be introduced. In order to evaluate the flipped classroom format further, we believe it should be evaluated when it has been thoroughly established in a "typical course" placed with an "average timing" in the program.

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