Flipped classroom in engineering education: the views of the main stakeholders

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ABSTRACT: Flipped classroom is a blended learning approach that is increasingly gaining popularity in university education in the recent years. This paper discusses the use of the flipped classroom approach in the context of a graduate course in petroleum engineering by investigating the views of two main participants: the students and the university educators. The student views were investigated via a survey and a reference group discussion. The survey was asking students about: 1) the effectiveness of the flipped classroom, 2) the appropriateness of the learning methods and the learning activities, 3) their effort (plus their open-ended comments). The reference group was focusing on broader issues of course evaluation. The investigation of the university tutors' views involved feedback from: a) a small group of university educators via lesson observation, and b) the teaching assistant, and the professor that was responsible for the course before introducing the flipped classroom to it via interviews. The student survey indicated mixed signals, since slightly less than half of the class think that the flipped classroom is generally more effective than the traditional model, whereas about 70% think that problem solving in class helps them better understand the theory and around 80% think the applied learning methods and activities helped achieving the learning outcomes of the course. The feedback from the observation resulted in action that was taken by the course responsible to encourage students to ask questions and get engaged in group work. The interview with the teaching assistant revealed (among others) instructional techniques to activate the students and encourage communication of ideas among them. Finally, the views of the previous course responsible gave some insight as to why flipped classroom would be an appropriate approach for this particular course. The contribution of the paper touches upon the fact that it adds to the dialogue of the educational community concerning the views of the students (which is a controversial topic) and the views of the university tutors (where there is a lack of research).

1. INTRODUCTION

Educational technologies hold the promise of creating an environment that promotes active learning, provided that they are integrated in an appropriate learning design (Keengwe, 2015). One of the approaches that has been associated both with active learning and the use of educational technologies is the flipped classroom. *The flipped (or inverted) classroom* (FC hereafter) is a popular instructional design model for blended learning in which activities traditionally conducted in the classroom and that are related to knowledge transfer become home or out-of-class activities, and activities that promote active knowledge construction, such as problem-solving or project work, become in-class activities. Research has shown that the FC model yields positive outcomes with respect to student achievement and satisfaction in the context of higher education (Long, Cummins & Waugh, 2017). The selection and the distribution of in-class and out-of-class activities are important elements of the FC approach (Bergmann & Sams, 2012), and typically the flipped classroom model consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom (Bishop & Verleger, 2013). A scoping review for FC in higher education showed that there is no single model of implementing a FC and that it can be better understood by its three central characteristics (O'Flaherty & Phillips, 2015): content in advance (before in-class time), educator awareness of students' understanding, and higher-order learning during class time.

Active learning can be more fully utilized in the FC (Betihavas et al., 2016; Lai & Hwang, 2016; Sohrabi & Iraj, 2016), where *active learning* is defined as "any instructional method that engages students in

the learning process" (Prince, 2004, p. 223). It has been suggested by the recent literature that via the FC model, more in-class time can be devoted to active problem-based learning and practice activities compared to the traditional model (Tang et al., 2020; Love et al., 2014). *Problem-based learning* is defined herein as "an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2015, p. 34). It has also been suggested that in the FC, the teacher helps students acquire higher-order thinking skills instead of merely delivering information, while the students become responsible for their own learning process. For example, they are given the opportunity to progress at their own learning pace (Lai & Hwang, 2016; Tawfik & Lilly, 2015) and access the videos that are provided to them before class as needed, which can in turn support self-directed learning (Tawfik & Lilly, 2015). The teacher can engage with students by means of learning activities, such as Q&A discussion, solving problems, project work, hands-on activities, and guidance.

Akçayır & Akçayır (2018) presented a systematic literature review on the FC to examine the reported advantages and challenges of this method, and to discuss the flipped model's in and out-of-class activities. The most frequently reported advantage of the FC (in 71 research articles selected for the review) is the improvement of student learning performance, while most of the challenges are related to out-of-class activities, such as lack of proper student preparation prior to starting the in-class session. Another challenge mentioned in the recent relevant literature is that the student workload in FC is higher compared to a traditional classroom, as perceived by the students (Bouwmeester et al., 2019; Chan, Lam & Ng, 2020). In addition to this, some research pinpoint students' unfamiliarity with the FC approach as opposed to lecture-based approach (Castedo et al., 2019). To this end, Murillo-Zamorano et al. (2019) created an introductory module in their course devoted to that.

The present study seeks to understand the views of both the students and the university tutors that were directly or indirectly involved in a university course that used the FC approach. In the scoping review of O' Flahert and Phillips (2015) on FC in higher education, it is mentioned that qualitative feedback from student evaluation has been controversial in several studies in the sense that students recognized benefits for them via the FC methodology, while at the same time they were negative towards its introduction. In the case of Chan, Lam & Ng (2020), negative student attitudes towards FC were related to the increased student workload (as perceived by the students), as well as to the fact that students were used to more traditional lecture-based approaches before participating in the FC. Also, it has been recently suggested that only a few studies on the FC address the tutors' perspective (Long, Cummins & Waugh, 2017). Thus, the paper contributes to the ongoing dialogue on FC in higher education with respect to the views of students and tutors.

The remainder of the paper is structured as follows: the next section presents the teaching context in which the FC was implemented. The following section discusses the methodology followed with respect to collecting data from various sources aiming to answer the research question. Next, our findings are discussed revealing the perspectives of students and university tutors involved in this research. Finally, the paper concludes by: summarizing the findings, positing our work to the existing recent relevant literature mentioned above, as well as discussing the limitations and future work.

2. TEACHING CONTEXT

The FC method was used in the context of a graduate petroleum engineering course taught at the Norwegian University of Science and Technology. The course is followed usually by 25 students and it is offered in the second semester of the third year in which students are taught specialized courses. Thus, typically students already have some background knowledge when they start the course. The teaching team involves the course responsible and a teaching assistant. The learning design of the course can be summarized as follows: the students study the course materials (videos and text mostly) before class and come to the class prepared to discuss possible questions or ask for further explanations. In this case, the videos were already created by another university professor than the course responsible. This professor was teaching the course in previous years and it is referred to hereafter as "the more

experienced professor". Most of the in-class time was invested on problem solving in student groups where the students could "ask questions, gather information, discuss with each other, come up with a solution, and share conclusions" (Chiang, 2017, p. 193). The use of the FC approach with problem-based learning in-class can be an effective combination (Chiang, 2017). Previous educational research has shown that having students in small groups interacting with and learning from each other, solving problems and challenging other people's ideas is a very effective learning approach (Herrington, Reeves & Oliver, 2014). A small number of mini-lectures were implemented by the course responsible on an as-needed basis and in that case the in-class time was a combination of mini-lectures with problem solving activities. These are referred to hereafter as "Summary lectures" because they were held mostly after a wide topic or chapter to recap the knowledge gained and check students' understanding.

Finally, the assessment schema of the course involved several home exercises that students need to complete individually and the in-class problems, where students were working mostly collaboratively in groups. The approved exercises and in-class problems were prerequisites for the final exam which accounted for the final grade in the course.

3. METHOD

The method focused on investigating the views of the participant students and the university educators. Regarding the students' views and opinions, a final survey (at the end of the semester) and three reference group meetings and discussions were implemented during the semester. The survey was online, anonymous and the participation to it was not obligatory. It was asking the students about: 1) the effectiveness of the FC, 2) the appropriateness of the learning methods and the learning activities, and 3) their effort concerning the basic teaching activities described in the previous section. Finally, in line with good practice of survey design (O'Cathain & Thomas, 2004), the last question was devoted to any relevant comments that the students would like to make. The reference group discussions were guided by a course evaluation template, which in turn was inspired by the quality assurance guidelines coming from NTNU. The participant students were self-selected (i.e. they volunteered to participate in the group), and the meetings lasted about 30-45 minutes each (3 meetings in total). The course evaluation report (submitted by the reference group) was semi-structured, and it comprised of three parts involving the students' opinions on: I) the didactic approach taken, II) the students' workload, and III) suggestions on specific measures or corrective actions for the future. The importance of the reference group is that its members should have an ongoing dialogue with other students throughout the semester, according to the course quality assurance guidelines of NTNU. Thus, most probably the voices of the reference group members, don't just represent themselves but also all the other students indirectly.

Regarding the university tutors' views, it involved feedback from: (a) lesson observation by three university educators and subsequent focus group discussion, (b1) the views of the teaching assistant, and (b2) the views of the professor that was responsible for the course before introducing the FC to it. Point (a) was implemented via a face-to-face focus group discussion, whereas points (b1) and (b2) were implemented via writing open-ended, reflective texts on their views of the FC implementation in the course. . It should be noted that both the teaching assistant and the experienced professor were directly involved in the implementation of the FC in the course: the former was involved in facilitating the exercise sessions and the problem solving procedures and the latter had the initial idea and vision for the FC endeavor. The focus group discussion occurred as part of an already established groupwork procedure in a collegial coaching group in which the course responsible was participating. The collegial coaching groupwork procedure had been suggested by the creators of a pedagogical development program for university tutors of NTNU. Regarding the student survey per se, it contained 5 closed questions using a 5-point scale ranging from "strongly disagree" to "strongly agree" addressing points 1 to 3 above, plus one last question that was open-ended. The questionnaire that was used in the online survey is presented in the Annex.

4. RESULTS

4.1. The views of the students

The survey was answered by 13 students, a number which accounted for a participation of 60% of the students actively following the course. The results showed that only slightly less than half of the class think that the FC is generally more effective than the traditional model (Q1). However, about 70% think that problem solving in class help better understand the theory (Q2) and around 80% think the applied learning methods and activities helped achieving the learning outcomes of the course (Q3). Having solved problems during the semester, around 50% have a clear idea of the expectations and the assessment criteria in the exam (Q4).

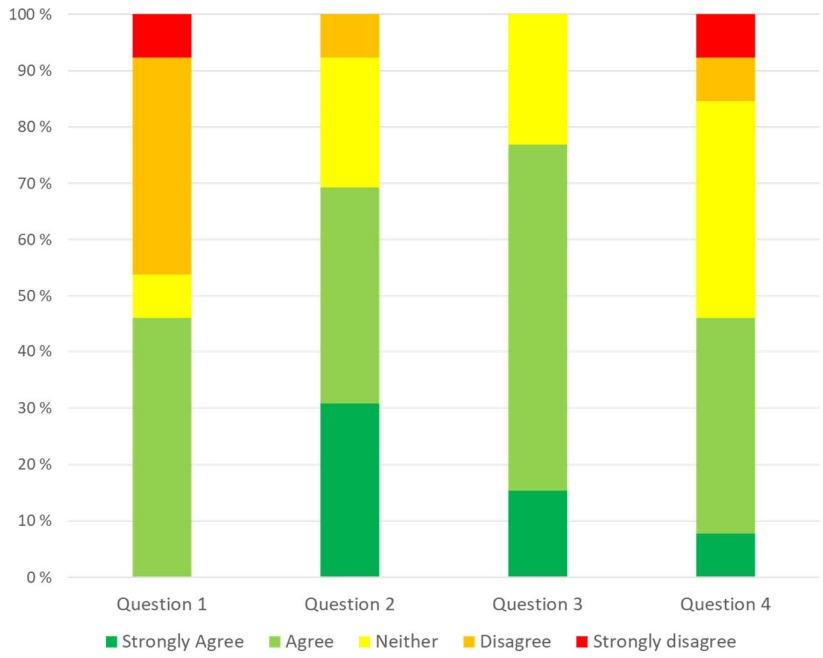

Fig. 1 The distribution of the scores in the answers of the student survey (Q1 to Q4)

Regarding question Q5 where the students were asked to self-assess their effort in basic course activities (e.g. preparing themselves before class, and being active in-class), Figure 2 depicts their answers.

Fig. 2 The distribution of the scores in the answers of the student survey (Q5)

In the last question (Q6), students left several comments, which in general were mentioning issues that are challenging for the students and some of these comments are:

- It would be better for students to physically meet the lecturer rather than via virtual lessons.
- Exercise sessions would be better if they are student-led.
- It's not so easy to watch a video and then ask a question about one week later.
- Very difficult to know which formula to use when, as there are so many. Would be nice with a document which clarifies this.
- Course content should be more updated with more problem solving in class.

The reference group was consisting of 3 students. The course evaluation and the perceived students' workload given by the reference group are shown in Table 1 and Table 2, respectively. These scores, which are expressed in the 5-point Likert scale, were given by the group as a whole after consensus among its members and not individually by each of the members.

Table 1. Course evaluation scores

Evaluation of:	**1 (very poor)**	**2**	**3**	**4**	**5 (very good)**
Relevance (with respect to the learning objectives)					X
Practical information about the course				X	
Summary lectures				X	
Exercises					X
Teaching assistants' contributions					X
Guidance/help given to students					X
Learning materials in the curriculum					X

Table 2. Perceived workload scores

Workload as compared to…	**1(little)**	**2**	**3**	**4**	**5(a lot)**
The norm of 12 hours			X		
Other courses			X		

As shown in Tables 1 and 2, the students were satisfied with the different components of the course and they think that the workload on their behalf in order to succeed in the course was similar to other courses and accounted for 12 hours of study per week. Finally, in the third part of the reference group meeting, the student mentioned that although they think that watching lecture videos before class is an effective way of learning, teaching physically in the class could still play the main role of the didactic approach in the course.

4.2. The views of the colleagues

The views and comments of the collegial coaching group members after observing one of the in-class sessions were mostly related to the learning design of this session and can be summarized as follows:

- The learning design of the session could be more effective, if more time was dedicated to only one problem while leaving enough time for discussion. (Two problems were discussed at the beginning of the class with the students in the observed in-class session.) According to the observers, that would probably result in saving more time for the students to solve problems on their own and seek feedback from course responsible and/or the teaching assistant on an as-needed basis.

- The casual discussions with the more experienced professor was perceived as something positive so that the course responsible could consider including it in future lectures, at least occasionally. (The professor who was in charge of the course previously was present in the class; he was also observing the session and occasionally contributed to explaining some of the main concepts discussed in the observed session.)
- One way to encourage the students to initiate questions about the problems is to give them some extra time (approx. 5 min) at the beginning of the class to discuss with each other their challenges in solving the problems that were given and discussed in the previous session; then, they could compare and contrast their approaches and after that the course responsible could devote some time to summarize. Even before the summary, maybe one of the groups could be invited to present their approach and their solution to the whole class. It is possible that their challenge may be an example of a common challenge other student groups faced.

4.3. The views of the teaching assistant

The main points mentioned regarding the FC endeavor from the viewpoint of the teaching assistant of the course are:

- One of the key parts of getting FC to work is to activate the students and encourage student-student communication of ideas. This should be done early on in the course to create a culture that benefits from the FC method.
- Some methods that he (i.e. the teaching assistant) had tried towards the previous point and that he could recommend are (1) informal in-class questions either given beforehand or in the classroom; or (2) discussion between the students about the topic of the day through group work (larger projects) or via a group quiz in-class e.g. allocate some time at the beginning of each session to point out the main ideas of previous sessions. This could be done for example by giving to the students some to-the-point questions or asking them to make a bullet-point summary of the important topics; or (3) extra informal challenges for the more enthusiastic students.
- There should be a change in the "power structure" between the teacher and student, from the traditional expert-novice relationship to more of a guide-learner e.g. instead of telling the student's what is right, to assist them in finding this for themselves by asking the "right" question. This also means that the tutor should allow the students to work on a topic without giving the "correct" solution. This assists in building a culture of student-student communication which is essential to make the FC method work effectively.
- The downside of the previous point is that this new teaching-learning situation can be somewhat frustrating for the students, especially if they are used to being given the solution from the tutor right away. So, they might need some time to get used to this new approach. Regarding this point, the teaching assistant recommended some channel of communication between the student and the teacher specifically orientated on the new teaching method.

4.4. The experienced professor views

The main points mentioned regarding the FC endeavor from the viewpoint of the experienced university professor who was offering the course previously are:

- Flipping the classroom involves using pre-recorded videos that students view prior to meeting in the classroom. This allows for students to view and re-view the videos until they feel comfortable with the topic and material being taught.
- The class meeting is intended to provide (a) time to discuss (students-with-teacher through Q&A), the topic and the lectured material, (b) opportunity for teacher to provide supplementary material that the videos did / do not cover (but should), and (c) provide more time for problem solving (of the video-lectured topic) together with the teacher.

- Recording the Q&A /problem sessions is also a good idea, providing those who could not /chose not to attend the lecture to still gain from the "live" teacher-student time together.

5. DISCUSSION AND CONCLUSIONS

The flipped classroom is an instructional design model that has recently gained popularity in the higher education sector worldwide, and especially during the time of the COVID-19 crisis when many universities had to close their campuses (Tang et al., 2020). Despite its popularity, in the recent literature and in the context of higher education there are: a) controversial results with respect to the students' views, and b) lack of articles that provide insight on the views of the tutors. The aim of the paper was to examine the views of the stakeholders who had some indirect or direct role in the development of an advanced course in petroleum engineering focusing on the implementation of the FC by participating in the course (students), observing and critically reflect on it (colleagues), supporting students (teaching assistant), and mentoring the course responsible (experienced professor). The opinion of the course responsible himself was not included herein, since he is one of the authors of the paper.

On behalf of the students, the main results indicate that slightly less than half of the class think that the FC is generally more effective than the traditional model (Q1), whereas about 70% think that problem solving in class help better understand the theory (Q2) and around 80% think the applied learning methods and activities helped achieving the learning outcomes of the course (Q3). Though the answers to questions Q2 & Q3 are the most important and valuable inputs regarding the perceived effectiveness of the learning design of the course, one may find this result a bit confusing as more than half of the class do not prefer this method, while the majority think the applied activities were helpful. This conclusion can also be drawn from the results of the reference group report. A possible interpretation could be that question Q1 is comparing the flipped and non-flipped methods, whereas questions Q2 & Q3 are only asking the students' view on the flipped model. Thus, it is probably not very relevant to establish a link between Q1 and Q2 & Q3. The reference group mentioned that although they liked the idea of the video lectures as preparation materials, some students prefer physical lectures over FC. Yet, these controversial results regarding the students' perspectives are not surprising in the sense that they are in line with some of the recent relevant literature mentioned in the introduction herein. Some research has suggested that one reason behind students' negative attitude towards FC could be the increased workload, as perceived by the students. This interpretation doesn't seem to apply herein, since the results of both the reference group report and the survey do not pinpoint this particular interpretation.

With respect to the suggestions coming from the university educators (the experienced professor, the teaching assistant and the collegial coaching group members), what they have in common is the emphasis on discussions among students during the in-class time; this is something also suggested by the literature. Another corrective measure that can be taken in the future rounds of the course would be to provide to the student clear information and instructions. This is important since students may not be used to this model and may feel they don't know what to do. The importance of familiarizing the students with FC is mentioned by both the teaching assistant and the relevant recent literature. Future plans include creation of guidelines that would explain to the students what the FC is about and what they are supposed to do in a FC, respectively; for example, guidelines on how they should use their pre-class time and more information about the course materials.

Limitations of this case study include the small sample size and the fact that the participating students correspond to a self-selected sample. Also, another possible limitation touches upon the design of the survey and the issue that is described i.e. that question Q1 is comparing the flipped and non-flipped methods, whereas questions Q2 & Q3 are only focusing on the FC model Future plans include adopting a methodology of design-based research to make refinements in the current learning design of the FC by taking input from the findings of this research, create an updated version of the course, implement it and evaluate it again with the main stakeholders. For instance, the course design will be revised following the constructive alignment principle (Biggs, 1996) which emphasizes constructivism theories

coupled with conceptual alignment among a) the learning objectives, b) the teaching/learning activities, and c) student assessment and feedback opportunities. Consequently, in the forthcoming round of the course the assessment schema will be revised so that project-based assessment will account for 80% and the final oral exam for 20% of the final grade, respectively. It is expected that this change will provide more opportunities for active participation and critical reflection on behalf of the students.

6. ANNEX: THE QUESTIONS OF THE STUDENT SURVEY

Do you agree with the following statements in Q1-4? (possible answers: strongly disagree, disagree, neither, agree, strongly agree)

Q1. FC teaching method is generally more effective compared with the traditional teaching methods.

Q2. The main goal in this course has been to establish a firm connection between the theory and the applications by problem solving. The problem solving (both by the lecturer and the teaching assistant) helped us better understand the theory.

Q3. The course material, the applied learning methods and activities, and assessment (course work) helped achieving the learning outcomes (knowledge, skills and general competence explained in the course information or on the course webpage).

Q4. Having solved many problems during the semester, I have a clear idea of the expectations of the lecturer from the students and the assessment criteria in the exam.

Q5. How do you evaluate yourself in performing these tasks?

- watching the videos planned for each session and referring to the reference book for more clarification.
- writing down my questions and bringing them to the class for further discussion.
- being active in problem solving. (also discussing and solving in groups)

Possible answers:

- I made a great effort and spent a lot of time.
- I did OK, but did not use my full potential.
- I did not follow up properly.
- Not relevant.

Q6. Please feel free to write any other comment that can help us better design the course in the future.

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