STUDENT PERSPECTIVES ON FLIPPED CLASSROOMS IN ENGINEERING EDUCATION

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ABSTRACT

We used focus group interviews and the student perspective in order to investigate student perceptions of flipped classroom in engineering education. The learning environment included web-based interactive video films, where students had to answer quizzes in order to continue seeing the films, and interactive in-class sessions with clickers. In general the students had experience of flipped classroom in many courses and subjects, and could compare different implementations in physics, mechanics and calculus. We studied perceived advantages, strengths, drawbacks, or difficulties, and students' views on learning with flipped classroom. Overall, the students were positive, or in one case indifferent to flipped classroom. They saw many advantages, but they also pointed out difficulties and had many opinions about how a flipped learning environment was best implemented. In the interviews, they also expressed their views on learning and described how they studied. Many used rote learning and surface approaches to learning, but many also had a focus on understanding. Some declared an intention to focus on understanding but still used rote learning. Some students expressed a strategic approach to learning with focus on the examination. Heavy workload and a threatening examination system seem to favor surface approaches to learning also in a flipped classroom learning environment. One of our interviewees had dyslexia and described her experience and special conditions. We conclude by suggesting a list of five key elements for flipped classroom. We think that the interplay between these elements is important, and that they are considerably weaker without the support of the others.

KEYWORDS

Student perspective, flipped classroom, approach to learning, dyslexia, CDIO Standards: 8,10

INTRODUCTION

Evidence that active or interactive learning can improve student performance (Deslauriers et al., 2011, Freeman et al., 2014) has inspired many teachers in engineering education to experiment with new methods for teaching and learning. Active learning is a broad and somewhat fuzzy concept and can include a variety of activities (Carr et al. 2015). In some subjects, projects could be a suitable form to activate students. In other subjects, where lectures are the traditional form of teaching, student activity may be promoted by increased interactivity in lectures. This can be done in very many different ways (Naccarato & Karakok,

2015), not only in different subjects, but even in a single course (e.g. calculus) which is taught by different teachers to several engineering programmes. In addition to differences in individual strengths and preferences, teachers have different experiences and different beliefs about teaching. These differences may affect to what extent they embrace the notion of active learning and, in turn, whether and how they incorporate active learning in their teaching. Some teachers incorporate only a few active learning elements in their teaching, others change their teaching more radically. And there are differences between student groups and study programmes, as well. What works extraordinary well one year for a certain study programme might prove to be comparable to ordinary lectures the next year. As teaching and learning are such complex phenomena, it is difficult to analyze the effects of teaching. There are also many different measures of success. Therefore, we do not think it will be possible to find one optimal way of teaching, which will once and for all be superior to other ways of teaching. Rather, we think that we need to identify important components in teaching and learning, which can be applied, when needed, in different situations.

It has long been evident that not all students embrace active learning and that there is a connection to deep and surface approaches to learning (Jenkins, 1992). This is also supported by results from a previous study, indicating that aversion to interactive teaching is connected to certain beliefs about teaching and learning (Weurlander et al, 2015). We believe that students' views on learning are related to the success of a flipped classroom.

At KTH Royal Institute of Technology there is presently a growing number of teachers experimenting with flipping their classrooms. With flipped classroom we refer to teaching where students receive the teacher's view on the subject and prepare for class by reading materials or watching films, and in class they work actively in interaction with peers and the teacher. Others report of a similar development (Love et al., 2014; Murphy et al. 2015; Naccarato & Karakok, 2015; Petrillo, 2015, de Boer & Winnips, 2015). The development at KTH began with experiments with Peer Instruction (Mazur, 1997) in solid mechanics and calculus (Cronhjort et al., 2013). In calculus, students expressed that understanding the textbook was the main obstacle, so a natural next step was to introduce short video films. At that time, many teachers were interested in developing flipped classroom implementations in a wide range of subjects, and received funding from KTH Royal Institute of Technology to do so in a three year development project called *E-science*. In the implementations, filmed presentations were offered as interactive web lectures on the platform Scalable Learning (www.scalable-learning.com), to help students prepare for in-class activities. The films were interrupted by quizzes, which had to be answered in order to continue watching the film. Statistics from the quizzes were available for the teacher before classes. Lectures were replaced with interactive teaching sessions, in general based on multiple choice questions or problems, and the students gave their answers by clickers. On a specific engineering programme at KTH, most courses in the first two years of study now contain flipped teaching.

The utility of flipped classroom still needs to be researched and documented, especially for introductory courses with many students (Love et al., 2014; Murphy et al. 2015). We use the student perspective to address the question of how to implement flipped classroom in engineering education. We focus the specific question: What advantages, strengths, drawbacks, or difficulties do the students perceive with flipped classroom? This is related to CDIO Standards 8 and 10: Standard 8 concerns teaching and learning methods based on active learning, which is a central theme in flipped classroom. Standard 10 concerns actions to enhance faculty competence in active and experiential teaching and learning methods. The *E-science* project aims at development of faculty competence at KTH Royal Institute of

Technology, and by sharing our findings we hope to facilitate for faculty, even elsewhere, to implement flipped classroom in engineering education.

METHODOLOGY

The present study focuses the second-order perspective (Marton, 1981) of students' experience and perceptions of flipped classroom in four different courses: solid mechanics, physics (medical imaging systems), single-variable and multi-variable calculus. Six teachers were involved in the courses. Data was collected from 13 students in semi-structured interviews. Three students were women and ten men. Ages varied from 18 to 25. We used focus group interviews and analyzed the transcripts by qualitative content analysis (Graneheim & Lundman, 2004) with focus on manifest as well as latent content.

Our largest focus group had five interviewees. Two groups ended up with only a single interviewee. The interviews were scheduled about a week after the examination of a course with flipped classroom, in two cases in the second year of study and in three cases in the first year of study. The groups were composed differently: One group had students who had failed the examination, one group had students with excellent results, one had mixed results, one of the single students had dyslexia, and the other single student had excellent results. Most students had experience of implementations of flipped classroom in other courses. Some mentioned and compared up to three courses. All interviews were held in Swedish, and all results and quotes were later translated into English.

The students were asked questions regarding their perception of the course, the flipped classroom design, what they thought helped them in their learning and what they thought was difficult. The interviews were recorded and transcribed.

We used different units of analysis for different purposes. Regarding perceived advantages, strengths, drawbacks, or difficulties with flipped classroom, it was not essential from whom statements came, as teaching should benefit all students, as far as possible. Therefore, isolated statements were in general sufficient units of analysis. In some cases, however, statements were better interpreted in the light of nearby statements from the same person. Regarding students' views on learning with flipped classroom, persons were suitable units of analysis.

In the analysis we coded statements containing views on flipped classroom. The codes were generated from the data. Statements were categorized as *Perceived advantages/strengths*, *Perceived drawbacks/difficulties*, and *How is flipped classroom implemented?,* respectively. We discovered that all interesting materials did not fit into these categories, and added three more categories: *Perceived equal to traditional teaching*, *Student suggestions about how to implement flipped classroom*, and *Views on learning with flipped classroom*.

FINDINGS

Views on flipped classroom

In general the students expressed a positive view on flipped classroom in the interviews (Table 1). This was valid for all focus groups, regardless of whether the students passed or failed the examination. Students who passed or failed the examination, respectively, expressed positive views to a similar extent. One student said regarding the film-based

interactive web presentations: "So I have nothing negative to say about it. But it was something fun, positive, and made it enjoyable to learn, you felt that you were given the relevant explanations before the lectures [in-class activities], I think."

Table 1. Perceived advantages or strengths with flipped classroom. Comments not expressed in the data are added [in brackets].

Films	• Usable for repetition, e.g. before examination • Possible to rewind, allows time for making notes • Flexible: adjustable pace and watched at suitable occasion • Offer more possibilities than live lectures: may include pictures, animations [and show specific locations or situations discussed in the lecture] • Effective, well used time, lectures would be superfluous if films covered more • Super as preparations for dyslexics
Quizzes during films	• Facilitate critical thinking • Give insight that you have not yet understood • Teacher receives feedback before lectures about what students find difficult
Encourages students to prepare for lectures	• Makes cheating more difficult. Quizzes are better than handing in a paper [as a proof of your preparations]. With papers, many students only copy a peer • Students feel seen. The teacher can see if I have prepared. • Easier to understand concepts during lectures when you are prepared. Acquiring the concepts goes faster
Creates a structure	• Deadlines and partial goals are appreciated. • Preparations for lectures get done
Guidance	• Better than YouTube as it reflects what the teacher finds important
In-class activities	• Clickers make you more active. You desire to perform well. • Students remain awake and focused with clickers
In-class feedback	• Clickers give feedback to each student • The teacher receives feedback from all students
In-class interactivity	• Gives faster communication and closer relationship between students and teacher • Facilitates asking questions. It is evident to what extent my peers [don't] understand • Interactivity is important, rather than a specific technique. Analogue discussions are also possible
General aspects	• Better perceived retention • The course is perceived as a role model • Fun • Gives confidence • No perceived drawback

The negative statements in general concerned how flipped classroom was implemented, rather than the concept in itself (Table 2). Many students claimed that it has been very helpful in their studies, but one student declared that flipped classroom has not helped him to learn the subject better or increased his motivation compared to traditional studying, even though he said it is likely to be beneficial to other students. This specific student had excellent results in the examination (and was probably coping rather well regardless of how teaching was arranged).

Table 2. Perceived drawbacks or difficulties with flipped classroom

Films	• Difficult to find a suitable degree of difficulty. It depends on whether students have read the textbook before the films • There is no index: It's difficult to find a certain passage • Ineffective [too long], too short, too easy or too personal films • Technical problems: Bad sound, didn't work on tablets • Students are distracted at home or on the web while watching the films
Ineffective in-class activities	• Too easy clicker questions, too much like repetition of the films, miss the challenge • Too difficult questions, I merely waited for him to present the correct answer • Too big span between the easiest and most difficult clicker questions • I get a feeling that the teacher is unprepared • Too many clicker questions give a messy impression • The greatest risk with clickers is that the lecture is merely a long sequence of questions, and nothing is ever presented
Examples	• Students request more contextualization and real world examples • Students request more examples of examination problems including hints and guidance, or step-by-step solutions and confirmation that they have done correct
General aspects	• Reading the textbook is not considered as an option • Better overview with traditional lecture notes. I need to go through the films before the examination in order to know that I don't miss anything • High pace and high work load • Difficult to take responsibility for one's learning, and judge whether I work enough • Clicker questions with a lot of text are difficult for dyslexics

Students had many opinions on how flipped classroom should be implemented (Table 3). These views displayed a large variation and were often contradicting. It is evident that views varied between individuals. In different focus group discussions, different themes were developed, also adding to variation. One focus group began to discuss how long a film should be, and had difficulties reaching a common position.

Table 3. Student's suggestions about how teaching should be

Films	• Focus on introduction of basic concepts, not on details • Short and informative • More materials should be covered in films • More challenging • Should whet the appetite and build confidence, establish a positive attitude to the subject • It mustn't be too difficult, you should not lose your self-esteem • Longer films could be divided in parts with add-ons to a basic film • Good when it contains reading instructions, a brief presentation, and some increasingly difficult examples
Clickers	• Should be used sparingly, giving the teacher necessary feedback • Important to find the right difficulty level and number of questions
General	• Films should focus the lowest pass grade, class activities intermediate to high grades, and additional assignments the highest grade • The lecturer needs to complement the presentations of the textbook • Include an intermediate test with examination problems early in the course for feedback to students

Views on learning with flipped classroom

In the interviews, students expressed their views on learning. Many described how they studied. Several students explained that they used multi-modal learning. In their opinion, it was important to watch the films (combines seeing and listening, and sometimes they watched the films several times), to make notes from the films, write summaries, discuss with peers, and work actively in class or with exercises at home. One said that without being active, it is difficult to learn. One student emphasized that the most important is to make many exercises. Another described flipped classroom as superior to tutorials: "If you compare, sometimes tutorials can be worthless, in my opinion". Some students expressed that solving earlier examination problems is important. One student expressed that there is no difference between how he learns with flipped classroom and traditional teaching. Without flipped classroom, he looks for relevant YouTube films. This student had excellent results on the exam. The student with dyslexia expressed that it is important to her to hear everything twice: first in a film, then in class.

Some students developed more abstract perspectives on learning. One student expressed that with flipped classroom, the student has the initiative and responsibility for making proper preparations and asking questions. Another described the cognitive aspect: In the films, the concepts are introduced and you start thinking. Then, in class, focus is on development of your thinking on a higher level. This student suggested that films should end with a 'cliff-hanger': A challenging question that would keep one thinking until class.

In a few cases, the discussion in the focus groups described students' approaches to learning. We identified three different approaches: Rote learning, understanding, and a strategic approach.

Rote learning was perceived to have a role for many students. At least four students expressed that it was important for the following purposes: Learning the basics ("…then one can begin being woolly and think for yourself…"), facts, information, theory or proofs. One student said that some things have to be accepted without understanding. As an example, she mentioned Compton scattering. Some students expressed that they used an imitative approach. This is similar to rote learning, as it implies accepting things without trying to understand. Some expressed an orientation towards rote learning. The student with dyslexia described rote learning as a major approach: "So you have to kind of adjust to this way of thinking [which is different to the upper secondary school] and to be able to learn things by heart, and it's also a bit difficult for us dyslexics to learn …uh, I think it's hard to learn all things by heart, for I have little blockage there with rote learning, it's a bit difficult, but uh finally it worked out, after about a hundred exercises, then it will work, perhaps…" One student expressed that his preferred way of learning was listening to presentations. The student contrasted presentations to reading the book, and no other ways of learning were considered.

Four students expressed that focus should be on understanding. One of them said: "I focused only on understanding the principles all the time. It was enough for me to get a good understanding…" The other three expressed that the teacher had a focus on understanding, and it was a little unclear to what extent they themselves embraced understanding as an approach to learning. One of them said: "[My teacher in Mechanics has emphasized that one should] understand why things turn out as they do. One should not only be able to use the tools, but really understand why they look the way they do. […] And actually be able to derive the most important concepts from the start. And then use math to solve it." Another student said: "For it will be very demanding when teachers want us to understand, which is good, that we shall surely do." On one hand, understanding is admitted as the preferable approach, but on the other hand, before and later, lack of time and a high pace are admitted to make it difficult. Two of the students who expressed that they used rote learning, also expressed that focus should be on understanding.

Two students talked about a strategic approach to learning, with focus on the examination. One of them said that what helped him most to learn were specific and detailed reading instructions, specifying the importance of "this small part of chapter one". He watched the films focusing on identifying what the teacher regarded as most important. The other student said that other students answered the quizzes by guessing, with the only purpose of getting an extra credit for the exam.

DISCUSSION AND CONCLUSIONS

Overall, the students in our study seemed to appreciate the flipped classroom design, although they identify some difficulties and areas of improvement. Furthermore, the positive and negative views expressed by students (see tables 1 and 2) are similar to what others have reported (Love et al., 2014). The flipped classroom design, with films and interactive lectures, offer students to use a variety of strategies when learning. This seems, according to our findings, to help many students. In this paper, we limit our study to qualitative aspects of flipped classroom. We intend to study quantitative results in a future paper.

Compared to the results by Weurlander et al. (2015), very little aversion is expressed to flipped classroom, but in some cases students indicate vaguely that other students may have objections. We see two possible explanations. Negative views are more easily expressed in

a written survey than in a face-to-face interview. Also, the teaching method has been under development for some years by now, aiming at coming to terms with the problem students expressed earlier. One of the main difficulties students had in the previous study was that the course book (in calculus) was too difficult to read and comprehend on your own (Weurlander et al, 2015). In this setting, the films may have served as a complement to the book and students may have experienced fewer difficulties with the book.

Students expressed more criticism of the clicker questions than the films. An explanation may be that if you don't like the films, they are easily avoided, e.g. by doing something else on your computer while playing a film. Those who like the films may watch them as many times they wish. In-class activities, on the other hand, are not easily avoided once you are in class. A conclusion is, as one student points out, that there are no drawbacks with adding films, but in order to get the benefits the films should be made considering the advantages, drawbacks and suggestions described in our results. As it is impossible to meet every student's desires about the films, a structure with short films is preferred. This makes it easier for students to watch the material they need or like, and avoid those that do not meet their needs. We wish to point out that the students' suggestions should be considered with some care. As we point out below, some students use surface approaches to learning, and their suggestions might not be the best for high quality learning. We believe that e.g. reading instructions should not be too detailed. Students may suggest things in order to reduce their responsibility or workload, rather than to increase their learning.

Our results show that an individual student may have several approaches to learning. Different approaches may coexist and be used for specific parts of a course, or they may compete on a more general level: A student may, on one hand, say that understanding is essential; on the other hand, he actually ends up using rote learning. Similar findings where students aim for different kinds of understanding during a course have been reported for medical students (Weurlander et al, 2016). Classical factors known to favor surface approaches to learning, e.g. a heavy workload and a threatening examination system, seem to apply as normal (Gibbs, 1992). For some students, surface learning is still the major learning approach, even in an active learning environment like flipped classroom. Students with a surface approach are likely to watch the films with a very different perspective than students focusing deep learning.

Flipped classroom may be suitable for dyslexics, as long as their special conditions are considered. Films are valuable complements to the textbook. Clicker questions containing long texts should be avoided in class, and even short texts and multiple-choice answer alternatives should preferably be read out loud, as reading may take significantly longer time for dyslexics.

Love et al. (2014) suggest that films are a key element of flipped classroom. Based on our findings, we suggest the following five components as key elements:

- Preparatory films with focus on basic concepts, as a complement to textbook presentations
- Quizzes connected to the films, to stimulate critical thinking and provide feedback to the teacher
- Individual response from each student on preparatory films or quizzes. Students feel seen and encouraged to do the preparations
- In-class interactivity, which challenges to performance and provides feedback to each student and the teacher. This can be achieved by clickers but also in other ways.

- Suitable degrees of difficulty on films and in-class activities, giving confidence as well as challenges.

We do not wish to highlight any single of these components as more significant than others. Most likely, the complex interplay between them is essential, and one component would be considerably weaker without the support of the others. The films, for example, are made more important by quizzes, which stimulate student thinking, provide feedback to the teacher, and motivate students not to skip the films, as individual responses are visible to the teacher. In addition, the proper degree of difficulty on films would be difficult to achieve without in-class interactivity.

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