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Why Can the Flipped Classroom Frustrate Students? Experiences from an Engineering Mathematics Course

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Abstract: This paper explores students' experiences with a flipped classroom in a first-year engineering mathematics course with 118 students. While most students were satisfied with the flipped classroom and expressed appreciation for the flexibility, freedom and independence induced by the teaching method, other students expressed frustrations. Based on two surveys with both open-ended and closed-ended questions, this paper explores possible reasons why a flipped classroom can be a source of frustration. Some students expressed having difficulty adjusting their study habits to the flipped classroom approach as well as having difficulty finding the motivation to watch the required learning videos before in-class activities. While some students experienced the group work associated with the flipped classroom format as a positive aspect of their learning, other students expressed irritation because of group members not meeting prepared for the group assignments. The expressed experiences are discussed in light of the self-determination theory and the self-regulated learning theory. Weaknesses with how the flipped classroom was implemented are also discussed.

Keywords: flipped classroom; student experiences; negative experiences; engineering education; mathematics education

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Citation: Nielsen, K.L. Why Can the Flipped Classroom Frustrate Students? Experiences from an Engineering Mathematics Course. *Educ. Sci.* **2023**, *13*, 396. https://doi.org/10.3390/educsci13040396

Academic Editor: Doris L. Watson

Received: 8 February 2023
Revised: 3 April 2023
Accepted: 12 April 2023
Published: 14 April 2023

1. Introduction

The flipped classroom is a popular teaching method that entails individual computer-based instructions outside the classroom, such as viewing instructional videos, to focus more on student-centric and collaborative activities inside the classroom [1]. Studies on the flipped classroom have shown promising results such as increased student performance [2–4], increased self-confidence [5] and perceived higher competence with the course material [6], as well as the promotion of creative thinking [5,7]. By focusing the in-class time on students working with peers, the flipped classroom adheres to a socio-cultural learning style [1,8], which theorises that learning is best fulfilled in a social context through interaction with others.

Abeysekera and Dawson [9] went further to explain the possible benefits of the flipped classroom by using the cognitive load theory and the self-determination theory, with the latter being a theory of human motivation and development. Students in previous studies have expressed appreciation for the ability to pause and rewind the pre-recorded videos [10,11], as well as the general time flexibility [12] and freedom [13] the flipped classroom offers. Abeysekera and Dawson [9] argue that the ability for self-pacing when watching videos might have a positive effect due to reducing cognitive load, i.e., the amount of strain posed on the working memory. This was the result of a study by Karaca and Ocak [14], in which the researchers found that the flipped classroom could reduce the cognitive load compared to traditional lectures. The reduced cognitive load might increase learning potential with the flipped classroom, and Abeysekera and Dawson [9] argue that the flipped classroom, as a result, might also increase student motivation due to an increased feeling of competence with the course material.

1.1. Self-Determination Theory

The self-determination theory (SDT) describes the need for competence as one of three fundamental psychological needs that influence human development and psychological wellbeing, with the others being the need for autonomy and relatedness [15]. The flipped classroom offers a great deal of choice and freedom for students to tailor the learning environment to their liking, i.e., giving them greater autonomy than being confined to passive listening in a lecture hall [9]. The flipped classroom is also argued to increase students' sense of belonging and relatedness to others [9], which can be indicated by some studies that have shown that the flipped classroom can increase students' willingness to work with peers [5,16] as well as inducing a feeling of commitment and shared responsibility to fellow group members [8].

According to the SDT, fulfilling the needs for competence, autonomy and relatedness can increase intrinsic motivation for a task or activity, i.e., willingness to perform the task because the activity itself is perceived as interesting and satisfying [15]. The SDT also describes another form of motivation, extrinsic motivation, which entails doing an activity not because it is satisfying or interesting, but rather to receive rewards or avoid punishment [15]. A student working hard on a subject to receive good grades, or as a result of social pressure to avoid being perceived as a failure, would be an example of behaviour guided by an extrinsic motivation. At first glance, intrinsic motivation seems like the obvious better form of motivation, and intrinsic motivation has been shown to produce better results than extrinsic motivation [17]. However, extrinsic motivation also has its place, for instance, to perform activities and tasks that, while necessary, are not perceived as interesting or satisfactory. Furthermore, according to the SDT, a sense of autonomy can still be fulfilled while extrinsically motivated if the students accept the importance and value of performing a task and make it their own, even when they have no choice in whether to do the task or not and the task is not necessarily satisfactory in itself [15].

The SDT describes various forms of external motivation that are differentiated by the relative amount of autonomy and how students internalise the behaviour into their sense of self, ranging from external regulation (acting as a result of external demands), followed by introjected internalisation (avoiding guilt or shame, or to increase a feeling of pride), identified internalisation (when an activity is seen as important and having value) and integrated internalisation (when the activity has been aligned with students feeling of self) [15]. In a flipped classroom, students are often 'forced' to work independently and with peers by the nature of the format, not because they chose to do. However, Abeysekera and Dawson [9] argued that the autonomy offered by the flipped classroom, both in the choices on how they work with the homework and by being an active participant in the in-class time, can increase students' ownership of their learning even though they might be extrinsically motivated, and as a result, increase the amount of internalisation, as described by the SDT.

1.2. The Current Study

Based on the theoretical frameworks and positive results from previous studies, the flipped classroom might seem like the 'silver bullet' of pedagogical teaching methods. The method certainty piqued this author's interest enough to make me want to try it out in one of my own courses back in 2015, a mathematics course for first-year engineering students. However, after the first weeks of the implementation of the flipped classroom, which will be described in detail in the next section, some students openly displayed strong frustration with the teaching format. This caught me by surprise. Why would some students have a strong negative experience with the flipped classroom?

While there are several studies that show positive results with a flipped classroom, other studies have shown mixed results with the format, such as lowering student motivation [18] and students preferring traditional lectures over the flipped classroom [19]. A common challenge with the flipped classroom is the lack of pre-class preparation by the students [12,19–22], which is a crucial part of success in the flipped classroom format.

The unfamiliarity with the flipped classroom format can be also a challenge for some students [13,22]. Studies have shown that students often need several weeks before being able to adjust their study habits to the flipped classroom [23,24]. There have been previous studies on the flipped classroom where students expressed frustrations with the format, although the students usually became more positive as they became more used to the flipped classroom [22,24]. Some students can feel overwhelmed by the amount of pre-class work that is required [20] and struggle to keep up with the homework [16]. In addition, Triantafyllou, Timcenko and Kofoed [10] argued that not all students can handle the autonomy that the flipped classroom offers, which goes against the self-determination theory that describes autonomy as a fundamental psychological need.

1.3. Self-Regulated Learning

As the flipped classroom relies more on independent work, it requires the students to, often drastically, change their study habits from the traditional lecture style, which increases the importance of students being able to self-regulate their learning. Zimmerman [25] describes three phases that are a part of being a self-regulated learner: the forethought phase, performance phase and the self-reflection phase. In the forethought phase, students must set their goal and plan how and when they are going to work. This is especially important in flipped classrooms since the students must figure out by themselves when they should watch the content. In the performance phase, students in a flipped classroom must have the self-control to do the necessary work, as well as self-observe how well their strategy is working. The self-reflection phase is where the students must evaluate how their strategy and performance worked, and if there are necessary adjustments needed [25]. Students must be aware of their strengths and limitations, which demands a high level of metacognition [25], i.e., their awareness of their thinking, to make correct evaluations and adjustments.

Studies on the flipped classroom have shown that students feel they become more independent [26] and that the method teaches the students to become more responsible for their learning [5,19]. However, although students in a flipped classroom can recognise the importance of regulating their learning [27], some students have shown resistance to change their study habits from the traditional lecture style [28] even when they receive poor results, such as scoring poorly on their mid-terms [21].

1.4. Aim and Goal

The main goal of this paper is to add to the knowledge of why some students can have negative experiences with the flipped classroom, as such knowledge can be used to avoid pitfalls when implementing the format. In the next section, I will give a description of how the flipped classroom was implemented. This is followed by a presentation of both positive and negative experiences expressed by the students on two anonymous surveys, with particular attention paid to the challenges and negative experiences. In the discussion section of this paper, I will discuss the expressed experiences in light of the self-determination theory and the self-regulated learning theory with the aim of providing possible explanations for the strong frustration expressed by some students. At the end of the discussion section, I will also reflect on the weaknesses in how the flipped classroom was implemented and how it might have been improved.

2. Method

2.1. Background

The flipped classroom approach was implemented in the second part of a mathematical course for a class consisting of 118 students from three different fields: chemical engineering, material technology and logistics studies, which they attended during their second semester in the spring of 2015. Before flipping the classroom, the students would attend three 2×45 min traditional theory lectures each week (on Mondays, Tuesdays and Thursdays). The students also had the opportunity to attend a guided session once a week where they

could ask a senior student for help on written assignments, and a certain number of written assignments needed to be approved to be eligible for the exam. Both the traditional and flipped part of the course was taught by me. The reason for only implementing the flipped classroom in parts of the course was due to time constraints in producing the out-of-class resources, such as learning videos. Before the flipped classroom, students had access to a textbook and old exams as out-of-class resources.

2.2. In-Class Activities

In the flipped classroom, the traditional one-way-style classroom lectures were substituted with student group activities and individual problem-solving sessions. Attendance in these sessions replaced the previous written assignments and counted towards the number of approved assignments needed for the exam. In order to be able to assist each student group during the group activities, the class was divided in half, and each half was assigned to either Mondays or Tuesdays for group activities. In each half, the students were divided into smaller groups of 4–6 students who worked together during the group assignments. In addition, a classroom was booked for Mondays and Tuesdays for students to use for self-study while the other groups attended group activities. The group sessions were held in a specialised room designed for group work where each group had access to their own Smartboard (see Figure 1d).

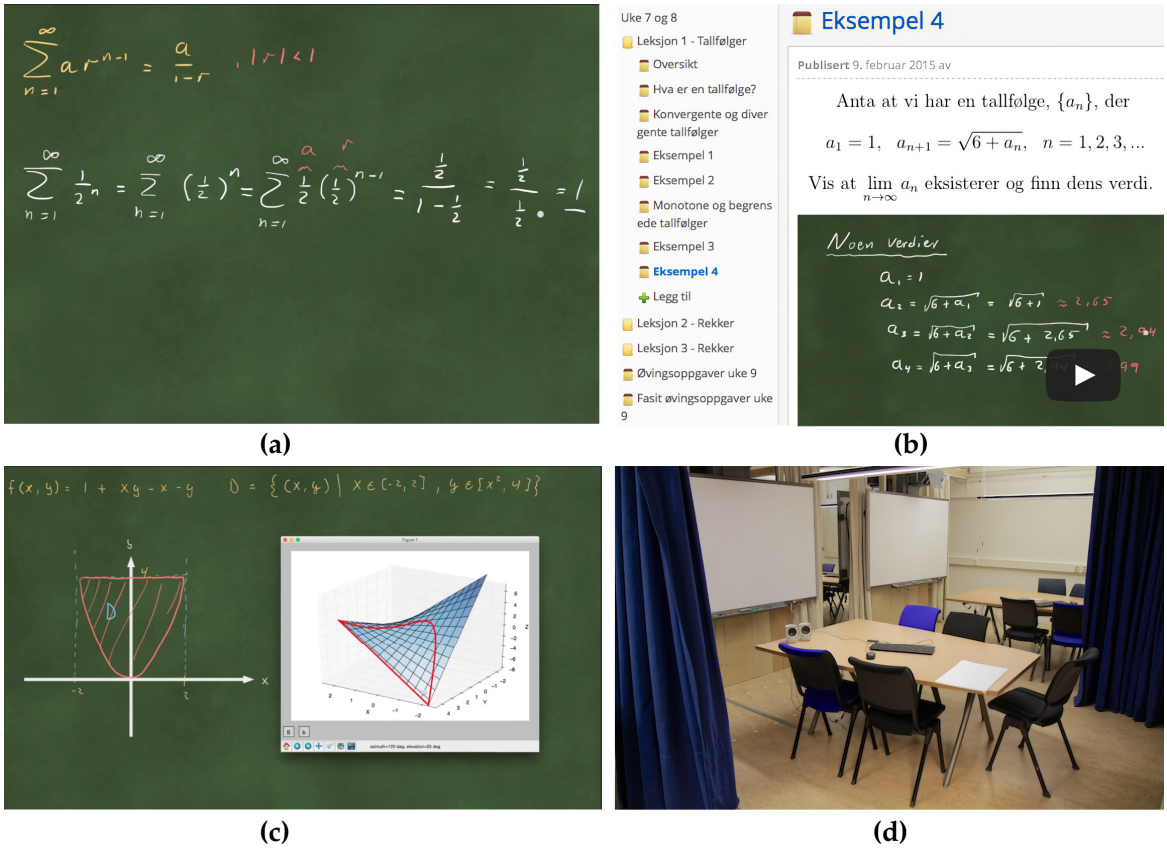

Figure 1. (**a**,**c**) Screenshots from learning videos. (**b**) A screenshot from the LMS 'itslearning' showing an example of how the videos were organised in 'lessons'. (**d**) The room used for group work sessions.

The in-class time on Thursdays was used for individual problem-solving exercises for all students in the lecture hall where the traditional lectures were held. The students were given problems during the first session (45 min) which were to be solved without collaboration with fellow students. In the break between the sessions, the students would use a student response system (SRS) to vote on which problems they found the most difficult. In the second session (45 min), I would explain the solution to each problem, in

which most of the time was given to problems students voted to be most difficult. A few weeks into the flipped classroom, however, the individual problem exercises were slightly changed to a format in which the students were given one problem at the time and used the SRS to vote when they finished the problem (or gave up). I would then go through the solution of the problem on a Smartboard before the students were given the next problem to solve. The reasons for this change will be discussed later in this paper.

While the inclusion of individual problem-solving exercises goes outside some definitions of a flipped classroom, for instance, the definition by Bishop and Verleger [1], which focuses on student collaboration, it was deemed as an important part of the in-class activities. Group work is an important part of a flipped classroom, adhering to a socio-cultural learning perspective [1,8], but participants in a group can have a tendency to over-estimate the efficiency of the group [29] and over-estimate their own performance [30]. While these results are not necessarily transferable to learning outcomes during group work, the concern was the possibility of individual students over-estimating their understanding of a topic or mathematical concept as a result of the group managing to solve the problems during the group sessions. The individual problem-solving exercises were therefore meant as a way for students to test their own knowledge after they worked as a group a few days before.

2.3. Out-of-Class Activities

A total of 104 videos were made to cover all the topics that would have been taught in the lectures. Watching these videos made up most of the out-of-class activities during the flipped classroom. Students were encouraged to take notes and work actively with the content in the videos. Out-of-class activities in a flipped classroom often include students answering quizzes to test their knowledge [1], but in the current implementation of the flipped classroom, there were no mandatory quizzes, with my rationale at the time being that I did not want to overwhelm the students with too much mandatory work. However, the problems that were to be solved during the group assignments were posted online at least a week before the group sessions, and students were encouraged to work with the problems before meeting in class. In addition, some videos that focused on solving specific problems had the problem stated in text above the video so that students could try to solve it before watching the video (see Figure 1b for an example).

All videos in the flipped classroom were made by me and followed the Kahn Academy style of digital handwriting (with the occasional computer animation to help illustrate certain topics; see Figure 1c for an example). The Kahn Academy style has been shown to be more engaging than videos consisting of PowerPoint presentations and lecture hall recordings [31]. Furthermore, the design of the videos followed several of Mayer's principles of multimedia learning [32], such as removing unnecessary visuals and redundant material when possible (the coherence principle), using the mouse cursor and colours to guide the attention of the viewer (the signalling principle), segmenting the content into smaller parts (the segmenting principle), using images and figures to aid in visualisation (the multimedia principle), etc. Screenshots from the videos can be seen in Figure 1. A colour blindness simulator was used on the colour palette used in the videos to make sure all colours used were visible on the green background for all students, independent of possible colour vision deficiencies.

The design of the videos also took points from the cognitive load theory, such as not including a talking head (a part of the screen showing the instructor talking) with the aim of reducing cognitive load. The presence of a talking head can be a distraction to the viewer [33] since there are two areas on the screen that will attract the viewer's attention: the instructor's face and the instructional material. Having to constantly shift focus between two areas of interest on the screen is argued to cause a split-attention effect, which adds to the cognitive load of processing the material [34]. That talking heads can attract viewers' attention was demonstrated in the study by Kizilcec, Papadopoulos and Sritanyaratana [35], which found that students would spend 41% of the watching time

focusing on the instructor's face when a talking head was present. The possibility of students not watching the instructional material for 41% of the time was deemed too undesirable for the videos designed for this flipped classroom because of the nature of the content in the videos, such as solving mathematical problems and deriving mathematical proofs, where paying close attention to each step in the video is important for understanding the concepts.

There are some benefits of having a talking head, however, such as students tending to watch more of a video when talking heads are present [31], and there are students that prefer having talking heads in videos [33]. Guo, Kim and Rubin [31] argue that the presence of a talking head makes the video more "intimate and personal", which could be beneficial for students' sense of relatedness according to the self-determination theory. However, since mathematics can be a very difficult subject for engineering students [36], and because I could use the group sessions to increase students' sense of relatedness, decreasing cognitive load was deemed more important than the increase in relatedness from the videos.

Based on their study, Guo, Kim and Rubin [31] recommend learning videos to be less than 6 min and preferably no longer than 9 min. However, others have criticised using this as a universal rule, for instance, Lagerstrom, Johanes and Ponsukcharoen [37], who found a video length of 12–20 to be a good 'rule of thumb' based on their own study. For the videos made for this flipped classroom, I targeted a video length of about 10–15 min, which is consistent with the study by Lagerstrom, Johanes and Ponsukcharoen [37]. However, the logical and natural segmentation of the content was prioritised over following a fixed time limit. Therefore, some videos would be shorter (as short as 3 min) and some longer (as long as 35 min). The average video length was 13 min.

The videos were organised into 'lessons', where a typical lesson consisted of 4–6 videos. There was a total of 20 lessons, usually bundled in groups of three that needed to be finished before the in-class activities. The total video length of each bundle would vary, but the average running time was about three hours. The videos were hosted on YouTube and were administrated to the students on the Learning Management System "itslearning" (see Figure 1b). The in-class activities and out-of-class activities would work in parallel, i.e., students would work with the lessons for next week's assignments at home while having in-class activities based on last week's lessons. The students would usually have one week to finish the required lessons, with some exceptions in which the students had two weeks (mostly due to various holidays). The flipped classroom lasted for the last 85 days of the course, with the last problem-solving exercise being on day 73 and the exam being on day 85.

2.4. Surveys

The students were subjected to two anonymous surveys, one given in the middle of the flipped classroom weeks and one given at the end of the semester. The first survey was given due to the frustration expressed by some students to see if this frustration was shared by the rest of the students and see if there was a need to change aspects of the flipped classroom format. The first survey had eight questions. Students were asked to rate the videos, group work and individual problem exercise sessions as well as state in their own words (open-ended questions) what they felt worked well with the format, what did not work well and how things could be improved. Students were also asked to rate their satisfaction with the flipped classroom so far, as well as having open questions in which students could state any other comments they had.

The second survey expanded on the first survey with 19 closed-ended questions and 2 open-ended questions. Some of the questions were created based on comments from students' answers in the first survey to see to what degree they represented a more general view of the student mass, such as having difficulty working with the videos at home or adjusting their study habits to the flipped classroom format. Other questions included asking students to rate to what degree they felt they got enough information about the flipped classroom beforehand (students were given a lecture on the flipped classroom

and how to study effectively before the first videos were posted), how they worked with the videos, rating how important different sources were for their learning (the textbook, videos, group sessions, old exams, etc.), and several questions regarding group work, such as rating how they felt their group functioned, if they felt members of the group came prepared, etc. The second survey also had an open-ended question in which students could elaborate their answer on a closed ended question, asking students to specify if they found it easier/more difficult to concentrate on theory when it was presented in a learning video versus traditional lectures. At the end of the survey, students were asked to rate their satisfaction with the format, similar to the question in the first survey, and an open-ended question in which students could freely write any comments was also provided.

2.5. Analysis

The open-ended answers were subjected to a coding scheme in which each line or sentence was given a code based on its content reminiscent of the line-by-line coding process of Grounded Theory [38]. This form of inductive or data-driven coding, i.e., in which codes are derived from the data itself, was chosen as a means of limiting pre-conceived notions of students' experiences when entering the analytical process. Charmaz [39] argues that the line-by-line coding strategy from Grounded Theory forces the researcher to interact with the data in a more in-depth manner and that the codes themselves provide a deeper insight into the phenomenon described by the participants than more general qualitative data-driven thematic coding. The codes were also to a large degree based on in vivo codes, that is, using participants' own words to define the codes. One reason for using in vivo codes was to reduce the risk of researcher bias when defining the codes, as I was the sole researcher in this study. Charmaz [39] also argues that in vivo codes can be a useful tool for the researcher when discerning participants' meanings. Coding was carried out using Tams Analyzer, which is software designed for qualitative analysis. In addition to coding, the software provides tools for summarising codes, grouping codes together and searching within codes.

It should be noted that I did not perform a proper Grounded Theory thematic analysis, as this process contains multiple steps normally used for the thematic analysis of, or theory construction from, rich qualitative data such as those from repeated semi-structured interviews. Rather, I used strategies from the Grounded Theory analytical process (line-by-line coding, identifying similarities and connections between codes, memo-writing, etc. [38,39]) as an aid to identify both positive and negative aspects of the flipped classroom implementation raised by the students and to provide context to answers to close-ended questions. After the initial line-by-line coding, a small summary was written for each student on both surveys in which the open-ended answers were put in context to what the student answered on the closed-ended questions. If a student did not provide comments on open-ended questions, a small summary was still written based on their answers on the closed-ended questions. These summaries were used as a tool to describe the experience of each student who answered the surveys. The students were then sorted by their satisfaction with the flipped classroom format (positive, negative and neutral). This was carried out for both surveys and made it easier to investigate comments and codes from students being positive, negative or neutral to the format. The qualitative analytical process worked closely together with the statistical analysis, for instance, by comparing student statements and summaries to answer distributions on closed-ended questions as well as correlations between survey-questions. All survey quotes presented in this paper have been translated from the students' native language, Norwegian. Statistical analysis on closed-ended questions was performed using RStudio, which is an integrated development environment for the statistical-analysis-centric programming language R. In addition to the surveys, video statistics from YouTube were collected. However, students' viewing behaviours during the flipped classroom are reported in another paper [40].

3. Results

3.1. The Learning Videos

A total of 87 students answered the second survey, while 64 students answered the first (about 74% and 54% of the students, respectively). While 69% of the students who answered the second survey were either satisfied or very satisfied, 20% of the students were either dissatisfied or very dissatisfied, and 11% answered with the more neutral 'neither satisfied nor dissatisfied (see Figure 2). This was a statistically significant increase from the first survey given in the middle of the flipped classroom weeks, in which 45% were satisfied, 33% dissatisfied and 22% were neutral (p = 0.015 with Mann–Whitney-U-test, effect size = 0.22 (Cliff's delta)). In the second survey, the students were asked if they felt that they were given enough information on how to study effectively as a flipped classroom student. While 72% of the students felt that they were given enough information to either a large or very large degree, 23% of the students answered with the more neutral 'to neither large nor small degree'. Only 5% of the students felt that they were not given enough information.

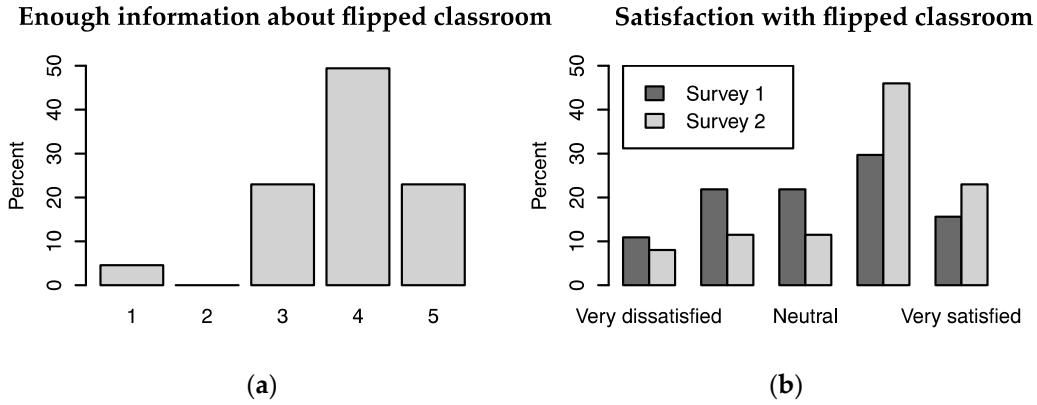

Figure 2. (**a**) Comparison of student satisfaction with the flipped classroom from the first and second survey (5 = "very large degree"; 1 = "very little degree"); (**b**) to what extent they felt they received enough information to study effectively with flipped classroom.

Most of the positive comments on the flipped classroom focused on the freedom given by the videos, both regarding the time control given by having the theory in video format, but also in form of the freedom to choose when and where to watch the videos. As one student put it:

> *You can do it in your own pace and study in a self-chosen environment. There are no social distractions. You do it when it suits you, i.e., if you are tired and unable to do it, you don't do it. More freedom for us students.*

While 53% of the students who answered the second survey felt that it was easier to concentrate on the mathematical theory when it was presented in a video, 33% of the students felt that it was easier during the traditional lectures, and 14% had no preference (see Figure 3). The freedom of the flipped classroom was not always a positive and could sometimes even be a hindrance, since it is easier to be distracted when watching on a computer at home. As three students put it:

> *When you must watch it on the computer there are lots of things that can distract you, while in a lecture you are there to be lectured, and then it is easier not to get off track.*

> *During the traditional lectures, you are 'forced' to pay attention because you only have this 'one' chance to really get the theory, while with the videos you are more relaxed because you know you can watch it multiple times.*

It is easy to skip examples and less 'important' things when you sit at home alone. It is much better to be 'forced' to listen during a lecture. It is easier to skip a small 5-min video compared to leaving a lecture.

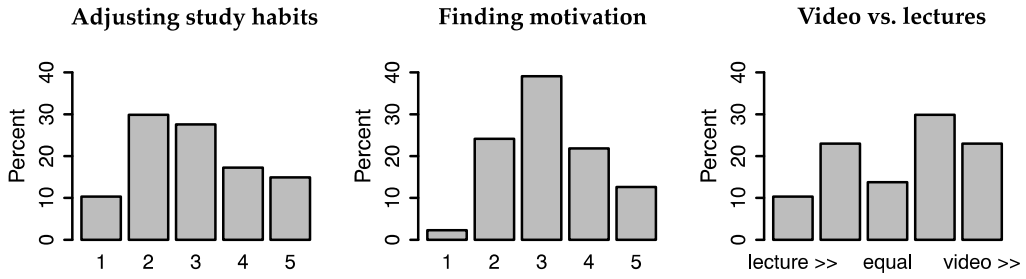

Figure 3. Questions from the second survey. (**a**) "How difficult did you find it adjusting your study habits to the flipped classroom method?"; (**b**) "How difficult did you find it finding motivation to work in the theory by yourself?" Alternatives on both (**a**,**b**): 5: "Very difficult", 4: "Difficult", 3: "A little difficult", 2: "Not particular difficult", 1: "Very easy"; (**c**) "How easy/difficult was it to concentrate on the theory when it was presented in lectures vs. a video?". Left alternatives: "easier/much easier with lectures". Right alternatives: "easier/much easier with videos".

One student also explained how being around other students could help with increasing the discipline of working with theory:

It is much easier to be disciplined to attend the lectures when there are people around you that notice if you are around or not, compared to when you sit down to work with the videos on your own.

Students who found it easier to concentrate on the theory with videos tended to be more satisfied with the flipped classroom (Spearman's rho = 0.67). Figure 3 also shows to what degree the students found it hard to adjust their study habits to the flipped classroom as well as how difficult they found it finding the motivation to work with the subjects on their own. The distributions of the answers are relatively wide, meaning that there are many students that found it hard to adjust their study habits and find the motivation to work by themselves, as well as a large portion of students that did not. There were negative correlations between these questions and how satisfied the students were with the flipped classroom, i.e., students that found it difficult to adjust their study habits and to find motivation to work on their own tended to be less satisfied with the flipped classroom at the end of the semester (Spearman's rho = -0.67 and -0.65 for 'difficulty adjusting study habits' and 'difficulty finding motivation', respectively; see Table 1 for a summarisation of the correlations). That unfamiliarity with the lecture format could have a negative impact on student satisfaction was also present in the student comments; for example:

Table 1. Spearman correlations for selected questions from the second survey ($n = 87$, $p < 0.001$ for all correlations). See Figures 2–6 for more details on the questions.

Question	Question	Rho
Difficulty adjusting study habits	Satisfaction with flipped classroom	−0.67
Difficulty finding motivation	Satisfaction with flipped classroom	−0.65
Concentration: lectures vs. video	Satisfaction with flipped classroom	0.67
Group member preparation	Rating of groups	0.67
Importance of group work for learning	Rating of groups	0.49

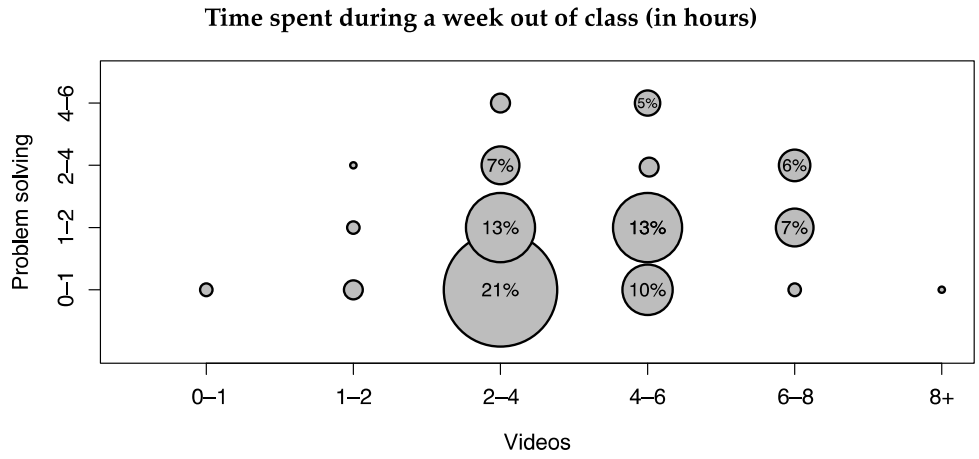

Figure 4. Student reporting on how much time they spent on the learning videos as well as working with solving problems out of class each week. Numbers in circles represent frequency.

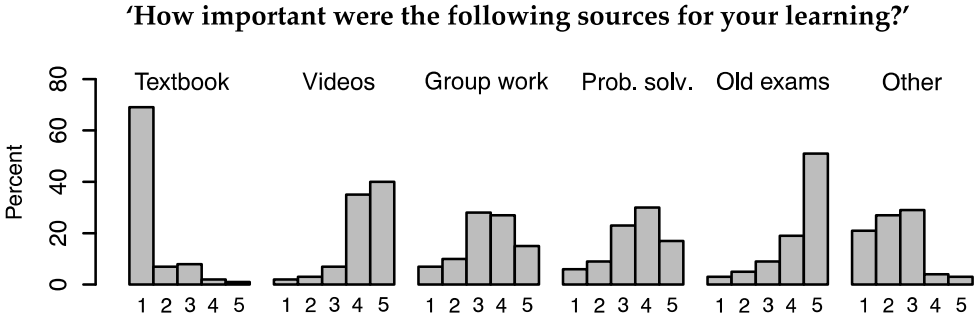

Figure 5. Student ratings of how important different sources were for their learning. Alternatives ranging from "very important" (5) to "very unimportant" (1).

> *The flipped classroom probably works better if you are used to it. I still do not quite know how to approach the lessons because I'm too used to the traditional lectures.*
>
> *Ever since primary school, I have been used to going to school and listening to a teacher talk. I think I am dissatisfied mostly because this is something I am not used to and because I have not chosen an online course, which I felt this was.*

In addition to the flipped classroom being an unusual pedagogical format for students used to traditional lectures, it is also more demanding on students' discipline and ability to self-regulate their learning. The students must set up their own schedule, find a place and time to work with the theory and have the discipline to follow their plan. As some students put it:

> *For anyone who is disciplined enough to watch the videos, flipped classroom is obviously better than traditional.*
>
> *I feel that the format is good, but it demands the students to be structured, something I know I must improve on myself.*
>
> *The importance of working independently and being well prepared is greater with such a format. Without independent work you get very little out of flipped classroom, much less than if you meet unprepared to a traditional lecture. But if you are good at working independently, meeting prepared and have a group that works well, then I think there is great learning potential in this type of format.*

One student elaborated further and explained how he/she saw how the flipped classroom made a greater distinction between students with good and bad study habits:

> *In this classroom format I see a greater difference between those who work regularly and well with the subject matter and those who do not. It is much easier to fall behind when*

everything is done at home, which requires some self-discipline. It is easier to go to a lecture than to sit down to complete the lessons at home. I see that those who previously showed up to the lectures, but did not work so much on their own, now neither watch much of the lessons nor are working on their own (and then it is no wonder you don't manage to follow along).

The video statistics from YouTube showed high spikes in the number of views on the days before the group activities, indicating that there were several students that waited until the last day before watching the learning videos. This was also reflected in some student answers; for example:

I find it difficult to set up a 'schedule' to be able to watch all the videos in time. I often end up watching everything on Sunday and Monday in order to finish before the group exercise on Tuesday. It will then be very much to do in a short amount of time.

The videos are long, and you feel that 'you just want to be done', so I end up watching all videos in one day and get sick and tired!

Two of the questions on the surveys asked students to report how much time they spent on the learning videos each week as well as how much time they spent on problem solving out of class. The results can be seen in Figure 4. Most students (44%) reported using between 2 and 4 h on the learning videos, followed by 4–6 h (30%). For time spent on problem solving, the most common answer was 0–1 h (39%), followed by 1–2 h (34%).

The students were asked to state to what degree different sources were important for their learning of the subjects, such as the videos, group work, fellow students and so on (see Figure 5). Most students found the videos to be important for their learning, as well as studying old exams, with 86% of students answering either 'important' or 'very important' for both sources. The textbook, on the other hand, was, for most students, not seen as an important source of learning, with 79% of students labelling it as 'very unimportant'. One student specified how some students might view the textbook:

For people who may not be as motivated every time they have to work on math problems, the overly thick math book can often feel like a big black hole that sucks all motivation out of you already at the first page.

A common complaint from the students on the flipped classroom method was that it took a long time to watch all the videos in time for the group activities. In addition, there were complaints that there was no possibility to ask questions during a video, and that the videos had too much focus on theory and not enough on problem-solving techniques, as well as the fact that the examples given in the videos differed too much from the problems given in the group and problem-solving activities.

3.2. The Group and Problem-Solving Activities

Although the group and problem-solving activities were rated as less important for the students' learning compared to the videos, they were still valued for many students as an important part of their learning (Figure 5). Positive aspects included the benefits of working together with other students as well as how the activities functioned as a motivator to work hard with the theory beforehand:

I am very happy that we do tasks together as a group. It is easy to weed out mistakes and uncertainties with discussion and explanation on the smartboard. The problem-solving exercises are hugely beneficial, whether you get it or not. The time you have at school are used much better in this way and you work more regularly. It was very easy to fall behind before this type of classroom format.

The format works very well. The group and problem-solving exercises force us to watch the videos so we don't end up falling behind.

However, not all students found the problem-solving exercises to be a positive aspect of their learning. As two students put it in the first survey:

> *Mathematics is a subject that needs to mature before getting the grip on it, and then it is very depressing for every problem-exercise to feel that you are not prepared when you have actually worked well through the lessons and group exercises and you see that you do not get it.*
>
> *I admit that on every problem-solving exercise I have 'cheated' by using the notebook to see if I find something similar. I do this so that I actually learn something. I am totally chanceless without these, and I am rarely able to solve anything even if I look at the notes. If I look around, I see that almost no one can do more than writing the problem text.*

There also may have been challenges with the group activities, especially when some group members were not prepared for the group activity. This could have resulted in less optimal group work, in addition to being a source of frustration for other group members. As three students put it:

> *The group exercises work fine, but not optimally. The problem is that not everyone in the group is well prepared, that is, has not seen the videos beforehand, and then it can be a bit difficult to work effectively as a group.*
>
> *I experienced several group exercises where I had to use my time explaining people what they should have seen in the video lessons beforehand. I will gladly help fellow students, but I have no interest explaining things from scratch because they didn't bother doing their homework.*
>
> *The group works poorly as people come unprepared and there is a lot of sitting around the table where we are not able to get anything done. This is both because people can't contribute because they are not prepared, and because there is little help to get if no one understands the problem.*

The students were asked to rate how well they found their group to function, as well as to rate to what degree they felt the group members met prepared for the sessions. The results can be seen in Figure 6. Students who felt that the group members met prepared tended to rate their group better (rho = 0.67). In addition, there was a positive correlation between group ratings and how important the group work sessions were towards learning the mathematical topics (rho = 0.49).

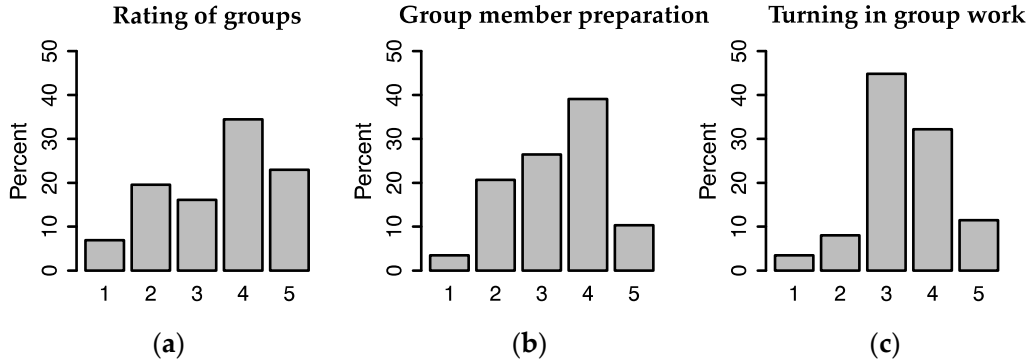

Figure 6. (**a**) "On the group sessions, I felt that my group functioned:". Alternatives from "very well" (5) to "very poorly"; (**b**) "To what degree did the group members come prepared?" Alternatives from "very high degree" (5) to "very little degree" (1); (**c**) "If you were required to turn in your work at the end of the group session, and that this had to be approved, how would this affect the group work?". Alternatives from "much better" (5) to "much worse" (1).

Some students argued that they felt the group activities would have worked better if all groups were required to turn in their work for approval. As two students put it:

> *Not having to turn in group work makes the group demotivated since no one sees any point in making an effort.*

The group assignments become a little unserious since we solve the problems just for 'fun' without being checked or something (which we were used to from last year).

In the second survey, the students were asked how they felt turning in the work for approval would have affected the group work (see Figure 6). While 44% felt that the group would have worked either "better" or "much better", 45% of the students who answered the second survey felt that it would have made no difference. The most common complaint concerning the group activities, however, was the lack of a student assistant. When a group got stuck on a problem during the group work, it could sometimes take a long time before they got assistance. This could result in time being wasted as the group could end up sitting idle while waiting for the lecturer.

4. Discussion

Despite what the title of this article might suggest, I would not call the implementation of the presented flipped classroom a failure (although there was much room for improvement, as will be discussed later in this section). While there were students that openly displayed frustration, 69% of the students who answered the second survey stated that they were satisfied with the flipped classroom at the end of the semester (11% stated that they were neutral). The positive experiences from the students in this study are consistent with positive experiences from previous studies, such as the ability to work with the theory at their own pace [10,11], the flexibility of the flipped classroom [12] and the freedom offered by the format [13].

However, while many students appreciated the freedom and flexibility offered by the flipped classroom, other students saw it as a hindrance. Some students expressed that it was easier to be distracted when watching videos on their computer at home, which is aligned with results from other studies [12,13]. While Abeysekera and Dawson [9] argued that the flipped classroom can lower the cognitive load required to learn the course material, which is consistent with the study by Karaca and Ocak [14], Jovanovic et al. [21] argued that the flipped classroom can have the potential to cause higher cognitive loads as students both have to learn the course material as well as adjust and evaluate their study habits to a different pedagogical format. Mathematics (in particular, calculus) can be a difficult subject for engineering students [36] that 'needs to mature before getting the grip on it', as stated by one of the students in this study. This could have contributed to the difficulty that several students in this study experienced on adjusting their study habits to the flipped classroom format, as seen in Figure 3. The correlation analysis showed that difficulties adjusting their study habits had a negative impact on student satisfaction. The negative impact could have been made worse by the fact that most students did not value the textbook as a good tool for learning the material, as seen in Figure 5. If the students struggled to study the theory when being presented in the videos, they would either have to go elsewhere for other resources or be stuck with no viable resource for learning the course material out of class. Not valuing the textbook can also be seen in other studies on STEM education; for example, [41,42].

Although Abeysekera and Dawson [9] used the self-determination theory to explain the possible benefits of a flipped classroom, it could also be a valuable tool to help explain negative experiences with the flipped classroom and why the format could be a source of frustration. For instance, if students end up with no viable resource for learning the course material, as explained above, it could have a negative effect on their sense of competence, which could lower motivation according to the self-determination theory. Figure 3 shows that many students, to a various degree, did have difficulties finding motivation to study by themselves in the flipped classroom, which also had an impact on student satisfaction, as seen by the correlation analysis.

Figure 4c and student comments on watching videos vs. lectures show that it can be difficult to make the flipped classroom accessible for all kinds of students. This is further exemplified by how one student viewed the lack of the social aspects of attending lectures as a benefit to his/her concentration, while another needed the social pressure from peers to

motivate him/herself. Being dependent on social pressure is aligned with being externally motivated, as they do the work to avoid being perceived as a failure. External motivation among the students is also indicated by the comments on group work, such as the group sessions being viewed as 'unserious' because the students were not checked or had to turn in their work for approval. External motivation could explain why a large portion of the students felt that the group session would have worked better if the work had to be approved, as seen in Figure 6. If students lack the intrinsic motivation to work with the course material, or at least being externally motivated with a sense of identified or integrated internalisation, they might struggle to find the discipline to do the necessary work required from a flipped classroom.

There are indications that some students had poor study habits in the flipped classroom, for instance, by waiting until the last days to watch the learning videos and/or meeting unprepared to group activities. Poor study habits from a flipped classroom can come from either being unable to adjust to the new format or from having poor study habits in general. The result of poor study habits might not be as apparent in a traditional lecture as there are no immediate negative consequences for not paying attention or taking good notes. The experience might be very different in the flipped classroom since the poor study habits will become very apparent, as he/she will not be able to solve the problems given in the problem-solving activities (as one student also commented in the survey). Poor study habits with the flipped classroom will also be more visible to other students, as he/she will not be able to contribute to the group assignments and might also receive resentment from other group members for not meeting prepared, as seen in some of the student quotes from the survey. Dissatisfaction with other group members in a flipped classroom can also be seen in the study by Fisher, LaFerriere and Rixon [12]. The increased visibility to other students can also be seen in a couple of comments on the survey such as 'In this format I see a greater difference . . . ' and 'I saw many students that struggled with this format'. As one of the students in the study by Steen-Utheim and Foldnes [8] so fittingly put it: 'In a lecture hall you can hide. You cannot hide in a flipped classroom'. In addition to possibly thwarting students' sense of competence by not being able to do the in-class problems or group exercises, negative reactions from the group could also have had a negative impact on the sense of relatedness with their peers.

The question then becomes how students deal with these negative experiences. Zimmerman [25] describes two ways a student might react during a self-reflection phase: they can adapt or become defensive. If a student lacks the motivation to work on their own in the flipped classroom, this motivation could be further diminished if the student encounters such negative experiences and reacts defensively to the experiences instead of managing to adapt. If a student has a negative experience from attending a traditional lecture, he/she can just choose to not attend future lectures to avoid negative experiences. This was not possible in the flipped classroom in this study, however, since a large portion of the in-class sessions were mandatory in order to be eligible for the exam. A possible hypothesis is that, for some students, this could have resulted in a vicious circle or negative feedback loop in which the motivation to adapt diminished further for each group assignment and problem-solving exercise the students attended. Even if a student normally has good study habits from the traditional lecture format, a negative feedback loop could still be a possibility if the student struggles to adapt to the flipped classroom format and lacks the tools needed to self-evaluate and self-regulate their learning in this new environment. The result could possibly be an even stronger negative reaction towards the flipped classroom since they used to be able to study effectively with the traditional lecture format. In other words, they can see their sense of competence being thwarted by the flipped classroom format, decreasing their intrinsic motivation as a result. As one of the students in this study put it: 'it is very depressing for every problem-exercise to feel that you are not prepared when you have actually worked well through the lessons and group exercises, and you see that you do not get it'. This is also consistent with the study by Mason, Shuman and Cook [24]

in which the frustration expressed by the students came particularly from students that typically performed well in engineering classes.

While there is not enough information in the data presented in this study to verify the hypothesis of a negative feedback loop, it could be a possible explanation as to why the flipped classroom could provoke strong frustration among some students. A possible explanation for the increase in satisfaction with the flipped classroom at the end of the semester could be that some students had an initial negative experience with the flipped classroom but reacted with adaption and managed to adjust. A focus for future research studies could be to examine the viability of the negative feedback loop hypothesis as well as determine if different student types are more likely than others to end up in the cycle.

Previous studies have shown that it can take three to four weeks into a course before the students get used to a flipped classroom [23,24]. While this might be because students are unfamiliar with the flipped classroom and therefore do not know how to study effectively with the format, the students presented in this paper mostly agreed that they received enough information on effective study habits (Figure 2). It is possible that the reason why it takes time before students start adapting their learning style is rather that they need time to develop the necessary metacognitive skills, as was seen in the study by Yilmaz and Baydas [23], which might also explain the initial reluctance for some students to change their study habits in the flipped classroom [28].

Maybe one of the greatest weaknesses with how I implemented the flipped classroom is the lack of focus on self-regulation. Besides from an initial lecture on how to study effectively as a flipped classroom student, there were no other assignments related to self-evaluation or metacognition, such as using self-evaluation surveys. Zimmerman [25] argues that it is important to actively develop students' skills in self-regulated learning and metacognition. This might be even more important in a flipped classroom since self-regulation skills and self-discipline become more important than traditional lectures (the latter also being pointed out by several students on the surveys). Having students regularly complete self-evaluation surveys could have been one way to do this. Having these be mandatory, as well as having other mandatory work associated with the pre-class work such as quizzes or similar, could also possibly provide the necessary external motivation that some students might need.

There is also room for improvement in other areas such as limiting the number of student groups that attended the group sessions. The students complained that they often had to wait a long time before receiving help during the group work. This could have been another factor that could have led to a decreased sense of competence since it became more apparent that the group was unable to solve the problems. In a class of a total of 118 students, it might have been more fruitful to divide the class in three instead of two to have a more manageable group size, or to alternatively have student assistants present during group work in addition to the instructor. The latter was a common suggestion from the students in this study.

The possible thwarting of a sense of competence was also the reason why the format of the problem-solving exercises was changed mid-semester. If a student could not solve the problems, the student could potentially be sitting for most of the first 45 min doing nothing. By having one problem at a time, the aim was to increase the sense of competence since the student would be doing something 'useful' for their learning after a few minutes even if they did not manage to complete the problem. Regretfully, there was no question on the surveys that specifically asked about the new format of the problem exercises.

It could also be argued that another weakness with how the flipped classroom was implemented was the large amount of video content that was required for the out-of-class preparation (a common complaint from the students). Based on the study by Guo, Kim and Rubin [31], which found a video length of 6–9 min to be the most engaging, one could argue that the further segmentation of the video content in this study to lower the length of each video could have been beneficial for student satisfaction. However, using a similar methodology as Guo, Kim and Rubin [31] on the video statistics in this study, which has

been discussed in more detail in another paper [40], resulted in a video length of 15–25 min rather than 6–9 min. Since the average video length was 13 min, this suggests that the amount of video content was a larger problem than the length of individual videos. While one could on the one hand argue that the time students spent on videos and problem solving out of class each week (Figure 4) was within the amount of work expected by students in higher education, it would probably have been more beneficial to reduce the amount of video content required to be watched before the in-class sessions to reduce frustration and video content fatigue.

In addition, even if one wanted to retain the amount of work expected by the students out of class, it could also have been more beneficial for student learning to replace parts of the video content with other activities such as mandatory problem-solving assignments or the self-evaluation surveys described earlier. In a study by Jensen, Kummer and Godoy [43], the researchers found no difference in learning outcomes from a flipped classroom compared to a non-flipped classroom that also implemented active learning. Based on their results, the researchers argued that any learning gains from a flipped classroom compared to a traditional lecture format are due to the flipped classroom focusing on active learning and not as a result of watching video content. While there are several benefits to having students prepare by watching videos out of class compared to receiving the same information in a traditional lecture, as has been explained previously in this paper, watching videos should not be the main focus of a flipped classroom. Instead, it should be regarded as a means to make it easier to implement active learning in the classroom.

Limitations

Although surveys can be an efficient tool to collect data on a large population, for instance, a class with many students, closed-ended questions on a survey are not efficient for obtaining a deep understanding of people's feelings or experiences [44]. Obtaining such deep understanding requires rich data, such as combining data from multiple sources, particularly interviews of participants [38]. Having open-ended questions on the surveys opened a window into students' experiences that could not have been done with using close-ended questions alone, but Charmaz and Thornberg [45] describe interviews as crucial for gathering quality data designed for obtaining a deep understanding of experiences, feelings and opinions as they allow for listening to answers and following up on participants statements to probe for further answers and elaboration on descriptions given by participants [45]. Such rich qualitative data would also allow for a more proper Grounded Theory analysis, which would result in a deeper understanding than could be gained from only using parts of the analytical process, as was carried out in this study. To investigate the viability of a negative feedback loop with the flipped classroom, future studies should therefore include student interviews. Another limitation is that the coding was performed by a single researcher. While line-by-line and in vivo codes were used to limit possible researcher bias, there is still the risk of bias as a result of a single researcher performing all the coding. Lastly, this study describes a single case of a flipped classroom, and the findings are therefore not necessarily representative of how other student bodies might experience similar flipped classrooms.

5. Conclusions

In this paper, I have reported on engineering students' experiences with a flipped classroom in mathematics and explored why some students can be frustrated with the format. Students' negative experiences were discussed in light of the self-determination theory and the self-regulated learning theory. While researchers have used the self-determination theory to explain the benefits of the flipped classroom, arguments were presented that they could also explain some of the challenges and frustrations experienced by some students. Not being able to adapt their study habits to the flipped classroom becomes very apparent and could possibly have a negative impact on students' sense of competence as well as a possible decrease in relatedness towards group members that respond negatively to

their inability to contribute. In addition, this paper presented a hypothesis that a negative feedback loop could arise where students' ability to self-motivate decreases with the negative experiences with the flipped classroom, which in turn makes it more difficult to find the motivation to adapt. However, additional studies are required to investigate this hypothesis. Although this article has mainly focused on students' frustrations with the flipped classroom format, most students ended up being positive towards the format at the end of the semester.

Funding: This research received no external funding.

Institutional Review Board Statement: Ethical review and approval were waived for this study due to that the data in this manuscript is based on two surveys that was anonymous, voluntary to answer and did not containt questions that asked for personal information that could be used to identify students, nor questions of that would be considered sensitive.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

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