Exploring Tensions in a Mathematical Course for Engineers utilizing a Flipped Classroom Approach

Helge Fredriksen[1], Said Hadjerrouit[2], John Monaghan[3] and Ragnhild J.Rensaa[4]

[1]University of Agder & The Arctic University of Norway, Norway; Helge.Fredriksen@uia.no

[2]University of Agder, Norway; Said.Hadjerrouit@uia.no

[3]University of Agder, Norway; John.Monaghan@uia.no

[4]UiT – The Arctic University of Norway; Ragnhild.Rensaa@uit.no

Flipped Classroom approaches to teaching are becoming increasingly popular in higher education, but there is a lack of empirical research. We present here a study performed during an engineering course for 20 students at a Norwegian university, on student appropriation towards Flipped Classroom through interviews, questionnaire, video/quiz usage statistics and classroom filming. We approach this research through an activity theoretical framework, focusing on tensions experienced as the students try to tackle the demand of video preparation and active learning in class. In line with much of the recent research on the topic, we find that most students seem to appreciate more collaboration with peers and teacher. However, there is also evidence that the new form of teaching creates various tensions; a minor part of the cohort demonstrates conflicting beliefs about mathematics learning, resisting the active learning part of Flipped Classroom.

Keywords: Activity Theory, Flipped Classroom, Tensions

Introduction

Flipped Classroom (FC) is most commonly known as a method that arranges the lecturing part of the teaching as homework through videos. This is considered the out-of-class part of the FC. When students come to class, the stage is set for learning in a student-centered manner, using various problem-solving activities (Bergmann & Sams, 2012). This is considered as the in-class part of FC. Both are vitally important for the FC learning model to work. The out-of-class video learning "primes" the students for the crucial in-class active phase (Seyfedine, Kadry & Hami, 2014), where hopefully the active "learning-by-doing" understanding and adaptation takes place. The idea is that through well-designed activity sets in class, the teacher has the opportunity to challenge the students at both a collaborative and conceptual level in this phase (Wan, 2015).

In this paper, we describe a study that was conducted in the spring term of 2016 at a Norwegian university, where students in their first year of engineering studies were exposed to several interventions of the FC way of teaching. The teaching setup in this university is well suited for flipped teaching. It is a small campus, with only 20-30 students per-year in a 3-year long bachelor study in computer engineering, allowing for a tight integration between the students and the teacher.

Many studies on the implementation of FC seem to indicate that motivation might increase among students in mathematics (Franqueira & Tunnicliffe, 2015; Seifedine et al., 2014; Roshan, 2015). In light of the above-mentioned issues, this makes it tempting to explore this fundamentally new approach of teaching. However, there are also research studies that indicate the opposite.

Wasserman, Quint, Norris, and Carr (2015) found that students in a flipped calculus III class were critical to the use of class time for group work. Strayer (2015) reports that students felt "lost" and disengaged with the material sooner than students in the traditional classroom did. Ramaglia (2015) did a comparative study between flipped and non-flipped high school and middle school mathematics classes in her PhD thesis, but failed to find consistently increased peer-to-peer activity among students. Referring to these mixed results from other studies, it seems interesting to gain more insight into what kind of tensions, strains and possible resolutions of these can be observed in a FC realization. Based on this background, our research questions are formulated as follows:

Research Question: What are the tensions that emerge from students' attempts to appropriate change towards FC facilitated by videos and quizzes?

Theory

We believe that learning can best be understood when considered as a common enterprise among students and teacher, emerging as culturally negotiated in an environment based on constructive criticism. Turning to Cultural Historical Activity Theory (CHAT) (Engström, 1994), we have a rich theoretical basis to put FC in a broader perspective.

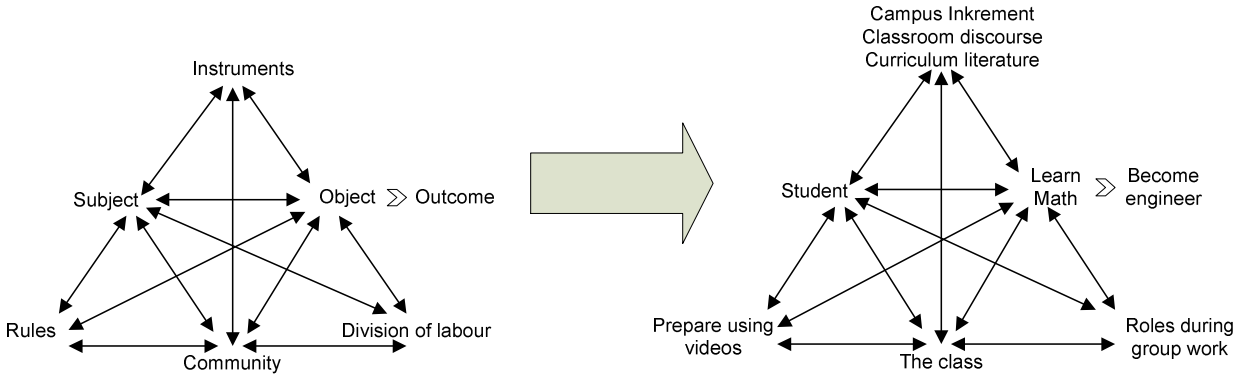

Figure 1: The CHAT triangle adopted to the Flipped Classroom from a student's perspective

The primary part of the activity system in this study is the student as a subject in her object-oriented activity to learn engineering mathematics. In attempting this, she uses various instruments. The most important ones are Campus Inkrement (a virtual learning environment used for distributing videos and quizzes), classroom discourse and curriculum literature. The dominant new rule governing FC compared to "traditional teaching", is the video preparation part, forming the out-of-class component of FC. The mathematics in the video should form a common ground of knowledge for the community consisting of students and teacher. For the division of labor, we consider how students attain various roles in their collaboration to solve tasks in-class.

In any activity system there exist tensions and contradictions. Engström (1994) summarizes activity theory in five principles, and among these, he mentions contradictions as one of the leading sources for change and development. Basically, contradictions can be defined as a misfit within elements of an activity system, between them, and between different activity systems. Engeström (1987) argues that four levels of contradictions are present in an activity system, and identified tensions in interactions within and between activity systems. The contradictions can be identified at four levels:

primary, secondary, tertiary, and quaternary. If we apply this model in the context of FC, we can describe the contradictions as follows:

1. The primary contradictions occur within the elements or components of FC as an activity system, e.g. within the community of students and teacher.
2. Secondary contradictions arise between the elements of FC, or when two or more elements of FC conflict with one another, e.g. between the community and subject (for example between the class and the individual student), between the object and the community, or between the rules and the community, etc.
3. Tertiary contradictions arise when a new and advanced method or artefact is used to achieve an objective, e.g. when videos are introduced as a new artefact to teach mathematics.
4. Quaternary contradictions occur between FC (as activity system) and another activity system.

Methodology

We performed two separate periods of FC teaching during the second semester of study year 2015/2016. We performed data collection by issuing an anonymous questionnaire, doing three semi-structured interviews and two rounds of classroom filming. In addition, students' usage statistics of video and quizzes were collected through the Campus Inkrement software. As our theoretical stance is in the socio-cultural field, an interpretative research paradigm was chosen. The questionnaire and the interviews were performed after the students' first encounter of FC teaching, informing us on student impressions on pedagogical and technical impressions with the learning platform chosen for distributing video/quizzes, the in-class group work activities and the quality of interaction with the teacher and the other students. Episodes relevant for the enlightenment of the research questions of the paper, tensions and student appropriation towards FC, are highlighted in the results section.

Campus Inkrement (CI) as a mediating artefact

Preceding each in-class session, a corresponding out-of-class session of videos and quizzes was presented to the students in CI, which is a web-application fulfilling the role of the out-of-class component of FC. Built from the ground up to be consistent with the FC teaching design, the teacher/researcher also has the capability to highlight video watching statistics and quiz results for the individual student. From a student perspective, CI brings the opportunity to give feedback on how well the student understood the current topic on a scale 1-5. In addition, self-perceived effort can be reported on a similar scale. The student also has the opportunity to ask for further guidance from the teacher on specific topics. This opens up for an out-of-class possibility for students to prompt the teacher for assistance without revealing their uncertainty to peers in-class.

FC implementation

In this class, there were 20 students following the course. Before attending the spring term, these students had all background from a 10 ECTS (European Credits) calculus based Math-1 course with traditional lecture-based teaching. The course in the spring term that was subject for FC teaching was labelled Math-2, consisting of 10 ECTS containing series, Fourier and Laplace transform, recursion equations, proofs and optimization on functions with two variables.

After having informed the students thoroughly about the new form of teaching in the beginning of the term, we started out the term with one month of FC teaching in January. The topic for this first round of FC teaching was sequences and series, studying criteria for convergence, and in the end Taylor expansions and Maclaurin series. Although we did not influence the curricula, obligatory assignments and exam, we could plan and implement FC as we saw fit, including the teaching performed in-class. The teaching consisted of two or three 90-minutes sessions each week. To prepare each in-class session, 3-4 videos each of 8 to 15 minutes in length were available for the students. In between the videos, quizzes directly related to video contents were given. The videos presented the mathematics in a chalk-and-talk fashion, screen-capturing teachers writing using a tablet, including some demonstrations made in geogebra. We produced 12 of the 36 videos, the rest were collected from online resources mainly from Khan Academy (https://www.khanacademy.org). The videos were procedural in content, in the sense that there was little time to go into proofs or elaborate on deeper concepts. This choice was intended to make the video homework manageable in length for the limited out-of-class time. In line with FC ideas, in-depth understanding should be elaborated in an in-class setting.

After this first attempt at FC teaching, we spent the middle of the course teaching traditionally with other teachers involved. The reason for this shift was the necessity for collecting feedback through interviews with a representative selection of students, in addition to an anonymous questionnaire. This to inform us on potentially needed adjustments in the second phase of FC. At the end of the term, we ran two more FC teaching weeks on the introduction of functions with several variables, linearization of these, partial derivatives and optimization. On most occasions, specially adopted task sheets were prepared for in-class active learning to provoke discussion and in-depth conceptual reflection about the mathematics, the purpose being to raise the abstraction level.

Results

These three sources of data, the questionnaire, the interviews and the filming, provide the possibility for us to triangulate findings. As this is a paper investigating tensions in the CHAT sense, we have been actively looking for excerpts where such qualities are prominent.

Questionnaire

At the beginning of March, we invited all students participating in the class to answer an anonymous questionnaire. Here we asked the informants to agree or not on fifteen statements, in a 5-point Likert scale fashion, about various features of our FC implementation. The purpose of this was primarily to inform us towards the next iteration of FC. Additionally, the questionnaire contained three open-ended questions, prompting the students to express their opinions about the method with their own words. n=15 out of N=20 students responded.

We have chosen to highlight three responses to the open-ended question: “What did you feel was most inconvenient with this method of teaching and learning mathematics”. The three statements below are representative for most of the answers to this question, and are important for the analysis of tensions:

"Personally, it works better for me when I spend time on my own with the tasks. Thus, the session in the classroom became wasted for me. I believe I should learn new things in the class, and then work on my own with the topic afterwards, and then turn to the videos for assistance."

"I got "pushed away" from the classroom using this method, since I do not like to work on tasks in groups. I feel that group work is difficult since many do not understand the topic 100%, which means that many just do not participate in the discussions."

"Group work was unsuitable, since mathematics is a more "individualistic" subject."

Interviews

In addition to the questionnaire, we performed interviews with a representative set of students in a semi-structured fashion. Due to time constraints, we had to limit the sample to three persons. This group of students was chosen as a representative sample according to gender and age, but also due to observed willingness to make critical remarks about the teaching. The interview tried to dig a bit deeper into topics of engagements, impressions about videos, group work and interaction with the other students and the teacher and lasted for about 30-40 minutes. With respect to our consideration of tensions, we present interview excerpts from students with positive and negative views on FC.

The first interviewee was an engaged student in mathematics, with almost 100% attendance in class. He favored learning by videos over traditional learning, and liked the fact that the teacher was more available for questions than traditional lecture-based teaching. As the problematic part of all the group work, he pointed at troubles with fluency in using new mathematical vocabulary. However, he noted that by trying to communicate verbally the task with the others in the group, it became easier to understand how to solve it for himself.

The third interviewee had most of his career from offshore industry but turned to engineering studies for health reasons. He had been away from mathematics for a long time and sometimes struggled to keep up with the pace in the group work

Student: I did not like the specially adopted tasks we got for the class session, and the way we worked in the groups was very inefficient for me. Because many in the class are above me, I am stuck behind the rest during the work.

Interviewer: Ok, but you liked to prepare using the videos?

Student: Yes, I liked that very much.

Interviewer: But you think it would be easier for you to find the answer to the tasks if you were all by your own solving them?

Student: Not easier, but it would have been a better way for me to understand them, since I would be alone to think it over, instead of the others in the group just working fast through them.

Interviewer: So you weren't able to engage in the conversation and participate with your own thoughts?

Student: Not to the degree I wanted.

Both interviewees 1 and 3 expressed concerns about using specially adopted tasks for the in-class work. They worried about the tasks not having sufficient relevance for the final exam, and would rather spend time solving tasks from the textbook. I chose to not include excerpts from the third person being interviewed, since there were little indications of tensions in this interview.

Classroom filming

During the second FC intervention period, we filmed two in-class sessions. We filmed several of the groups, primarily motivated by how the out-of-class teaching affected in-class group work. Two or three students worked together solving problems related to the videos, but on a slightly higher level than the examples used in the videos. One episode in particular caught our attention. One student in a pair (let us call her Silvia) attended class seemingly well prepared and brought notes with her that she had taken from the videos. The other student in this pair (let us call him Nick) seem to be quite unprepared. A study of CI usage statistics confirms this impression. He did not bring notes, and barely spoke during the beginning of the episode. Silvia was clearly leading the discourse. In addition to this, she was actually very interested in how the formula of linear approximation for functions in two variables came about. The formula referred to is the well-known linearization

$$\Delta f = \frac{\partial f}{\partial x}\Delta x + \frac{\partial y}{\partial y}\Delta y$$

The first author hinted that this formula was based on an extension of the single variable case that was derived in the video, but Silvia was clearly not satisfied with this, wanting to know more. In addition, she was the dominant speaker in the group: In the 22 minutes that the episode lasted, we counted 488 words spoken by Silvia, whereas Nick spoke 236. He did catch up in the last third of the episode though, speaking almost as much as Silvia does then. We observe from the videos that this occurs after he had listened carefully to her struggles with the problems and the conversation that she had with the teacher in connection with this.

It was evident from the CI user statistics that many students had not prepared in the last period of FC teaching. This was influencing their progression in-class, although many seemed to use other means of catching up with the topic. They used other resources such as the curricula book, discussions with more knowledgeable peers like prepared students and the teacher, and even to some extent looking at the videos in-class on their own laptop.

Discussion and summary

As previously discussed, activity theory can be used to depict tensions in the FC teaching. Studying the activity triangle in Figure 1, one of the most prominent changes in FC compared to traditional teaching are the rules. These undergo a radical change in FC, enforcing video preparation for in-class active learning.

There are two important observations we would like to highlight. Firstly, the second statement from the questionnaire excerpts hints towards a lack of understanding among several group members (the community) about the mathematical topic at hand. It seems that many members in the group had not

grasped the mathematics in the videos, or they simply had not watched them, leading to a breach in the quality of student group collaboration.

The filmed episode of Silvia and Nick confirms this impression. Nick appeared to struggle to follow the arguments of Silvia, although there were evidence that he somehow moved, towards in the end of the episode, from being an 'eavesdropper' of her struggling and collaboration with the teacher. However, Nick was not playing as the part of a collaborating peer, and thus failing to support Silvia in the discourse. We believe that this was due to his lack of preparation using the videos.

Classroom discourse is considered a vital instrument of learning in FC, and it constitutes a major tension if this is not taking place inside a group. We consider this as a secondary contradiction between rules and community. As previously explained, the major rule to consider in the student FC activity is the necessity to arrive at the in-class session being 'primed' by the out-of-class session. If a major part of the group has failed to do this, the in-class discourse, considered a CHAT instrument, is hampered. Thus, this contradiction could also be seen as a secondary contradiction between rules and instrument.

Considering the data excerpts, we can also mention the tensions below, even though not substantiated through triangulation as the one already mentioned:

1. Tension in expectations/beliefs/rules: Students expect to be "taught" by the teacher, but FC rules and division of labour directs students towards learning through collaboration with peers (subject – division of labour tension), (secondary contradiction).
2. Students disagree with the new rule that tasks should be solved during class time. Preference towards solving them in solitude (object – rules tension, students feel this is not the best way to learn math), (secondary contradiction).
3. Students need to adopt to a new paradigm of work: Preparation through video lessons requires discipline, which results in tension, especially when a heavy workload is expected in courses taken in parallel (subject – rules tension), (tertiary contradiction).
4. Fluency in discourse. Problems expressing the mathematical problems verbally to other students. (subject – instrument (discourse) tension), (tertiary contradiction).
5. Students failing to keep up with the others during group-work (subject – community tension), (secondary contradiction).

As we discussed earlier on, in the filmed classroom episode with Silvia and Nick there is indication that students who have prepared by engaging in the out-of-class work seem to express themselves fluently in the mathematical problems, and in addition seem eager to learn more about the concepts behind the procedural mathematics shown in the videos. This provides empirical evidence (though only a single case) of the potential of FC to motivate students to strive towards a higher level of abstraction.

Validity and reliability issues

This paper must be viewed in the context of a report on a pilot study. More elaborate studies will be carried out during 2016/2017 and 2017/2018 with engineering students in the same institution. Thus, there is little rigid design according to how data have to be collected to obtain optimal analysis and results. Handpicked excerpts from the data material were chosen to highlight the

findings. There is also the issue of the researcher being present as the teacher, a classical objectivity dilemma found in many small-scale educational research settings. However, as we are presenting the data using several methods, both quantitatively and qualitatively, we can to some degree state that we have made valid triangulation of the findings.

Conclusion

Our analysis of the data collected in this study, shows evidence that there exist several tensions in FC; some of these could be expected from the outset, while others are surprising. Data seem to point towards various aspects of the *active learning* being the most problematic part for many students towards a FC realization. Considering the activity system of the student, a secondary contradiction or tension materializes between the rules and the community, since many students was not adhering properly to the out-of-class part of FC. This is also seen to hamper the in-class discourse, considered to be an important instrument of learning.

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