Teachers' development in a flipped classroom for applied mathematics: a use case in a transdisciplinary engineering study

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INTRODUCTION

The flipped classroom is an instruction method that has gained momentum during the last years due to technological advances allowing online sharing of teaching material and learning activities. In 2000, Lage et al. gave the following definition for this instruction model: "Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa" [1]. In 2013, Bishop and Verleger found this definition very broad and noted that it implies that the flipped classroom just represents a re-ordering of in-class and out-of-classroom activities. Therefore, they defined the flipped classroom as "…an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the

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classroom" [2]. In this paper, we use the term "flipped classroom", as defined by Bishop and Verleger. In the methods section, we provide more information about our own implementation of this instructional model.

This paper presents findings on teacher development during a three-year implementation of an applied mathematics flipped classroom in a transdisciplinary engineering study [3, 4] [references removed for review]. Our experience has shown that teachers were forced to reflect more thoroughly on their own teaching even before the event of teaching, because the design of a flipped classroom requires careful consideration of the course structure and content. Moreover, teachers reflected on each flipped session (out-of-class, in-class) and they adjusted the next one throughout the semester, and after the end of the semester they reflected on this experience as a whole. These reflections promoted the redesign of their flipped classroom approach for the next year.

1 BACKGROUND

So far, research on flipped classroom has mostly concentrated on student perceptions, engagement and achievement level, e.g. [5-7]. Few studies have focused on teacher perceptions and development in flipped classrooms. Hao and Lee [8] investigated pre-service teacher concerns about teaching in flipped classrooms. They surveyed more than 470 pre-service teachers and they related their answers to differences in self-efficacy for teaching, teacher knowledge, and other demographics. Their results indicated that pre-service teachers had mostly self-concerns and they found that self-efficacy and non-technological teacher knowledge were associated with most stages of concern. Moreover, females had more awareness and management concerns, while seniors had the highest awareness for flipped classrooms. Non-science pre-service teachers had more information, personal, and collaboration concerns. They concluded that teacher education programs should equip pre-service teachers with skills for teaching effectively in such classrooms.

Wanner and Palmer [9] conducted a study on a flipped university course, which also included flexible assessment components. They collected 47 responses form a teacher survey on flexible and flipped learning and they also conducted interviews with teachers. Although there were strong series of neutral responses, teachers overall believed that flipped classrooms required greater amounts of work. Moreover, approximately half of all teachers indicated that they had a low level of commitment to the flipped classroom but felt under high levels of pressure to include them in their courses. Some teachers had done flipped classroom "by default" and others were currently "experimenting" with it as they were currently providing a blended learning environment through some online content. Many were open to flipping their classroom in a context of budget constraints and more time demands for teachers. Finally, there was a consensus that there need to be clear guidelines about course structure and assessment.

Muir and Geiger [10] have also contributed to the limited research on teacher perceptions of the flipped classroom. They investigated a mathematics teacher's and his students' perceptions of the affordances of a flipped classroom to meet challenges associated with mathematics teaching, such as cover the prescribed curriculum, help students learn difficult concepts, prepare students for future studies, and incorporate digital technologies. They reported that the teacher's desire to implement a flipped classroom approach to his teaching was initially made possible due to the robust technological infrastructure in the school. However, the real impact

on his students' engagement and motivation was a consequence of the resources he developed to support his students' learning. The teacher also reported that although preparation of video resources was time consuming, this was a positive experience.

In the following section, we report our experiences regarding teacher reflection and development in flipped classrooms.

2 THEORETICAL FRAMEWORK

In the literature, there have been used various theoretical frameworks to justify the flipped classroom and support the design of in- and out-of-class activities. Such theoretical frameworks typically argue for the benefits of student-centered and collaborative learning (e.g. active learning, problem-based learning, and peer-assisted learning) [2].

Throughout our research, we are inspired and guided by the Problem-Based Learning (PBL) pedagogy, which is applied at Aalborg University since its establishment in 1974 [11]. PBL is a student-centered instructional approach, in which learning begins with a problem to be solved. Students need to acquire new knowledge in order to solve the problem and therefore they learn both problem-solving skills and domain knowledge. The goals of PBL are to help the students "…develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation." [12].

At Aalborg University, PBL is also combined with group work [13]. While working in groups, students try to resolve the problem by defining what they need to know and how they will acquire this knowledge. Additionally, PBL represents a paradigm shift from the traditional one way instructional methods. In PBL, the teacher is not an instructor but rather a tutor, who guides, supports, and facilitates the learning process. The tutor has to encourage the students and increasing their understanding during the problem-solving process. Therefore, the PBL teacher facilitates and challenges the learning process rather than strictly transmitting domain knowledge.

Therefore, the flipped classroom that employs computer-based individual instruction outside the classroom and devotes classroom time to group activities with the teacher as facilitator is well justified by the aforementioned principles of PBL. The goal of a flipped classroom is to let the student study individually at her own pace while providing the appropriate support material for out-of-classroom instruction and then come into class, where groups of students engage in group activities facilitated by the teacher. Since our previous research has shown that mathematics courses at Media Technology follow mostly the one way transmission model (lectures as presentation of information) [14], we decided to introduce the flipped classroom approach in mathematics related courses for Media Technology students for aligning them with the PBL pedagogy.

3 METHODS

The empirical considerations in this paper are based on three studies that we conducted during three semesters at Aalborg University Copenhagen. For these studies, we introduced the flipped instructional model during three consecutive semesters at the Media Technology department. In the first semester, we introduced a flipped classroom approach for a part of a statistics course [15], while in the second semester we used this approach for a workshop on mathematics related to computer graphics rendering [16]. During the third semester, we applied the flipped classroom approach to a statistics course during a whole semester [3].

3.1 Course design

Our own flipped classroom design was guided by the PBL pedagogy, which Aalborg University applies since its establishment in 1974 [11]. PBL is a student-centred instructional approach, in which learning begins with a problem to be solved [12]. PBL is well aligned with the aim and structure of a flipped classroom and has affected our decision to integrate the flipped classroom in educational practice. Moreover, PBL has guided decisions regarding the content of activities and the materials used and also the setting for learning activities.

In all semesters, the learning process generally followed the same sequence. Prior to class, students were expected to watch the related video lessons/pencasts and read the external web resources. In the second and third semester, students were also provided with practice problems. During class, a question round took place, in order to clarify aspects that students found challenging. Then, students were provided in-class assignments to reflect on, discuss, and practice what they had learned. The classroom activity was mainly not teacher led; instead, students in groups worked on the assignments while the instructor provided individual guidance as needed. The in-class activities were structured so as to provide students with a variation of the tasks they completed when watching the video, providing opportunity for both practice and transfer of learning to new situations. Students were required to upload their in-class activities after class, in order for the teachers to check their progress.

Regarding assessment, we made diagnostic tests in Moodle and in-class activities part of the student assessment. The format of the final exam for the course involved a small scale project, where students had to answer questions on specific course topics and argue for the statistical methods to be employed for the experiments of their semester projects. This exam format is imposed by study regulations and was the same in the years prior our flipped classroom implementations.

Our flipped classroom design was facilitated by the Moodle VLE. Before each in-class section, we provided students with the opportunity to send feedback to the teacher by using the “feedback” module in Moodle. Moreover, we were able to observe student activity and interaction with the provided resources by using reports in Moodle. For more information on the implementation in Moodle, the reader is referred to [17].

3.2 Online resources

To facilitate the flipped classroom instructional approach, we provided students with online resources for out of classroom instruction.

In the first semester, we created our own screencasts (recordings of the computer screen output, while the teacher solves an exercise). These screencasts were combined with selected sections of the www.mathisfun.com webpage, readings from the www.betterexplained.com webpage, and scanned lecture notes from students’ past mathematics course covering the relevant subjects. The online resources were chosen with the criterion to provide straightforward and intuitive explanations. In-class assignments were provided along with each lesson.

In the second semester, we substituted our screencasts with selected Khan Academy screencasts and related practice problems (https://www.khanacademy.org/), because our experience revealed that creating quality screencasts is time consuming and hard. Students were required to choose at least one of the proposed resources for studying before lectures and then answer

some short exercises. We estimated that going through any of the provided resources would not take more than one hour and a half to complete.

In the third semester, we created video recordings with the teachers of the course and a list with online resources about the topic of each class. Before classes, students had to study this material and also read suggested parts of the course book. Moreover, students had to submit their answers either to multiple choice questions or to short exercises before attending each class. The questions and exercises covered the preparation material. We used these assignments in order to observe student understanding, misconceptions and common mistakes, and in order to motivate students to do their preparation.

3.3 Evaluation

During all semesters, we conducted studies for investigating student perceptions and behaviours, which have been described elsewhere [3, 15, 16]. One of the authors of this paper has designed and taught the first two flipped classroom implementations and another one has taught the flipped statistics course together with another faculty. The third author contributed together with the other authors to the design of the evaluation and observed the whole process. After each implementation, the involved teachers were interviewed on their experiences with and reflections on the flipped classroom. To analyse the teachers' experiences, we have used Cowan's reflection loops [18] together with the Learning Design Teaching Cycle [19] as a general model for teacher reflections (*Fig. 1*). The Teaching Cycle describes teacher reflection before (design), during and after (evaluation) a flipped course execution. In this Teaching Cycle, reflection is not a separate stage in the Cycle but it is present in all stages of the Cycle like a vertical dimension (before (reflection for), during (reflection in), and after (reflection on)). The Professional Development stage becomes the horizontal dimension, which evolves together and because of the reflection loops [20].

In the following, we discuss teachers' development in the flipped instruction model using as a framework the aforementioned Teaching Cycle with reflection loops.

4 RESULTS

The teacher interviews were conducted in a semi-structured way and employed questions on time requirements of the new approach, experiences and considerations on preparing the online material and the in-class activities, the perceived effect on student communication with the teacher, and plans and suggestions for the next year. A detailed description of teacher responses is given elsewhere [21]. In the following, we analyze teacher responses and our own observations regarding teacher reflection and development using the Teaching Cycle presented in the previous section (*Fig. 1*).

4.1 Reflection-for-teaching

The re-organization of the out-of-class and in-class activities in the flipped classroom required teachers to carefully consider which part of each lecture should be on video and what kind of out-of-class and in-class activities made sense for each lecture. Such considerations provoked teacher reflection on their own practice since they had to go through their material for the course and decide which parts can be used in the flipped version of the course and which parts have to be replaced by new material.

When reviewing existing teaching material and producing new material, the teachers had to reconsider the learning objectives of each activity in the course and of the course as a whole module. These considerations helped them to produce short and

precise videos and meaningful practice problems in order for students to check their understanding during out-of-classroom instruction. Moreover, the teachers had to develop in-class activities that would provoke discussion and collaboration in the new class setup and adjust their teaching to this direction.

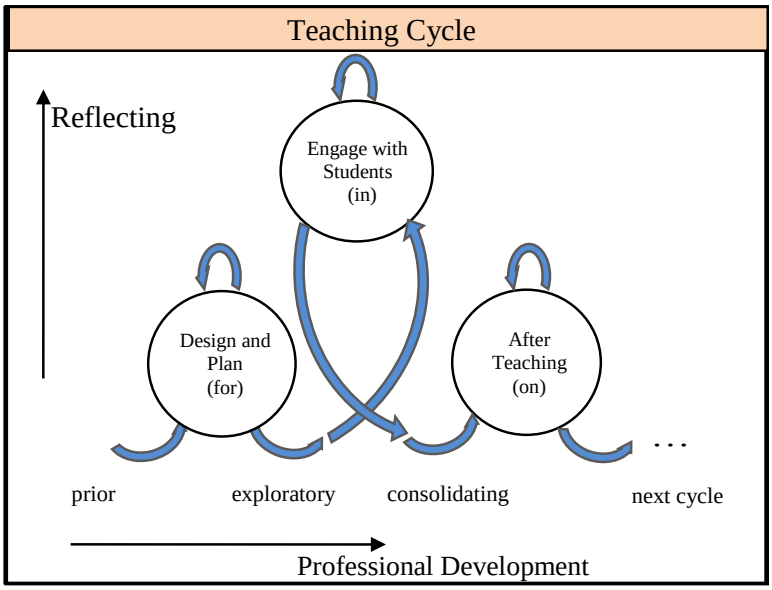

Fig. 1. The Learning Design Teaching Cycle adapted to Cowan's reflection loops model

Another aspect that promoted teacher reflection during the design of the flipped course is the production of video lectures. The teachers reported that they got valuable feedback on their own style of teaching, which they were able to improve during the loop video capture – watching – improving – recapture. Since the video lectures were accompanied by presentation slides, the teachers had also to adjust their existing presentation slides to the content of the video.

Finally, the teachers reported that the process of "flipping" the existing order of lecturing revealed the need for a pedagogical approach to support such processes. We have indeed observed that teachers conducted their own research on this new instruction model in order to develop a pedagogical framework to support their teaching according to this model.

4.2 Reflection-in-action

Regarding teacher reflection while engaging with students, the teachers reported that they got continuous feedback from the students on their learning outcome and progression during the class. Therefore, they were able to reflect on and adjust their own teaching during class time by giving alternative explanations and/or by provoking discussions on an individual/group/class level. Student feedback enabled also the teachers to get insight on student misconceptions. They were thus able to come up with activities or questions to challenge such misconceptions.

In general, teachers believed that the flipped classroom significantly improved the teacher-student communication, which promoted teacher reflection during instruction. The more "loose" environment of the flipped classroom provided teachers with time to adjust and immediately apply their instruction plan.

4.3 Reflection-on-action

After each class session, the teachers reported that they often adjusted the online material in Moodle in order to add explanations or resources related to points that were reported as unclear/difficult by several students during class. This process provoked reflections–on-action, where the teachers identified and defined any development which might (or might not) have taken place in the action completed. Moreover, we observed that teachers reflected by the completion of the whole "flipped" course by identifying material, activities and actions that yielded positive results and others that needed to be improved during the redesign of their flipped classroom approach for the next year.

4.4 Micro-reflections

In the previous, we have discussed the reflection taking place before, during and after the action. However, Cowan noted that apart from these planned and joint "grand" reflections, incidental and personal "small" reflections also take place during exploration and consolidation [18]. Our observations and teacher responses described in the previous sections presented such "small" reflections. For instance, teachers reflect during course design but also later during exploration while implementing this design (material preparation). The same applies for the consolidating phase, where teachers adjusted the material for the section that had just taken place. We call such kind of reflections "micro-reflections" and we propose the use of Cowan's modified reflection diagram [18], which includes a lot of smaller reflection coils between the major reflection loops (*Fig. 2*).

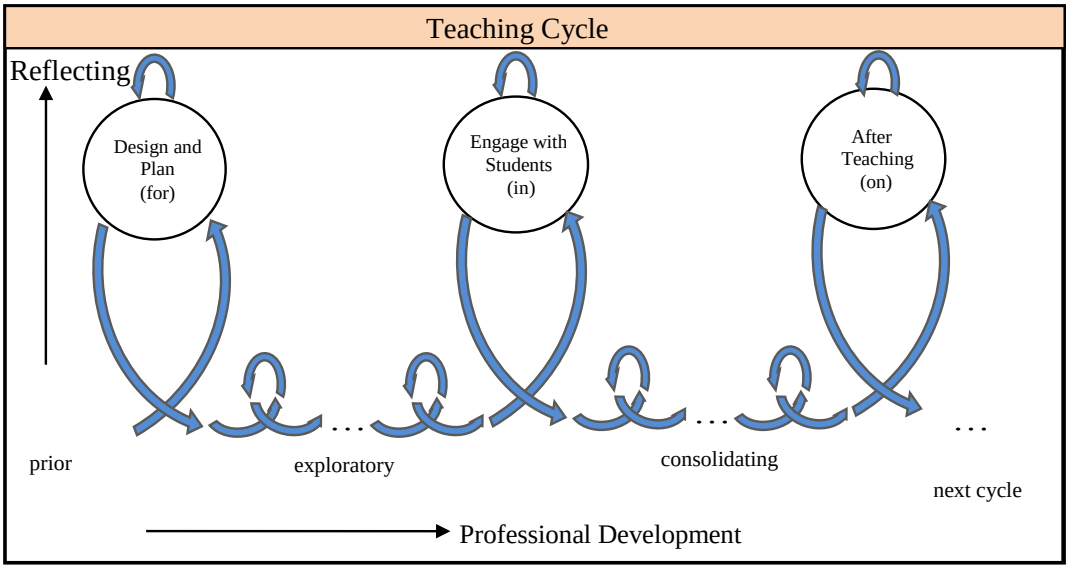

Fig. 2. The Learning Design Teaching Cycle including Cowan's micro- and macro-reflection loops

5 DISCUSSION AND CONCLUSION

In this paper, we discussed how the flipped classroom approach promoted teacher reflection and development. We looked at the teaching cycle from a flipped instruction model perspective and we adjusted it to cater for the reflection loops teachers are involved when designing, implementing and re-designing a flipped classroom. Interview and observational data showed that the flipped classroom design and implementation forced the teachers to reflect on their own practice, and reconsider the learning objectives of specific activities and the course in general.

Another aspect that promotes teacher reflection was the production of video lectures. The teachers reported that they got valuable feedback on their own style of teaching, which they were able to improve during the loop video capture – watching – improving – recapture. Moreover, they got insight on student problems and misconceptions, so they reflected on each flipped session (out-of-class, in-class) and adjusted the next one throughout the semester. At the end of the semester they reflected on this experience as a whole. These reflections promoted the redesign of their flipped classroom approach for the next year.

In this paper, we proposed the use of the Cowan's modified reflection model in order to include incidental and "small" reflections that take place between the planned reflections (reflection-for, -in, and -on action) and we exemplified all types of reflections by using interview and observational data. We believe that this reflection model may be employed not only to observe teacher development in flipped classrooms, but also to guide teachers throughout design and implementation of such classrooms.

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