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Flipped Classroom Model and Its Implementation in a Computer Programming Course

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Abstract – The flipped classroom approach provides implementation of a student-centered learning environment. By changing the traditional classroom lectures and homework elements of a course, it facilitates active learning and higher-order understanding. This paper presents initial experiments on a flipped classroom approach and its application in a programming course. The course results and evaluation show that this approach is rewarding, and why it deserves further investigation.

Keyword: flipped classroom, active learning, constructive alignment, computer science

1. Introduction

In computer science and computer engineering programs, introductory programming courses are fundamental. Programming courses are thought to be among the most difficult courses, and we have experienced challenges with poor programming skills among our students. In April, we started a new course "DT130A Programming in C" for the computer engineering program. We wanted to explore some new learning models for the course, and chose the flipped classroom approach (the Flipped Learning Network).

The flipped classroom model is a relatively new approach to teaching and learning. It has become very popular in all grades of education. This paper presents our initial results on the partial implementation of the flipped classroom model. The rest of the paper is organized as follows. In Section 2, active learning, Cone of Experience, as well as the flipped classroom approach are discussed. In Section 3, the problems with programming courses are presented, including various difficulties and challenges. In Section 4, the course design and implementation based on the constructive alignment and flipped classroom approach are presented. The results show that the flipped classroom approach is well accepted among the students and the course failure rate is lower than traditional programming courses. In Section 5, conclusions and discussion.

2. Active Learning and Flipped Classroom Approach

2.1 Active Learning

Active Learning is anything the students learn, apart from passively listening to an instructor's lecture. Active learning is a process in which students engage in their learning activities, such as reading, writing, discussions, or problem solving. Different learning activities lead to different learning effects. An old Chinese proverb, originally from Confucius's saying, is often used in the discussion on learning activities and their corresponding effects.

"I hear and I forget;

I read and I remember;

I do and I understand".

With active learning, students become more engaged in their learning process, and it results in deeper learning via high-order learning activities. Based on a large-scale comparison of science teaching methods, Freeman et al. (2014) showed that active learning increases student performances in science, engineering and mathematics.

2.2 Learning Activities and Cone of Experience

In his book on audio-visual methods in teaching, Edgar Dale introduced the Cone of Experience. He says that learners retain more knowledge by what they "do" as opposed to what is "heard", "read" or "observed" (Dale 1946). The Cone of Experience is a visual model for various types of mediated learning experiences. The Cone of Experience has been modified since then, and has been adopted by many instructors and researchers to design instructions and research on instruction methods. Figure 1 shows the Cone of Experience adapted from Edgar Dale (Study Guides and Strategies). It is said that people remember:

- 10% of what they read
- 20% of what they hear
- 30% of what they see
- 50% of what they see and hear
- 70% of what they write and say
- 90% of what they say as they do

It should be noted that the Cone of Experience is essentially a visual metaphor around learning activities. The learning activities can be placed in broad categories, and should not be used to advocate the selection of certain media and methods over others. The numbers given in the Cone of Experience should not be looked on as definite or with scientific verification. It only says that more active learning activities lead to higher order understanding, and thus people remember more.

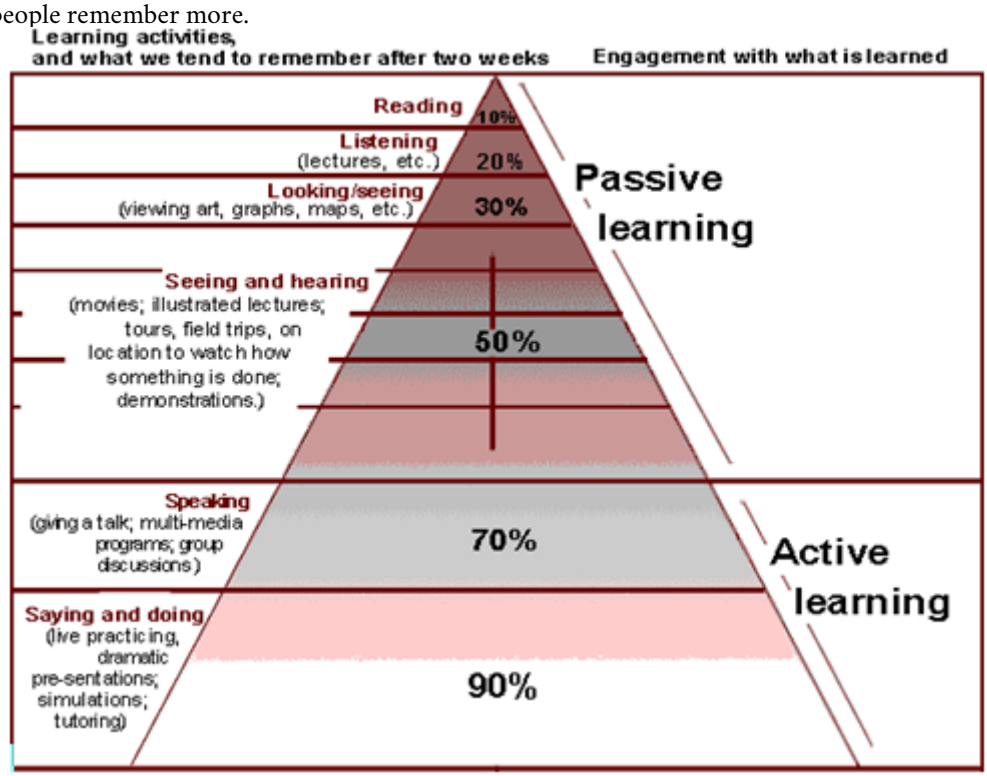

Figure 1 - *Cone of Experience, adapted from Edgar Dale.*

2.3 Flipped Classroom Approach

The term flipped classroom has been widely used to describe a new pedagogical model, in which the traditional lecture and homework elements of a course are flipped. In this approach, the students view the short video lectures at home before the class session, while during the class time, the students apply the knowledge by doing the exercises, projects or participating in discussions. This approach frees up class time that can be used for other activities e.g. practical work. Students learn by doing, which promotes active learning, and engagement in learning. It facilitates student-centered teaching and learning, and students get instant help during class time. There is a formal definition for the flipped classroom approach. It is called flipped learning by the Flipped Learning Network:

> Flipped Learning is defined as "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter." (FLN, 2014). By moving from a flipped class to actively engaging in Flipped Learning, teachers are able to implement new or various methodologies into their classrooms. It frees up class time, allowing for more individual and small group instruction.

The Flipped Learning Network also defined 4 pillars of FLIP and 11 indicators for educators to use as a self-assessment or guide in the implementation.

Figure 2 - *Four pillars of FLIP by the Flipped Learning Network.*

- **Flexible Environment**: Flipped learning implements flexible environments via a variety of learning modes. 3 indicators on flexible environment are:
- 1) I establish spaces and time frames that permit students to interact and reflect on their learning as needed.
- 2) I continually observe and monitor students to make adjustments as appropriate.
- 3) I provide students with different ways to learn content and demonstrate mastery.
- **Learning culture**: Flipped learning shifts instructions from a teacher-centered to learning-centered approach and allows the students to be actively involved in the knowledge construction via meaningful activities. There are 2 indicators in the learning culture:
- 4) I give students opportunities to engage in meaningful activities without the teacher being central.
- 5) I scaffold these activities and make them accessible to all students through differentiation and feedback.
- **Intentional content**: Educators use Intentional Content to maximize classroom time in order to adopt methods of student-centered, active learning strategies. There are 3 indicators about intentional content:
- 6) I prioritize concepts used in direct instruction for learners to access on their own.

- 7) I create and/or curate relevant content (typically videos) for my students.
- 8) I differentiate to make content accessible and relevant to all students.
- **Professional educator**: The role of an educator is even more important, and often more demanding in the flipped learning approach. A professional educator should enable flipped learning to occur. There are 3 indicators about this:
- 9) I make myself available to all students for individual, small group, and class feedback in real time as needed.
- 10) I conduct ongoing formative assessments during class time through observation and by recording data to inform future instruction.
- 11) I collaborate and reflect with other educators and take responsibility for transforming my practice.

The Flipped Learning Network (FLN) and Sophia Learning conducted a joint survey, "Growth in Flipped Learning: Transitioning the focus from teachers to students for educational success,", in February 2014. The term "Flipped Learning" was recognized by 96% of teachers, an increase from 74% two years prior when a similar study was conducted. The number of teachers who indicated they had flipped a lesson during the school year increased from 48% in 2012 to 78% in 2014. Of the teachers who do flip, 96% say they would recommend it to a colleague.

2.4 Flipped Classroom in Higher Education

More and more instructors in higher education have started incorporating elements of the flipped learning model into their classes. Some well-known universities like Harvard University, Stanford Medical School, Michigan State University, University of British Columbia, University of Southern California, Georgia Institute of Technology have implemented the flipped classroom approach in some courses (the Flipped Learning Network, Kim et al. 2014, Bishop & Verleger 2013). Flipped Learning Network is a professional learning community for educators. In January 2012, there were about 2500 members. Now there are 21,344 members and 131 groups. Flip Research on Higher Education group has 92 members, while College-Level Flippers group has 180 members (read on 2014.07.31). A recent online survey conducted by Flipped Learning Network and Sophia Learning showed that 80% of flippers were taught in secondary schools and 27% were in higher education (some of them were both in higher education and secondary schools).

Based on 22 articles on flipped learning in a higher education setting, a set of motivating factors for flipped learning were found (the Flipped Learning Network):

Table 1 - *Motivating factors for flipped learning*

Goal	Importance
Improve students' critical thinking/creative problem solving/ higher-order thinking/21st century/professional skills	1
Increase student participation, engagement, and motivation	2
Improve students' team-based skills and peer-to-peer interaction	3
Customize/differentiate learning	4
Make students the center of learning/encourage student ownership of learning	5
Better faculty to student interaction	6
Increase faculty freedom/enjoyment	6
Improve learning outcomes	6
Dealing with absences	7
Encourage faculty collaboration	7
Compensate for limited classroom space	7

3. Problems with Programming Courses

3.1 Introductory Programming Courses

Introductory programming courses are part of Computer Science and Computer Engineering curricula. Programs generally offer several programming courses consisting of fundamentals of programming, object-oriented programming (usually Java). The introductory programming courses are difficult for the new students. Some common challenges for instructors and problems with the students include:

- Wide variation in the students' background and knowledge
- Most students find programming to be a difficult task
- Most students do not have knowledge on problem-solving and logic thinking
- It is difficult to balance between time for teaching the language syntax and for problem-solving
- Many abstract terms in programming (e.g. variables, memory address etc.) do not have equivalents in real-life
- If the program contains even one single syntactical error, it will not run
- Many students do not have enough motivation to learn programming, as the programming profession is considered boring
- Students are not engaged and they take the surface approach of learning.

3.2 Common Problems and Interventions

Programming is a very useful skill and it is fundamental in a computer science and engineering education. Many students say it is difficult to develop computer programs even after they have completed several programming-related courses. When encountering problems and difficulties, the students may lose the motivation and enthusiasm for programming. If students are not motivated, they will not learn (actively), and subsequently they will not succeed. Therefore the dropout and failure rate is high in the introductory programming courses.

In a traditional teaching setting, the students are assigned to read textbooks, come to the lectures to listen to the instructors, and work on homework after the lectures. This is a typical teacher-centered approach of teaching and learning, which leads to the passive learning style, and students are not well engaged in their learning. It is common to have a failure rate of about 50% for a programming course.

As it was shown that active learning increases the learning performance (Freeman et al. 2014, Stone 2012), and as the flipped classroom implements an active learning environment, we decided to introduce the flipped classroom approach in the DT130A Programming in C course, in order to face the challenge and to improve the learning outcomes.

4. Experiment with Flipped Classroom Approach

4.1 About the Course and Students

"DT103A Programming in C" is a campus course in the computer engineering program. It is placed in the last study period in the first year of the program. Although the course does not need any prerequisites, the students have had the courses "Fundamental Programming 7.5hp" and "Object-Oriented Programming 7.5hp". There were about 20 active students from Sweden and other countries taking this course. At the start of the course, a programming knowledge test was taken to learn about their fundamental knowledge in programming. The test results were used to design the course delivery. Figure 3 shows the results of the test. The individual question reports can be used to assess problems among the students and avoid un-necessary repetition.

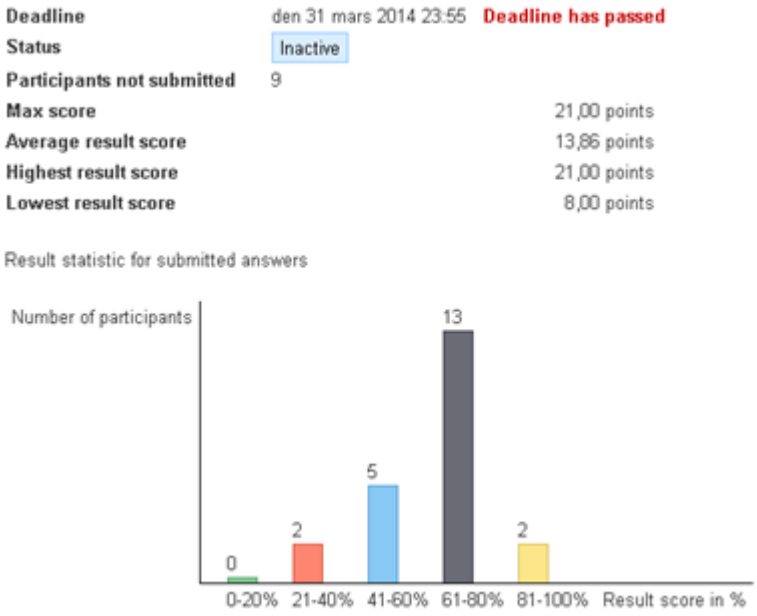

Figure 3 – *Programming Knowledge Test Report.*

4.2 Course Design

Since 2014.01.01, all campus courses at Kristianstad University (HKr) can be hosted on the learning platform "It's Learning". With this platform, many useful functions like discussion forum, online test, chat, messaging, etc., can be used to improve the social, teaching and cognitive presence. The constructive alignment is used to design the course (Biggs 2007). Formative assessments are implemented to provide instant feedback and guidance for improving the learning outcomes (Elmgren & Henriksson 2013). The flipped classroom approach is applied to implement the active learning and student-centered teaching/learning environment.

The course is divided into 8 units. For each unit, we provide a document that states the intended learning outcomes for the unit, aligned activities, and guiding review questions. Since the flipped classroom approach is used: short video clips together with the listed textbook pages are provided for the students to learn outside of the classroom, at their own pace, time and place. In this way, the passive learning activities are placed outside the class. Within the

classroom: lecture and tutorial, practice and exercise, pre-lab and laboratory are provided to discuss difficult concepts, and allow students to learn by doing. In this way, more time for interaction and discussion are achieved. Each unit has an online test as the formative assessment. Based on Cone of Experience and constructive alignment, following activities are implemented in the course:

- **Lecture and tutorials**– Various programming concepts and techniques will be introduced, explained, and demonstrated with examples. Since it is shown that it is difficult to keep a high concentration level after about 20 minutes, it is a good idea to combine lectures with other activities.
- **Reading and self-study**— Students should read materials from the textbook and watch videos outside the class, before the exercises and laboratory work.
- **Practices/exercises**—Practices/exercises are designed to enable students to practice more on the theory covered in the lecture. Group discussion and team work will be implemented to enable active learning.
- **Pre-labs**— Designed for the students to go over related concepts from the lecture, discuss and understand the tasks to be solved in the lab, as well as design test cases.
- **Laboratory work**—laboratory work are more challenging tasks compared with practice/exercise. They follow the pre-lab activities. They are designed to enable the students to put theory into practice and become proficient in C programming language. The laboratory work consists of programming tasks. The students need to analyze the requirements, develop algorithms to solve the problems, and implement them in computer language C, by applying (and combining) various techniques learnt from lectures and exercises. The students need to write a report to explain their ideas/algorithms using suitable presentation methods (flowchart or pseudo-code), as well as observe the program output for the designed test cases in pre-lab to test if the solution is correct. Oral presentation is required, and instant oral feedback/comments will be given to students on their work.
- **Quizzes**—the quizzes assess the students' achievements at various stages during the course. It provides formative assessment on their learning progress.

4.3 Example Module and Implementation

We take the first module in the course DT130A as an example. It is important for the students to know the expected learning outcomes for the module, and what activities are planned for this part of the course. A document containing intended learning outcomes and planning is available. It serves as the guidance in their learning. The intended learning outcomes for this module is as follows:

At the end of this course module, the students should be able to

- Identify the **structure** of a C program.
- Explain the **variables,** choose the right data type and explain the operations of the operators.
- Explain **identifiers** in C and analyze if a name is a valid identifier.

The course module is implemented according to the flipped classroom approach. Short video clips with up to 15 minutes have been produced. iSpring Free is used for producing video clips based on PPT slides; Camtasia for more advanced video clips (with quiz questions), and Screencast-o-matic for producing video clips to show practical operations. The students are informed that they are supposed to spend about 6 hours for preparation and other off class activities in their learning process. An online quiz is designed to assess their learning outcomes. For quiz questions, some necessary feedback is provided (for each question, suggestions on which pages in the textbooks to read are provided.) In the exercise session, we start with the quiz questions, check the results, and discuss the confusions and problems.

For each laboratory work, there is a pre-lab session, and we implement group discussions on the main task in the

laboratory. After the discussion, the students should design and implement their own methods and solutions. When they complete, each one should do an oral presentation for the instructor. During the presentation, the instructor will give instant oral feedback on the designs and solutions. The students can then use the feedback to write the laboratory report and submit it for grading.

Figure 4 shows the design/implementation for Module 1 Basic C and Lab 1.

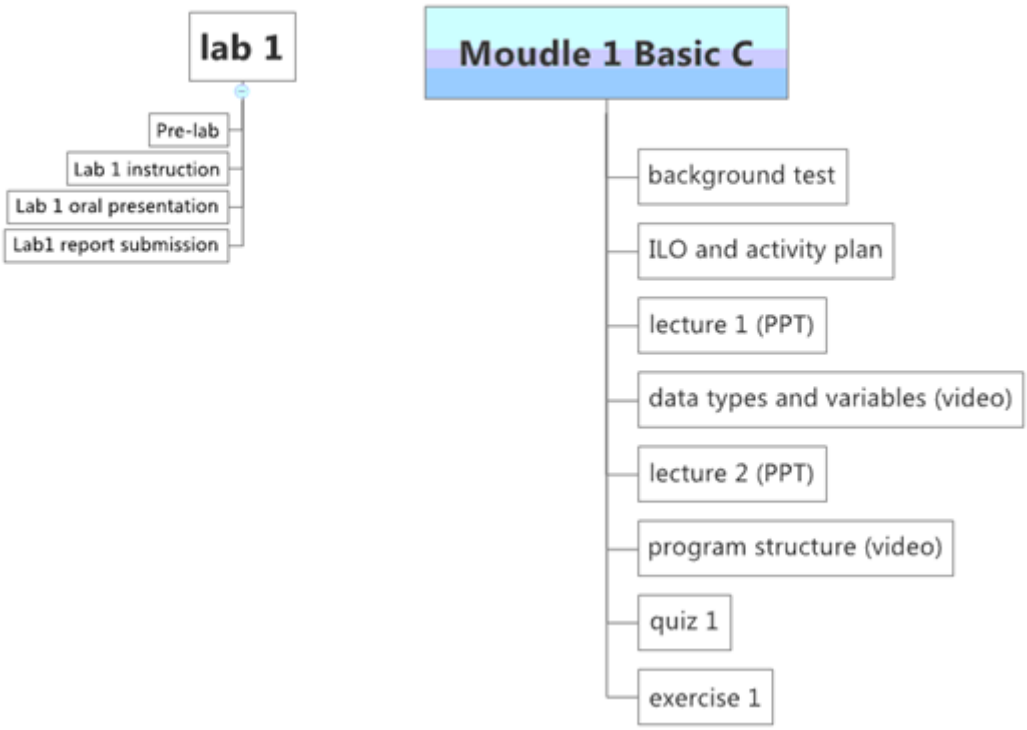

Figure 4 – *Module 1 Basic C and Lab 1.*

4.4 Examination and Evaluation

Examination and evaluation can be formative or summative. It is common to have only one final written examination in an engineering course. The problem with such a summative examination is that students are not active at the beginning of the course, and feel stressed at the end of the course. So in this course, we have provided 6 online quizzes to serve as formative assessments. The quiz questions include feedback on which pages or sections the students can read to improving their understanding. The results are mainly used as feedback. This formative assessment follows the concept of the flipped classroom approach, and allows us to continually observe and monitor students to make adjustments as appropriate.

At HKr, it is mandatory to have a final course evaluation when the course is completed, i.e. it is summative. The problem with such a summative evaluation is that students are not engaged in completing the evaluation, since the result will not directly affect their own study. So in this course, a mid-way (3-week) simple course evaluation is introduced to collect feedback from the students. In this way, we integrate the formative assessments and evaluation into the learning process to make students active and engaged in the learning process. Figure 5 shows the result of one question in the evaluation.

Answer the following questions:

	too low (för låg)	reasonable (lagom)	too high (för högt)
course level has been (nivån har varit)	7,1%	78,6%	14,3%
pace has been (tempot har varit)	7,1%	78,6%	14,3%
my own activities have been (min egen aktivitet har varit)	28,6%	71,4%	0%

Figure 5 - *Mid-way course evaluation.*

4.5 Course Results

It is common to have about 50-60% passing rate in programming courses. There were 20 students taking the examination in this course, and 30% of them failed. The examination results were as follows:

Table 2 - *Examination results.*

Grade	# of students	In percentage
3	4	20%
4	4	20%
5	6	30%
U	6	30%

Among those who failed, 2 students were not very active during the course, and 2 students were very close to passing the course. It should also be noted that all students who actively followed the course have successfully completed the course after taking the re-examination.

4.6 Final Course Evaluation

The final course evaluation was taken under the schedule and management of the HKr course evaluation group. Since we were moving from campus Hässleholm to Kristianstad at the end of the course, the final course evaluation was not implemented, due to administrative reasons.

5. Conclusion and Discussion

5.1 Conclusion

Introductory programming courses are difficult for novice programmers and we have experienced that quite a lot of students could not program well even though they have taken several programming courses. To face the challenge and solve the problem, we introduced the flipped classroom approach in the course “DT130A Programming in C”. The implementation was based on constructive alignment and Cone of Experience. The flipped learning approach is used to promote the active learning in a student-centered learning environment. The course evaluation showed that 71% of the students liked the flipped classroom approach. The course examination results showed that 70% of students passed the course at the first examination, meaning, the passing rate is higher than traditional programming courses. After 2 re-examinations, all active students have succeeded in the course.

Our results also confirm that the flipped classroom approach increases active learning and student engagement, as well as the learning outcomes (Stone 2012, Freeman et al. 2014).

5.2 Some Feedback from the Students

In the mid-way course evaluation, we asked the students about what was good with flipped classroom teaching approach and gave some examples. Some feedbacks are listed below:

- I can't say exactly what is better with this method. But I feel like I am learning more.
- Get a good perspective on your own and then make exercises with the class together. I think this is actually better because you learn faster.
- The demand on that you have to do some homework before you attend the lecture have been a good help, it means that you are forced to do your homework. I feel that the focus on doing more practical exercises in the lectures have been very educational.
- It will help us to study more by our own
- I like to learn things with exercises right after. I have a very bad short memory. I want to say that I forgot fast what is been told in the class room after some minutes and it would be good to have exercises together with each lesson.
- Approach ensures adequate preparation before classes. The problem is how many student can understand a topic independently. Students are also ashamed of being the one who doesn't understand a simply topic. So everybody plays the smart guy.
- Att man får testa själv och har någon att fråga om man inte förstår.
- You need to think for yourselves which is vital for learning to program. If you just sit and listen to a lecture, you won't learn very much.
- examples, trying and learning
- During the exercise sessions I learn a lot more because of the combination of the quiz and exercise, even if you don't have time to complete the exercise, you learn more because of the quiz and the walkthrough of the quiz.
- testen som vi gör hemma och sen går igenom, att vi alltid får prata med klass kamraterna om man inte förstår så man kan diskutera tillsammans.

5.3 Discussion

As "It's Learning" is used as a course platform for the campus courses, it is relatively easy to distribute the course materials in various media forms, and provide good communication and interaction between and among students as well as instructors. The online assessments can also easily be implemented . Therefore, the flipped classroom approach is a natural alternative for the instructors using a learning platform like "It's Learning".

We faced several problems during the implementations. The campus course is given in a short period of at most 10 weeks (including examination). To fully implement a flipped classroom approach, a longer period is preferred. Another problem is the learning technique. Some students are passive and need to be commanded by their instructors. For those students, introduction to the learning technique and promotion to active learning are desired.

Due to the limited time, it is not possible to completely implement the flipped classroom model in the course. But we have succeeded in reducing the number of traditional lectures and increasing the time for student-centered activities. The course evaluation gave us positive feedback, and the course examination results were good. The implementation of flipped classroom model is a process that requires time and other resources. With the gained experience, more time and resources, we can further develop and improve the teaching and learning based on the flipped learning model.

Many other instructors have also marked that traditional lectures are too passive and few students attend the lectures. They have also started to have more activities integrated into the lectures. If the flipped classroom model is introduced, active learning and better results could be achieved. We expect that the flipped classroom approach will be implemented in more courses in our department in the future.

Acknowledgement

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