On the Advantages and Disadvantages of Using a Flipped Classroom Learning Model for Teaching Higher Mathematics at Technical Universities

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Abstract

A flipped classroom learning model has recently been attracting much attention, as it increases students' involvement in the learning process and improves the interaction between the educator and students. This model uses technology to make study content more accessible, to encourage students' in-depth learning of the material, and to develop students' critical thinking. The present paper provides research on the pros and cons of using the flipped classroom model for teaching higher mathematics to engineering students at technical universities. This qualitative and quantitative research is based on the opinions of surveyed students, the teaching experience of mathematics professors and an overview of the relevant literature.

Keywords: *flipped classroom, mathematics, engineering higher education*

1. Introduction

Online tools and new technologies used in education today have been improving and changing classical teaching methods and giving rise to new teaching methods and models, in which traditional pedagogical strategies are enriched with technology to increase students' engagement and improve their learning outcomes and academic performance [1]. The flipped classroom (FC) model is one of these models which has recently become popular and widely discussed. The flipped classroom is a teaching model that flips traditional on-site lectures and at-home mastered after-lecture homework. In other words, it switches what is done on-site with what is done at home, referring to the traditional learning model. At the university level, this model means that instead of attending lectures conducted by a professor on-site in an auditorium, students are provided with video lectures, presentations and other necessary online materials, which students should master before the on-site meeting in class.

Numerous articles are dedicated to the use of the FC model for teaching different disciplines both at schools and in higher education (e.g. [1], [2], [3], [4], [5], [6], [7]). The most frequently discussed questions concern the efficiency and specificity of using the FC for teaching different study subjects, and the readiness of educators and students to use this model. The open-access publication [2] presents a systematic literature review of online FC approaches in higher education during the COVID-19 pandemic and up to the end of 2021. The authors analysed 205 publications in total and 18 in detail, covering the questions related to the main findings about the success of the implementation of online FC and recommendations for future research on the effectiveness of the FC in different courses and contexts, the cognitive and emotional aspects of student engagement, students' data protection, etc. It also points out the need to examine various aspects of the online part of the FC more comprehensively, and with more rigorous research.

A series of publications discuss the use of the FC model for teaching mathematics in higher education. In [3], the authors studied the effectiveness of the FC approach in the academic performance of students from Quezon City University in Mathematics by using the experimental research design and survey questionnaire. Students were divided into two groups: the control group (50 students) and the experimental group (50 students). Results revealed that the FC approach is highly effective and scored highly on the criteria of purpose, content, delivery, usefulness, and impact on the students' academic performance. The experimental group showed significant performance improvement compared to the control group. The FC was concluded to be an effective teaching method that enhanced students' cognitive skills, promoted students' independence, and increased students' engagement and academic performance. However, in addition to the positive aspects of the FC found in this study, there were several challenges for educators such as creating a digital divide among learning, dependence on preparation and trust, and an increase in the time in front of the computer screens instead of with people [3].

In [4], the authors conducted a meta-analysis to evaluate the effectiveness of the FC in mathematics education and to identify the factors influencing its efficacy by surveying educational databases (e.g., ERIC, ProQuest) to find all the published and unpublished studies measuring the efficiency of the FC in mathematics education between 2010 and 2017. A total of 34 studies were included in the meta-analysis, which compared the FC to a control group when implemented video lectures as an out-of-class activity requiring the student's presence in the classroom. The analysis showed that the impact of the FC was positive, although not as strong as those of other popular educational interventions, and that the success factors of the FC should be investigated in more detail. As the preliminary analysis shows, the effectiveness of the FC model is influenced by the duration of the intervention, the type of activity conducted outside of the class, the participants' language and their grade level.
In [5], the study shows that students value the FC model positively and corroborate its great potential from academic, competence, personal and social perspectives. However, some students demanded a greater presence of an educator during the educational process. A small group of students was even critical of the FC model and would prefer to keep using the traditional methodology. Thus, for the authors in [5], who conducted 266 interviews over 5 years, there is still not enough evidence of the FC model's advantages and disadvantages in the university stage. Therefore, it is important to continue analysing the impact of the FC on the learning, satisfaction and interaction of the different agents of the university community, considering the diversity of the results reported in [5]. A very recent publication [6] points out the same, that more studies should be conducted to find out the readiness of teachers and students for the FC in pre-university education in Malaysia, that further investigation of the implementation of the FC model is required to offer useful insights and the formulation of educational policies.
The FC model has many advantages. For instance, the FC model makes students free to learn at their own pace and get more time to study deeper, but it also requires that each student grasp a topic before moving on to the next one. Thus, the teaching approach shifts from a teacher-centred to a student-centred environment. Nevertheless, the FC implementation involves the great dedication of educators who select, design or create quality didactic materials before conducting every on-site session [5]. While creating educational materials, it is necessary to pay great attention to the quality and visualisation of educational materials. Visualisation in the study of mathematics materials engages students in mastering mathematics, exploring mathematical problems, understanding concepts, and performing mathematical experiments and simulations. In [8], the authors share their experience in using visualisation techniques in teaching engineering mathematics at the technical university, considering the tools GeoGebra, Mathematical Visualization Toolkit (MVT), Microsoft Project, RStudio, Java Modelling Tools (JVT). Through examples from subjects like Mathematical Analysis, Optimization, Operations Research, Numerical Methods, and Statistics, the authors demonstrate how these tools can illustrate theory and solve practical problems.
Due to the growing popularity of the FC approach in higher education and the efforts required for its implementation, it is important: (i) to study in detail the effectiveness of this approach, (ii) to identify the factors that influence its effectiveness, (iii) to verify students' readiness for independent learning in different study subjects, including mathematics. Mathematics courses for engineering students at technical universities should provide not only the main concepts of mathematics and students' basic skills but should also develop logical thinking, mathematical reasoning, the ability to justify answers and processes, as well as problem-solving skills for students to prepare them for studying further specialised disciplines and to make them competent specialists capable of professional growth and self-education. The current research aimed to investigate the attitude of students and mathematics professors of the Riga Technical University (RTU) towards the FC model implementation for teaching mathematics to engineering students at RTU, and to evaluate students' readiness to master mathematics theoretical parts independently. The opinions of the RTU students about the advantages and disadvantages of the FC model were collected from the students' survey with open-ended and closed questions.

2. Methodology

The qualitative and quantitative data were obtained from the students' survey provided for the 1st year engineering students enrolled in the course "Higher Mathematics" and for the 2nd year students enrolled in the course "Supplementary Mathematics" at Riga Technical University. The survey was conducted using Google Forms. The survey contained open-ended and closed questions. Besides, the research implies the opinions of RTU mathematics professors based on their teaching experience in different conditions: (i) face-to-face teaching in a traditional class, (ii) online teaching during the Covid-19 pandemic and (iii) blended teaching model while returning from the online teaching to on-site one after the pandemic. Additionally, the research was completed with an overview of the related literature.

3. Discussion

As mentioned above, this study aimed to investigate RTU students' readiness to study mathematics using the FC teaching model. For this purpose, the authors surveyed RTU students to find out how ready they were to independently master the theoretical parts of higher mathematics to be prepared for on-site classes and to collect students' opinions about the possibility of studying higher mathematics using the FC model. RTU mathematics educators were also interviewed to disclose their attitudes to the FC teaching model regarding teaching their current students.

Before the COVID-19 pandemic, innovative methods such as flipped classrooms and virtual classrooms for mathematics teaching looked attractive and highly promising. However, later during the COVID-19 pandemic, when students had to study mathematics materials independently and had remote tutorials, many disadvantages of these methods were revealed regarding students' academic performance and knowledge [9]. The students' problems were mostly related to their low motivation and weak self-organisation.

When interviewing the RTU mathematics educators about implementing the FC model into the mathematics study, they were mostly very sceptical, because of their teaching experience. The RTU educators were confident that some RTU students would not prepare for the on-site classes by watching pre-recorded videos and analysing theoretical materials independently before coming to on-site classes due to the lack of motivation and self-organisation among most students. Another reason for students' lack of independent study and self-preparation would be a lack of time. Many students work and do not have much free time to study mathematics materials in advance, but it is well-known that independent learning requires much more time and effort from students than just attending lectures. Due to the students' lack of self-preparation for on-site classes, an educator will be forced to repeat and briefly explain the theory that the students have not learned, which will slow down the learning process and the quality of the on-site class will be low.

In the opinions of the surveyed educators, the initially low level of mathematical knowledge of the newly enrolled first-year students is one more reason why many students will not be able to adequately prepare for on-site classes within the framework of the FC study model. Students with insufficient knowledge levels find it extremely difficult to master theoretical material independently, and in some cases, it may be even impossible for them. In RTU, during the 1st class on the higher mathematics course, the newly enrolled students have a classroom test on elementary mathematics to reveal their knowledge level. In the 2024/2025 academic year, 26 % of new students scored less than 5 out of 10. Thus, for first-year students, the FC teaching model can negatively affect the quality of their education. The surveyed educators note the great significance of both tutorials, where students solve problems under the guidance of an educator, and on-site lectures, where the professor explains the theoretical basis of the topics and shows the basic principles of solving problems, contributing to easier understanding of the material for students and allowing them to ask questions as soon as they arise if something is not clear.

The students' survey showed that students understand the importance of mathematics lectures, because 89.7% of the first-year students attended 76 % to 100 % of the lectures in the 1st semester, and only 3 % of the students attended less than 50 % of the lectures. The percentage of attendance at tutorials is approximately the same. Second-year students, as expected, are more serious about attending on-site classes, namely, all second-year students attended 50 % to 100 % of on-site lectures in the 3rd semester. The reasons for missing lectures among first-year students varied. The most frequently mentioned factors were "because of work" (9 %), "the lecture starts too early" (11,9 %) and "I prefer to study the theoretical material on my own" (11,2 %). Attendance at tutorials was significantly higher: 90.8 % of students attended 75 % to 100 % of all tutorials. Answering the question "Do on-site lectures help you learn mathematics materials?", 95,6 % of the surveyed students answered "Yes" or "Help partly" (see Fig.1).

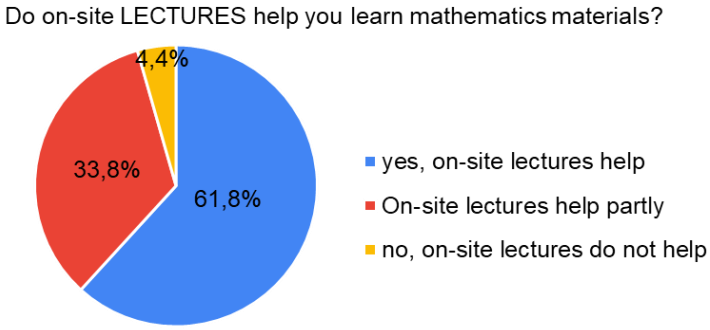

Fig. 1. Role of lectures in learning mathematics.

Fig.2 shows the students' answers to the question "How often did you study mathematics outside of on-site classes?", but Fig.3 shows how students rated (from 1 to 5) their independent work while mastering mathematics.

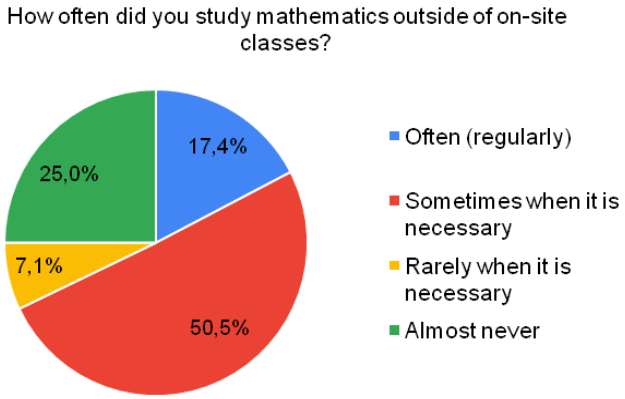

Fig. 2. Frequency of student's learning outside of mathematics classes.

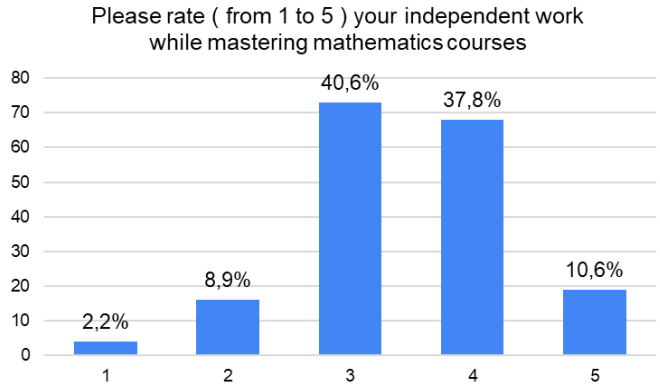

Fig. 3. Students' independent work while mastering mathematics.

The students were questioned whether they had difficulty learning mathematics independently outside of classes, using course materials, books, video lectures, etc. It should be noted that all necessary learning materials, including course materials, lecture notes, video lectures, etc are available for students on the Moodle platform. One can see from Fig.4 that only 16,6 % of the students answered that they don't have any problems with independent study. Other students responded that they sometimes find the material challenging but can manage it independently (55.8 %), and a group of the students stated that they struggle to understand the material without an educator's help (25,4 %), or the students reported that they are unprepared for independent study (2.2 %).

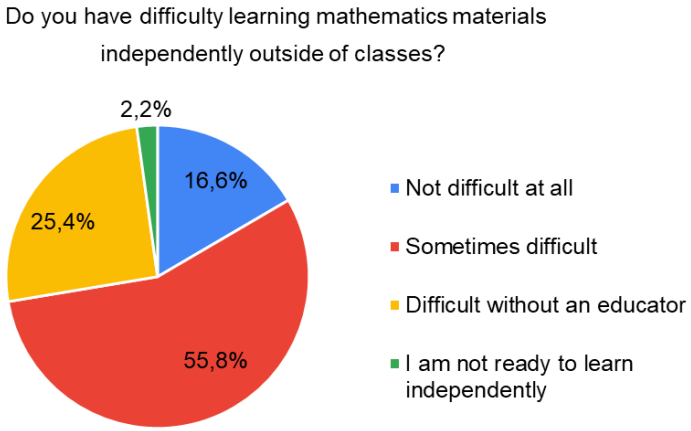

Fig. 4. Difficulty for students to learn mathematics materials independently.

In response to the question “Are you ready to devote more time to an independent study of mathematics if the number of on-site classes is reduced, provided that a sufficient amount of learning materials is available on the MOODLE platform?”, 56.7 % of first-year students answered “Yes,” while 39.4 % answered “No”, at the end of 1st semester. However, the more experienced second-year students, clearly stated that they were not ready to devote more time to an independent study of mathematics (60 %), and only 24.3 % responded that they were willing to do it. Thus, the second-year students value the help of on-site lectures more than the 1st year students in the context of assimilation of the material.
The surveyed students were also asked whether they knew about the FC teaching model. Then a detailed definition of the FC model was given. The students were questioned from the point of view of their attitudes towards this teaching method. To the question “In the case of FC, how would you organise the on-site classes with the instructor-consultant and fellow students, 81 % of all respondents answered: “Like a traditional tutorial with problem-solving under the supervision of an educator.” Other students chose the answers “I would solve homework" and "I would solve interesting problems having real-world applications together with classmates”.

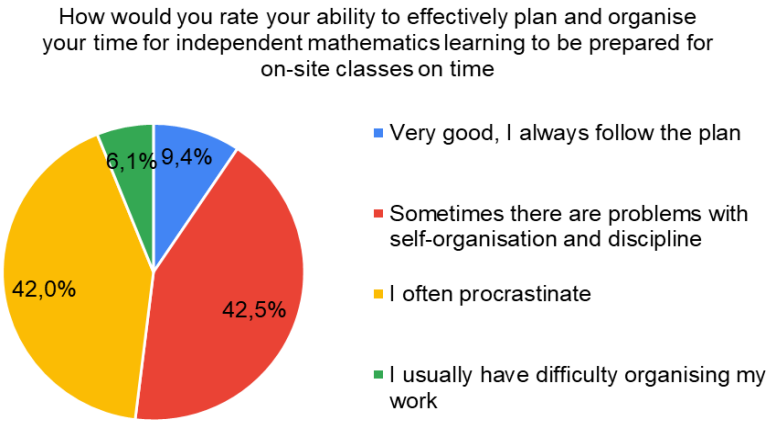

Fig. 5. Students’ skills of self-organisation and time management.

As mentioned above, the authors were interested in understanding how students evaluate their self-organisation and time management skills, as these abilities play a crucial role in learning within the FC model framework. Fig.5 shows the students’ answers to the question of how students would rate their ability to effectively plan and organise their time for independent mathematics learning to be prepared for on-site classes on time, where only 9.4 % of the students answered “Very good, I always follow the plan”, but 84,5% indicated problems with self-organisation and discipline, and that they put everything off until the last minute. Fig.6 shows that only 27,6 % of the students would not have been able to find

time to study the necessary material to be prepared for on-site classes on time if the FC model had been implemented. For other students (65,7 %), it would have been difficult for various reasons.

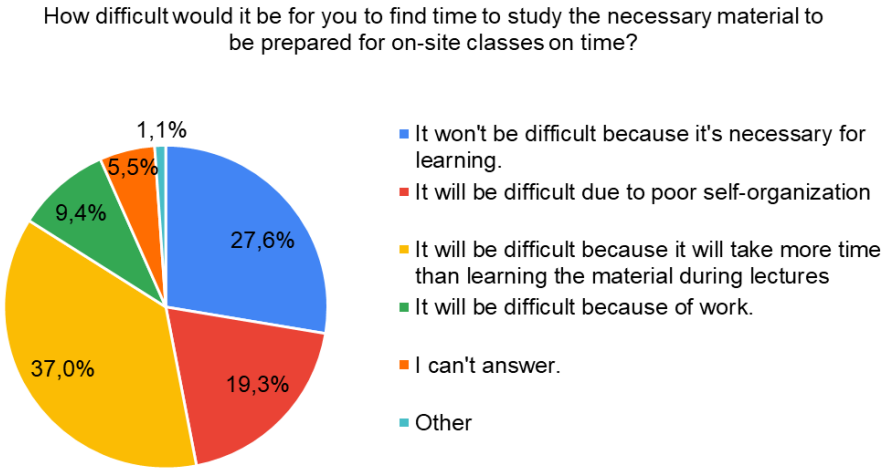

Fig.6. Students' difficulty level in finding time for independent study.

In addition to the question "What difficulties may you encounter when learning mathematics material independently?", multiple-choice answers were provided, where 60% of the students mentioned "Weak self-organisation", and 68.9 % pointed out that "Independent learning of the material takes more time". To the multiple-choice question "What would you not like about the FC learning model when studying mathematics at university?", students most often selected "It is difficult to find time to prepare for on-site classes on time", "Poor self-organisation", "It will be difficult to master independently the necessary theoretical materials", "There will be no opportunity to ask questions to the educator right away (compared to on-site lectures)". At the same time, to the multiple-choice question "What would you like about the FC teaching model when studying mathematics at a university?" students most often chose "The opportunity to master the material at your own pace" (57.8%) and "The opportunity to use your time more effectively" (42.8 %).

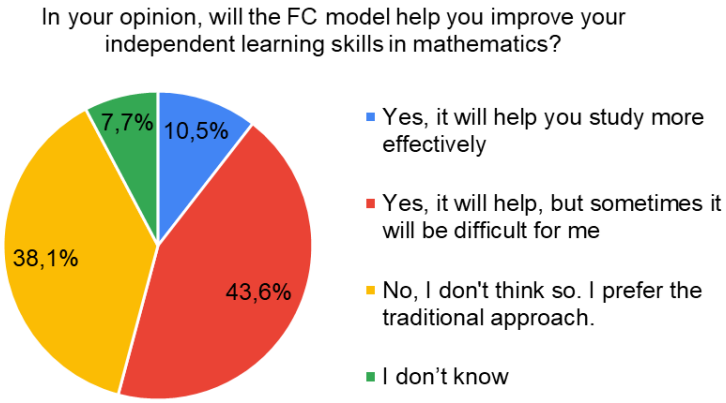

Fig.7. Improvement of student's independent learning skills in mathematics.

The authors were amazed by the number of the students' responses to the open-ended questions because usually, students are more passive in writing comments. The idea of implementing the FC model into the mathematics study at RTU seems to have touched the surveyed students deeply. About 60 % of the students expressed their opinion about the FC model in the text form and mostly sceptically. In their comments, students indicated difficulties in learning mathematics materials at home on their own due to their poor self-organisation. Let us cite some of them.

"Weak motivation and self-discipline. While at home, I feel free without being pressured by others to do anything else except mathematics, which is the main factor why I will always be against self-study or distance learning";

"Attending on-site lectures, I have no choice but to take notes and listen to a professor, not thinking about the things that might interfere with studying at home (bed, computer, family). So, if I have fewer on-site mathematics classes, I'll learn less, and what I really don't want";

"Currently, I go to lectures and then study at home if and what I don't understand on-site. According to the FC model, everything would have to be learned at home, where learning would take much more time. I don't think I could concentrate on learning the material for that long at home";

"Students will not be sufficiently prepared for on-site classes. It will be more difficult for students to develop self-discipline because it is easier to come on-site and start learning with an educator than on your own. I think that you can learn the subject better if there is an educator present who can immediately answer difficult questions. When studying on your own, it is more difficult to progress in a topic if no one can answer and help, making the entire learning process easier and faster";

"I think the FC model is not a bad idea, but it cannot be applied to everyone. Some students need the presence of an educator to learn the subject more easily";

"The FC model would make it difficult to easily understand the topics because the questions cannot be asked at once. This is not a good model, because the student is not motivated to learn if he has to learn on his own";

"Not a good model for students with weak backgrounds in mathematics. There is no way to ask questions while at home";

"Essentially, 80% of all students either won't understand on their own or won't do anything".

The best summary is a quote from one student: "If I wanted to study at home, I would be home-schooled. If I'm at university, then teach me at the university. I don't understand what the point is. Educators do teach. Isn't that right? That's their job. Then let them do their job and teach me".

4. Conclusions

The current study discusses the readiness of engineering students at Riga Technical University to learn mathematics using the flipped classroom teaching model. The research is based on the teaching experience of RTU mathematics professors and the RTU students' opinions collected through an online survey.

The survey showed that the surveyed RTU students are mostly not ready to study mathematics using the FC model, they prefer the traditional teaching model when the educator explains the theoretical materials and shows basic methods of solving problems during lectures. The students point out that an independent study of mathematics materials demands much more time than listening to well-prepared lectures on-site. At the same time, the academic performance of students who actively participate in on-site lectures and tutorials is excellent. The students' main problems with using the FC model are weak self-organisation and low motivation. In addition, students with a low level of basic knowledge in mathematics experience significant difficulties in studying the theory without the support of an educator. Among the advantages of the FC model, students noted the opportunity to study the material at their own pace and to plan their time flexibly. The FC model looks more appealing to students who enjoy independent learning and are interested in a deeper understanding of mathematics, in their ability to solve complex math problems and develop their critical thinking. Thus, the FC model might be good for 3rd-year students to study specialisation subjects and for master's students who are already motivated to study.

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