ON A BALANCE BETWEEN CLASSICAL MATHEMATICAL STUDY AND CONTEMPORARY TENDENCIES IN HIGHER EDUCATION FOR ENGINEERING STUDENTS

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Abstract

In this paper, the authors discuss the need to maintain the relevant balance between innovative contemporary approaches and methods, and classical methods of teaching higher mathematics at technical universities. Over recent years, a lot of attention has been paid to the question of using innovative approaches to teaching mathematics at schools and higher education institutions, while classical teaching approaches and methods are often considered boring and uninspiring for students. However, numerous recent articles in the field of educational psychology, show that excessive emphasis on digitalization of the teaching-learning process while ignoring the more classical teaching methods, negatively impacts the process of perception of material by students. In the article, the qualitative and quantitative research is based on reviews of articles in psychological science in the field of education, on surveys for students and mathematics professors at Riga Technical University (RTU), and the professors' experience gained both during classroom teaching and emergency remote teaching enforced by the Covid-19 pandemic.

Keywords: Higher education, study process, subject mathematics, contemporary technologies.

1 INTRODUCTION

The pace of life is speeding up constantly, and study processes at universities are participating in this rush as well and that causes changes in teaching and learning methods for all subjects. Over the last decade, a lot of attention has been paid to the development, implementation and use of innovative approaches to teaching-learning mathematics at schools and universities. Innovative approaches involve the use of new teaching methods, new learning strategies and new technologies. Many articles have been addressed to this issue (e.g. [1], [2], [3], [4]). For instance, in [5], the authors have selected and introduced into the teaching-learning process different strategies for improving the students' performance. Another study [6] discusses the influence of student learning styles and teaching strategies on academic performance in mathematics. Another paper [7] provides a review of emerging trends in mathematics teaching in higher education for STEM subjects (Science, Technology, Engineering and Mathematics), and indicates constraints in implementing new approaches in teaching mathematics, and also discusses arising questions of the shift towards teaching mathematics in innovative ways. Research [8] describes the positive impact and the importance of modern teaching methods, and even recommends that all Maths teachers should use modern, interactive methods in order to improve the performance of their students.

New innovative teaching methods should be student-centred and increase students' motivation to learn mathematics. For students, success or failure in mathematics study depends on such significant factors as self-efficacy, belief, motivation, engagement, involvement and attitudes towards mathematics. In order to enhance students' interest in mathematics, it is also important to show the connection between mathematics and real-life environments ([3], [9]). Engineering students need to have it explained to them why knowledge of mathematics is essential for their future practical work. Mathematics should be regarded as a language for expressing physical, chemical and engineering laws. Nevertheless, the theoretical background should be properly balanced with practical applications and it should not be minimized for the sake of appealing to contemporary trends. The objective of teaching mathematics to engineering students is to find the right balance between practical applications of mathematical equations and in-depth understanding [9].

New technology and online tools that nowadays are widely used in education, have been changing mathematics teaching techniques. Technology makes life easier for both students and educators. The use of contemporary technologies at universities is attractive and motivating for a new generation of students, whose life in a media environment and use of digital technologies on a daily basis has become the norm. It should be noted that technologies and teaching methods are closely related. Due to

information technology and online tools, new innovative teaching methods such as flipped and virtual classrooms, mobile learning etc. have been developed [4]. In recent years, an increasing emphasis has been placed on the digitalization of the education process. At the same time, classical teaching approaches and methods such as the use of whiteboard-and-pen, methods of repeating and memorizing information, proof of theorems in lessons, and hand-written notes made by students during lessons, are often considered boring and unmotivating for students [8]. However, the authors' experience of working with students as well as numerous articles appearing recently in the field of educational psychology, demonstrate that excessive digitalization of the teaching-learning process and ignoring classical teaching methods negatively impacts the process of perception of the material by students.

The main goal of technical universities is to prepare competent specialists capable of professional growth and self-education. Mathematics courses for technical specialities are the basis for studying specialized disciplines. They should provide not only basic skills and the main concepts of mathematics but should also develop logical thinking and problem-solving skills for students which are essential for their further career development. All this, together with a current popular tendency to simplify the basic higher mathematics course in order to facilitate the learning process for students, does not allow the achievement of the above-mentioned goals of mathematics courses at technical universities. Thus, there is a new challenge for technical universities to find an optimal balance between classical mathematics study and the use of contemporary technologies in the study process.

In this current article, the authors pose the question of how reasonable is to forget and principally move away from the classical methods of teaching higher mathematics at technical universities just because it is perceived as less interesting and not entertaining, taking into consideration that the learning process is work, but all work requires effort in order to achieve a result.

2 METHODOLOGY

On the basis of reviews of publications in educational psychology and RTU students' surveys as well as observing the teaching experience of RTU mathematics professors, the authors analyse factors influencing the organization of the study process. The surveys were conducted using Google Forms, an open source application for online surveys, and addressed to the students of the Faculty of Civil Engineering, Faculty of Mechanical Engineering, Transport and Aeronautics, and Faculty of Power and Electrical Engineering.

3 DISCUSSION

Over recent years, a lot of attention has been paid to the question of the development and introduction of innovative approaches to teaching mathematics at higher education institutions, which involves both teaching methods and new technologies. The use of contemporary technologies at universities is attractive and motivating for a new generation of students. In recent years, an increasing emphasis has been placed on the digitalization of the education process. However, as noted in the introduction, excessive digitalization of the teaching-learning process and ignoring classical teaching methods negatively impacts the process of perception of the material by students of the material, and hence, this also impacts the learning process. One shouldn't forget that mathematics is one of the basic, fundamental and important subjects for engineering education. Mathematics courses for technical specialities provide a basis for studying specialized disciplines. Many special courses assume a good knowledge of mathematics so that mathematics lessons at university should provide not only basic skills and the main concepts of mathematics but also should develop logical thinking and problem-solving skills for students, which are essential for their further career development.

New technology and online tools, that nowadays are widely used in education, have been changing mathematics teaching techniques. Nowadays, PowerPoint slide presentations are widely used by educators to present materials. This allows educators to save time, which is very important in current circumstances when mathematics contact hours are reduced, and this also gives an opportunity to provide information to students on a qualitatively different level by using more visualization. The perception of information from slides depends on how the information is provided on the slides (for example, with or without a lot of information, main points, arrangement of material on slides). Some teachers fill the slides with text to provide the content, other teachers use slides to only highlight some statements which facilitate the structure of their verbal teaching, some teachers insert statistics or animated images. The use of this tool may have a differential impact on teaching. It should be noted that it is important for a good result that the students do not perceive the content of the slide as more

important than the explanations given by the teachers and do not reduce their attention [10]. It was emphasized that students who tend to pay more attention to the content of the slides than to oral explanations are more likely to suffer from lowered attention levels, and their ability to remember oral information decreases. Thus, the content of the slides is an issue. Presentation slides with overabundance of information and visual content along with verbal explanation by the teacher can cause cognitive overload in students as the cognitive requirements exceed the computational capabilities of the students. Slides created by the teacher should be a digital assistant for his/her oral lecture.

Many researchers noted the positive effect of slides on the teaching process (e.g. [11], [12]). The student's attitude to slides presentations also was investigated in (e.g. [13], [14]). When students were asked about their perceptions of using or not using digital presentations in class, the response has also been uniformly in favour of using digital. However, these positive student perceptions do not reflect the clear positive impact of using slides on students' perception of information. Recently, there have appeared serious studies analysing the impact on students cognitive learning when using PowerPoint in class (e.g. [15], [16]).

The article [16] evaluated the impact of the provision of slides on student academic performance and attendance, where its outcomes revealed that access to slides developed by teachers had a negative impact on student performance and attendance in classes. Student academic engagement and study strategies were found to modify the relationship between academic performance and access to slides.

This paper [17] addresses the effects of access to slide copies during lectures using PowerPoint for undergraduate students on their learning outcomes depending on the quantity of notes they take and immediate vs. delayed testing. The results revealed that accessibility to slide copies and students' note-taking predicted their learning outcomes. The effects of no slide copy were significant in both short- and long-term memory conditions as compared to those with access to full and partial copies. Access to full and partial slide copies did not have significantly different results. However, according to the interaction results between accessibility and memory, the long-term encoding effect was assumed for a partial slide copy condition. Regarding note-taking variables, students' performance was considerably impacted by the number of markers but not the number of words. The findings suggest educational implications for the way slides are prepared and provided and the way students take notes during slide-based lectures from the perspective of writing-to-learn.

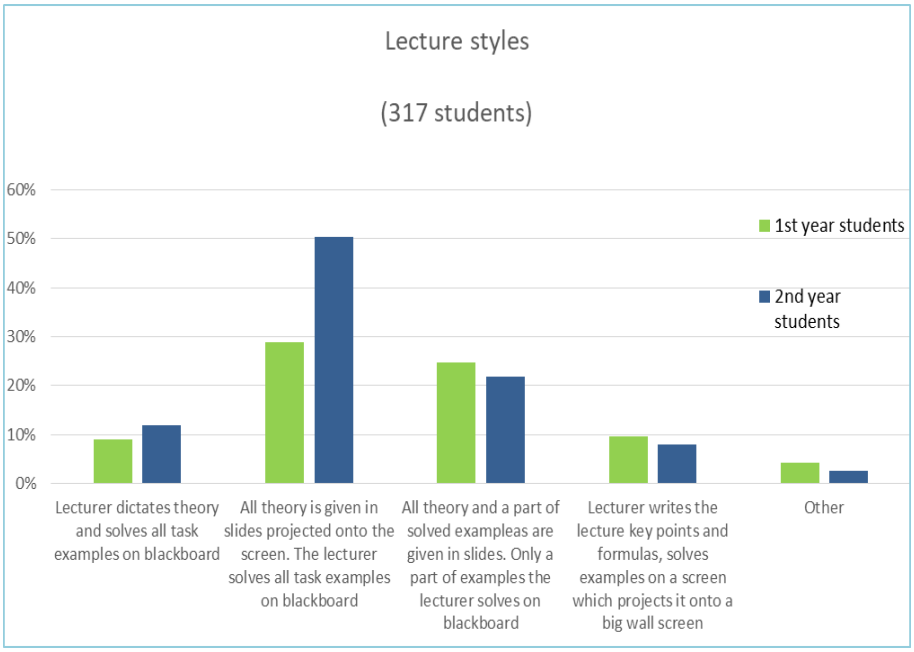

Figure 1. Lecture preferred styles

In order to use slides in teaching mathematics, it is very important to understand what can be presented on slides and what should be written on a board for better understanding and perception of material for students. It is also to be noted that what is good for teaching languages, biology, etc., may not be acceptable for mathematics. In [2], students were asked to choose the most preferable options for conducting a lecture with slides. In Fig. 1, one can see that students prefer it when theory is given in

slides, but tasks and examples are solved on a board by the lecturer. Educators also believe that the solutions of tasks in mathematics should be shown step-by-step on a board, and that it is necessary to make students write it down too.

The authors do not raise the question (the authors are unaware if this is being studied in literature) of how well the theory from slides is received, or how good the cognitive perception of theoretical material from slides may be. However, it is essential to understand that most students do not take notes from slides classes, which negatively affects the long-term perception of the material. [17]

Note-taking is one of the first and most established cognitive technologies [18]. The ability to make notes is one of the main student skills that affect academic performance. There are numerous publications demonstrating the importance of note-taking as a part of effective learning strategies for students of all ages ([19], [20]).

For students who have reached middle school level, note-taking skills begin to play a role in their classroom achievement. In general, students who take more notes learn and remember classroom subject matter better [21]. However, the quality of the notes is equally important. Useful notes typically reflect the main ideas of a lesson or reading assignment (e.g. [22], [21], [23]). There exist different strategies about note-taking to enhance cognitive performance [24].

Nowadays, with wide use of laptops and tablets, the idea of taking notes by hand seems to be old-fashioned to many students, because typing notes is faster. However, different studies conclude that students who write lecture notes on paper remember main ideas better than those who write on a computer. One of the reasons is the risk of student distraction when using laptops. These studies show that students should be slower when they take notes by hand, and it is this that makes the process more useful in the long run [1].

The study [25] published in Psychological Science tested how note-taking by hand or by computer affects learning. Research suggests that even when laptops are used solely to take notes, they may still be impairing learning because their use results in shallower processing. In three studies, it was found that students who took notes on laptops performed worse on conceptual questions than students who took notes longhand. It was shown that whereas taking more notes can be beneficial, laptop note takers' tendency to transcribe lectures verbatim rather than processing information and reframing it in their own words is detrimental to learning.

There are two hypotheses as to why note-taking is beneficial. The first idea is called the encoding hypothesis, which says that when a person is taking notes, "the processing that occurs" will improve "learning and retention." The second, called the external-storage hypothesis, is that students learn by being able to look back at their notes, or even the notes of other people [1].

In another recent study [26], the authors underline the value of hand-written notes, showing the failure to find state-dependent effects when using a laptop to take notes and complete quizzes. They also point out that the use of laptops for the sole purpose of taking notes can negatively impact academic performance: the participants who took notes by hand performed better on the quizzes overall and better on conceptual questions. The study suggests that taking notes by hand may improve how students encode material, and result in higher quality external storage used by students when studying for quizzes. This reinforces the notion that taking notes by hand may benefit quiz performance for lecture-style information and could improve student performance in class.

In [27] the author focuses on the importance of writing in learning of mathematics. Writing is an essential part of the mathematics curriculum. The educator should encourage students to read and write in many different ways. Writing raises the "cognitive bar", challenging students to problem solve and think critically.

In [28] the author researches the relationship between language and mathematics learning, asserts that writing supports mathematical reasoning and problem solving and helps students internalize the characteristics of effective communications. He suggests that teachers read student writing for evidence of logical conclusions, justifications of answers and processes, and the use of facts to explain their thinking.

As a result of the introduction of new technologies and digitalization into the learning process, tests and quizzes have become widely used to evaluate students' knowledge. The use of online tests and quizzes in mathematics has its advantages and disadvantages. Online tests significantly facilitate the work of educators so that there appears a tendency of substituting hand-written homework by online tests. In authors' opinion, this substitution worsens student academic performance. Previously, the authors

conducted a student survey about students' attitude to hand-written homework and classroom tests and if they are needed ([29], [30]). The survey showed that the majority of students think that hand-written homework are needed for better preparation for classroom tests and exam (see Fig. 2), and classroom tests are needed for better preparation for the exam. This is an important learning moment. The main functions of hand-written homework are teaching, educating, and only then diagnostic, but during the online test, the learning function becomes minimal. There are several reasons of that. Firstly, if a student has an incorrect answer in an online test, then the student does not know where his/her mistake is. That leads to mistakes, which may appear in other tests and exams. At the same time, when the test is retaken again, the student repeats the same fundamental mistake. Secondary, everyone knows that there are often situations when, with a correct decision, an error appears when entering the answer. In this case, the student believes that the solution is wrong. Finally, when doing hand-written homework, the student must not only solve the tasks, but the student also shows and explains the steps of the solution drawing up his work. Writing the solutions step by step studens arrange and systematize his/her knowledge. As it was mentioned above, writing and note-taking are extremely important in learning mathematics and are essential for improving cognitive perception. In authors opinion, mathematics online tests are useful for students as tools for self-study and self-check but not appropriate instead of traditional hand-written homework.

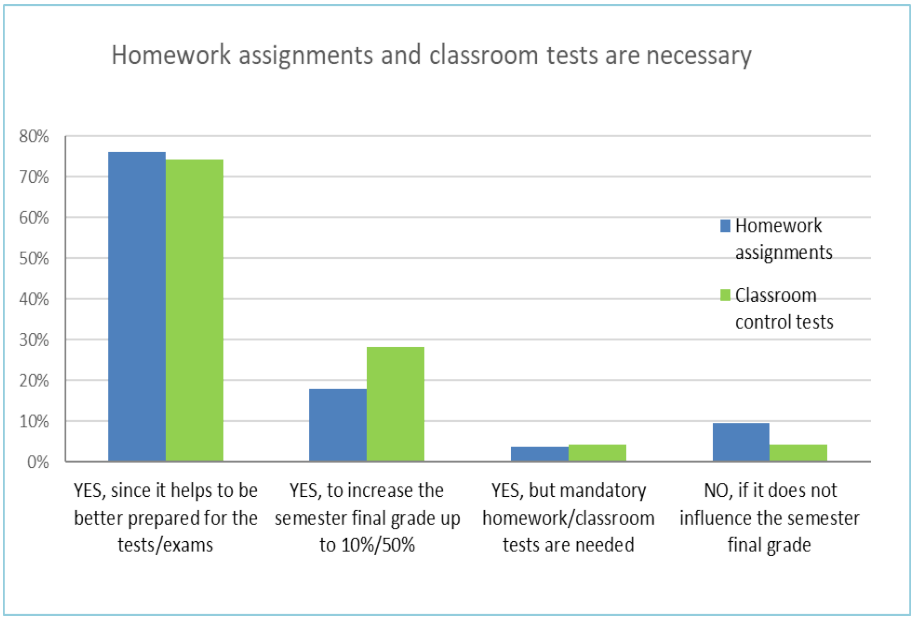

Figure 2. Necessity of homework and classroom tests

During the test, the learning function becomes minimal. In literature, when discussing the effectiveness of online tests and comparing them with traditional classroom tests made on paper, they examine the objectivity of assessment ([31], [32]). In the authors' opinion, it is not worth replacing traditional classroom tests by online tests and quizzes, since as a result of testing, the educator receives grades that do not allow them to judge the mistakes and knowledge of students, and the educator does not see the steps of task solving. When checking classroom tests, the teacher sees the steps of the solution and mistakes. On seeing mistakes, the teacher can assess what exactly was not clear to the students and, consequently, emphasize this topic in lessons and consultations. On other hand, the student also sees his/her mistakes and learns from it. When the teacher sees the progress of the solution and the mistakes of students, both in homework and tests, teacher-student feedback appears, and that improves the quality of learning. Nevertheless, online tests and quizzes are appropriate for a brief check at the end of lecture to quickly understand the level of assimilation of the lecture material by students.

There is also an interesting study [32], where the attitude to online tests was examined depending on the experience of the teacher, and the survey showed that the more experienced teachers had a worse attitude towards online tests.

Let us discuss now innovative teaching methods as flipped classrooms and virtual classrooms for mathematics teaching [4]. The flipped classrooms is where students watch video lessons and learn the material at home, then come to school and have class time to work on problems where the teacher and fellow students are available to answer questions. A virtual classroom is an online learning environment

in which the learners and instructors interact visually together as if they are in a face-to-face classroom. This environment comes together with e-learning platforms containing audio features, blog, chat rooms, video component, simulation tools, grading books, emails, online calendars, examinations and quizzes [4]. Before the Covid-19 pandemic such innovative methods looked very attractive and perspective but, now the world has experience these in full due to removed teaching. These methods have been shown to have a lot of disadvantages for math teaching regarding to students' academic performance and knowledge [33].

The author's experience of teaching mathematics at Riga Technical University shows that there is a lack of motivation in most students to watch pre-recorded videos and read materials on their own before the lecture. As a result, students come unprepared to the mathematics lectures and the teacher has to waste time for explaining the basics of the video lecture which the students have not watched.

As to the virtual classroom idea, the authors have already discussed this in detail in their recent paper [33]. According to the student surveys conducted at RTU and dedicated to the remote teaching-learning of mathematics during Covid-19 pandemic [33], they prefer traditional face-to-face classroom lessons or, in the worst case, they choose online lectures but on-site tutorials (see Fig. 3). The remote teaching-learning had a very negative impact on students' academic performance and their knowledge. Thus, in the authors' and their students' opinion, if possible, mathematics study must be only on-site.

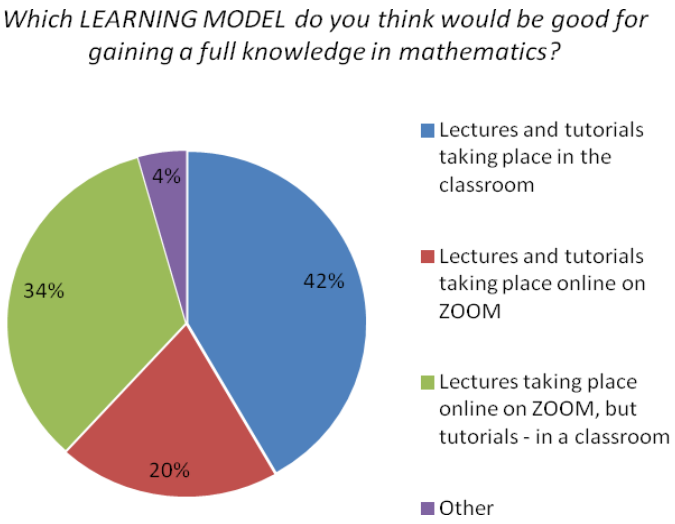

Figure 3. Students' choice of a learning model

Mathematics is one of the basic, fundamental and important subjects for engineering education, where implementation of contemporary technologies into the study process shouldn't substitute classical mathematics study which involves good theoretical basis, proofs of theorems and step-by-step solving of tasks by hand on a paper. Information technology should be only an assistant in teaching-learning mathematics as well as motivation for students [33]. Thus, there is a new challenge for technical universities to find an optimal balance between mathematics classical study and the use of contemporary technologies in the study process.

4 CONCLUSIONS

The current study provides a discussion about the importance of keeping the right balance between traditional mathematical study and contemporary innovative teaching techniques and digitalization which are being introduced into study processes and which are influencing the teaching-learning of higher mathematics for engineering students at technical universities. The discussion is based on literature review, RTU student surveys and the personal experience of RTU professors. Advantages and disadvantages of excessive digitalization were observed in relation to mathematics study. Teaching methods that are good for some other subjects, e.g. languages, for mathematics should be used very carefully with some applied modifications and restrictions.

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