

# SPECIFICITY AND PURPOSE OF ONLINE TESTS AND QUIZZES IN TEACHING HIGHER MATHEMATICS AT UNIVERSITY

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## **Abstract**

The introduction of digitalization and new technologies into the learning process has changed teaching approaches and has led to the wide use of online tests and quizzes as a form of both evaluating a student's knowledge and providing tutoring across many subjects, including higher mathematics. The form and effectiveness of using online tests differ from subject to subject. Due to the specificity of higher mathematics topics, online tests and quizzes in higher mathematics should be used very carefully with applied restrictions and modifications. The experience of mathematics professors at Riga Technical University (RTU) shows that the use of online tests in higher mathematics should be well-balanced. The current research provides a detailed study on a very actual and disputable question about the effectiveness, specificity, advantages and disadvantages of using online tests and quizzes in teaching higher mathematics at universities for engineering specialities. This research is based on the RTU students' and professors' surveys, and is also complemented by reviews of recent publications in this area.

Keywords: Higher education, online tests in higher mathematics, engineering specialities.

## **1 INTRODUCTION**

Over the past few decades, the development of new technologies has changed the way mathematics is taught in both schools and universities. Innovative approaches, new technologies and online tools have become widely spread due to the rapidly growing digitalization of the learning process.

Digitalization of the learning process and the introduction of new technologies have led to the wide use of online tests and quizzes in the teaching and learning of many subjects, including mathematics. These new technologies significantly facilitate the work of educators by allowing them to avoid reading and marking large numbers of students' hand-written papers. Online tests have become a part of mathematics study both in schools and universities. For the new generation of students' online tests seem more attractive and more interesting than hand-written homework and are time-saving as well because they can use only draft papers for finding a problem solution.

However, there are advantages and disadvantages in using online mathematics tests and quizzes in teaching and learning higher mathematics at universities [1]. In higher mathematics, due to the specificity of the subject, online tests and quizzes must be used very carefully, with restrictions and precautions, and they should not substitute traditional methods of teaching and evaluating student knowledge, rather, they should be used as an additional tool in the study process to achieve better academic performance for students (e.g. [2], [3], [4], [5]).

In literature, one of the frequently discussed problems is the objectivity of the assessment of students' knowledge through the results obtained from the students' online tests in mathematics (e.g. [6], [7], [3], [1]). There are also articles describing the basic requirements for creating reliable tests and the difficulties that arise when using tests in the educational process [5]. In [2], the authors consider features, advantages and disadvantages of using testing in modern education as a method of students' knowledge pedagogical control at the institutions of secondary professional and higher education. Particular attention is paid to the use of computer-based online testing, its types and technologies in educational activities. A number of articles are devoted to the issue of using online tests in the teaching process, pedagogical conditions of the use of testing in the organisation and control of students' self-study process and monitoring the process of students' independent work (e.g. [2], [3], [4], [5], [1]). The article [8] provides mathematical and statistical analysis of the quality of the tests in different math topics and their reliability in the assessment of student's knowledge and skills.

The problems and disadvantages which may appear while using computer-based math tests in teaching higher mathematics for engineering students at technical universities was raised and briefly discussed in the authors' previously published article "On a balance between classical mathematical study and contemporary tendencies in higher education for engineering students" [9].

In the present paper, the specificity and purpose of online mathematics tests for teaching engineering students as well as advantages and disadvantages of using online math tests in the higher mathematics course at technical universities are considered in detail, considering that the course of higher mathematics is the basis for studying specialised disciplines for technical and engineering specialities which require a good knowledge of mathematics. Moreover, mathematics courses at a technical university level should develop logical thinking and problem-solving skills for students to make them competent specialists who have the capabilities to extend their professional growth, self-education and further career development. In the current article, particular attention is also paid to the issue of the acceptability of replacing hand-written mathematics homework with online mathematics tests at technical universities.

## 2 METHODOLOGY

This research is based on the surveys conducted by the authors and subsequently offered to the RTU mathematics professors of the Department of Engineering Mathematics, and to the 2<sup>nd</sup> year engineering students who had already gained some experience in taking online mathematics tests during the 1<sup>st</sup> and 2<sup>nd</sup> semesters in the main course of higher mathematics at RTU. The students who were surveyed are from the Faculty of Mechanical Engineering, Transport and Aeronautics, and the Faculty of Power and Electrical Engineering. The mathematics professors were questioned in person and their opinions were summarised and presented in conclusion.

The survey was created using the Google Forms online application. The authors' present research is qualitative, quantitative, and based on the questionnaire method. The study is also complemented by reviews of recent publications in this area. Besides, the research provides examples of questions of online mathematics tests on ORTUS offered to engineering students studying the basic course of the higher mathematics at RTU, and gives a detailed explanation of how particular online questions influence students' understanding and their academic performance. ORTUS is the e-learning platform, based on the MOODLE (Modular Object-Oriented Dynamic Learning Environment), which RTU has been using since the 2007/2008 academic year [10].

## 3 DISCUSSION

Nowadays, online tests and quizzes are commonly used in teaching and learning higher mathematics. All students at Riga Technical University (RTU) are enrolled in the course of higher mathematics during their 1st year of studies. This course is the basis for studying specialized disciplines for technical and engineering specialities which require a good knowledge of mathematics. Online math tests have become a part of mathematical study at RTU.

In the course of higher mathematics, there are two types of online math tests. The 1st type of online math tests are tests where students solve problems or answer given questions but as answer they submit only numerical results. Such computer-based tests are usually offered to students as mandatory homework or as an additional possibility of training and self-check for students. Another type of online math test are multiple-choice tests, where a student has to select a correct answer from a list of available answers. Such tests are used in RTU for evaluating students' knowledge of theory in mathematics. thinking while reasoning the steps of problem-solving. Usually, a student has 3 attempts in taking each online math test at RTU, and his/her best result is taken as their score.

The use of mostly online mathematics tests in the course of higher mathematics at university, has its advantages and disadvantages. Due to the specificity of the subject, computer-based math tests must be used very carefully and they should not substitute traditional methods of teaching. Let us consider now the question about the good and bad sides of using computer-based mathematics tests in teaching and learning higher mathematics at technical universities in detail. Since online tests can significantly facilitate the work of educators, there appears a tendency to substitute hand-written math homework by online math tests. In the authors' opinion, based on their long teaching experience, avoidance or significant reduction of traditional hand-written mathematics homework, worsens student academic performance. The main functions of hand-written homework are teaching, educating and only then diagnosing, while for online tests, the educating function becomes minimal.

There is also the problem of incorrect assessment of a student's work by the teacher if the teacher doesn't see the mistakes but only the final answer as to how it happened by using computer-based tests. The difficulty with online tests of higher mathematics is that any mathematical problem-solving at the university level is usually multi-step, where each step is important. There can be different situations. Firstly, if a student solves a problem incorrectly and submits an incorrect answer to an online math test, he/she is

unable to identify in which step of solving the problem, exactly where a mistake was made. Moreover, there may also be instances when a student obtains a correct answer but he/she made several mistakes in the problem-solving process or even missed some steps in solving the problem. In this case, the student is sure that his/her solution is correct. That leads to mistakes, which may appear in other tests and exams. At the same time, when the test is retaken, the student repeats the same fundamental mistake.

Let us explain the above-mentioned cases with an example of the following question taken from an online test of the 1<sup>st</sup> semester of the higher mathematics course. For instance, the task is to find the largest value of a function on a given interval  $[a,b]$ . In this case, the solving consists of several steps: (i) Find the derivative of the function, (ii) Find the function's maximum on the interval  $[a,b]$ ; (ii) Find the function's value at the interval  $[a,b]$  border points  $a$  and  $b$ ; (iii) Compare all obtained values and select the largest one as an answer. For instance, when the authors asked their students to submit not only the answer to a question of the online math test, but also to attach a draft of their solution, the authors repeatedly observed situations, where the submitted answer was correct, but the solution of the problem was wrong or student hasn't carried out all necessary steps towards solving the problem.

Case 1: The function's largest value is reached at the maximum point, but the student after finding this value doesn't check the function's value at the interval border points. The student submits the answer and receives the automatic response that the answer is correct. What does the student think in this situation? The student feels sure that he knows how to solve such tasks due to the correct answer.

Case 2: The function's largest value is reached at one of two interval border points, and the student starts with checking these two border points, but forgets to find the function's maximum point, or while finding this maximum point, the student makes a mistake in differentiating the function. That is a grave mistake. The student is again sure that his solution is correct since the submitted answer is correct, so the student will repeat the same mistake in any similar question in the exam.

However, such situations wouldn't be possible if instead of solving this task as an online test, the student was to solve it on paper as hand-written homework which later would be corrected by a math professor, then the student wouldn't repeat the same mistake in the exam. It is to be noted that in the above-mentioned situations, the tutor does not see mistakes, and therefore cannot correctly evaluate the student's work and knowledge. Besides, most tutors are familiar with situations when a student obtains a correct solution to the problem on paper but an error appears while entering the answer. The student again understands that there is a mistake, but does not know where. In this case, the student believes that the solution is wrong. Moreover, the automatic test evaluation gives zero points to the student, although the teacher would have given more points for the assignment. In the considered situations, on the one hand, the student does not see his/her mistakes, and therefore during the online math tests, the learning function of homework becomes minimal, on the other hand, the assessment of the student's work will be unobjective.

There exists a difficulty in creating an effective and well-posed online test on higher mathematics because the course problems are mostly complex and require multi-step solving. Thus, it is more reasonable not to run ahead with the application of contemporary innovations with no exception, but rather, on some mathematics topics, to remain with traditional hand-written mathematics homework.

Finally, in hand-written homework, the student not only solves the tasks but also explains and shows all steps of the solution, and systematizes his/her knowledge. Writing and note-taking are extremely important in learning mathematics, mathematical reasoning, developing mathematical understanding and improving cognitive perception [9]. In [11] and [12], the authors note that educators should encourage students to write and should read what the students have written for evidence of logical conclusions, justifications of answers and processes, and the use of facts to explain their thinking. Thus, hand-written homework is the best way to make students write and develop their logical thinking through reasoning the steps of problem-solving. In the author's opinion, online math tests are useful for students as tools for self-study and self-check but not appropriate instead of traditional hand-written homework.

The authors decided also to ask their students their opinions about hand-written mathematics homework in comparison with homework in the form of online math tests, from their perspectives of received knowledge, the objectivity of assessment, their preferability, their motivation and achievement of goals. Here are some results of the survey. RTU mathematics professors assign two types of homework to the students. On some topics, such as differentiation and integration, students are assigned hand-written homework. Students take online tests on other topics, such as linear algebra, limits, vector algebra, etc. Some professors practice more traditional teaching so that they assign only hand-written homework on all topics (see Fig. 1).

One can see from Fig. 2 that about 50 % of the surveyed students completed the online math tests entirely by themselves or by themselves but checked the results using internet resources and/or another person,

37 % - completed the tests through a mix of their own work and help from internet resources and/or another person, and only 4 % - completed the tests using internet resources and/or the help of another person.

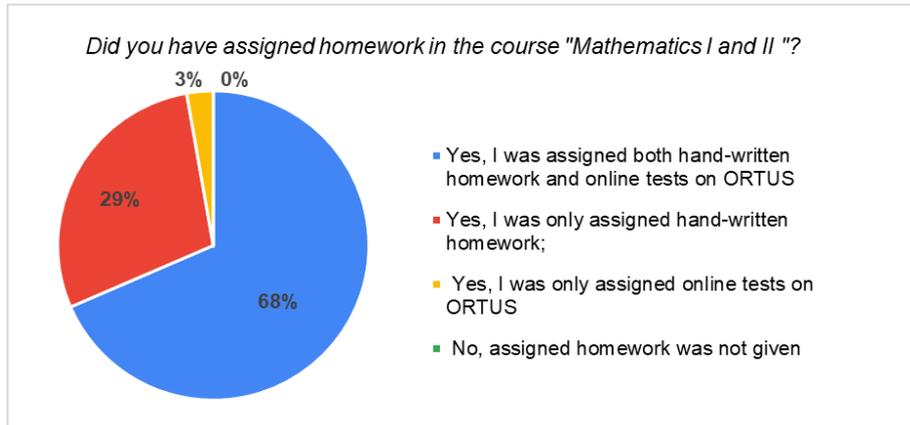


Figure 1. Assigned homework.

In addition, almost 83 % of the students, who completed the online tests entirely by themselves, answered that they never or rarely submitted the test answers mostly through guesswork (see [Fig.3]). This means that the survey was mainly taken by students who are motivated to study and to master the study material. The opinions of these students are especially important to math professors.

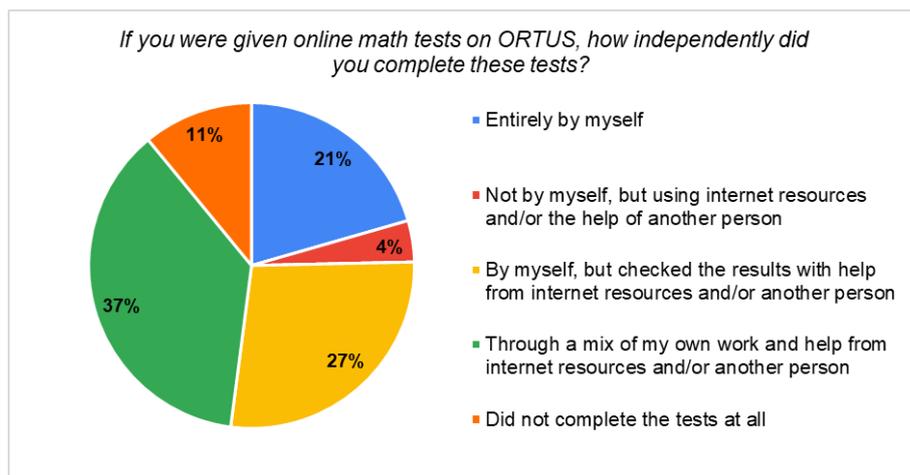


Figure 2. Online math tests completed by students.

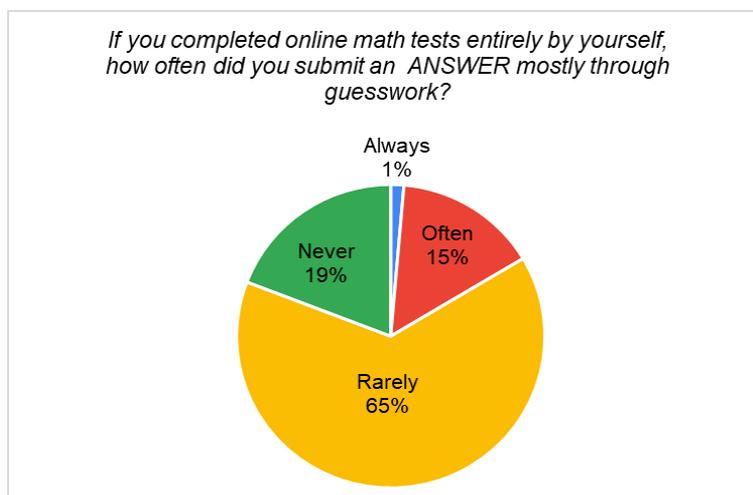


Figure 3. Students' guesswork while completing online math tests.

The majority of the surveyed students think that online math tests are needed for self-preparation for classroom tests and the final exam, for repeating and memorizing the subject topics and for self-check (see Fig. 4)

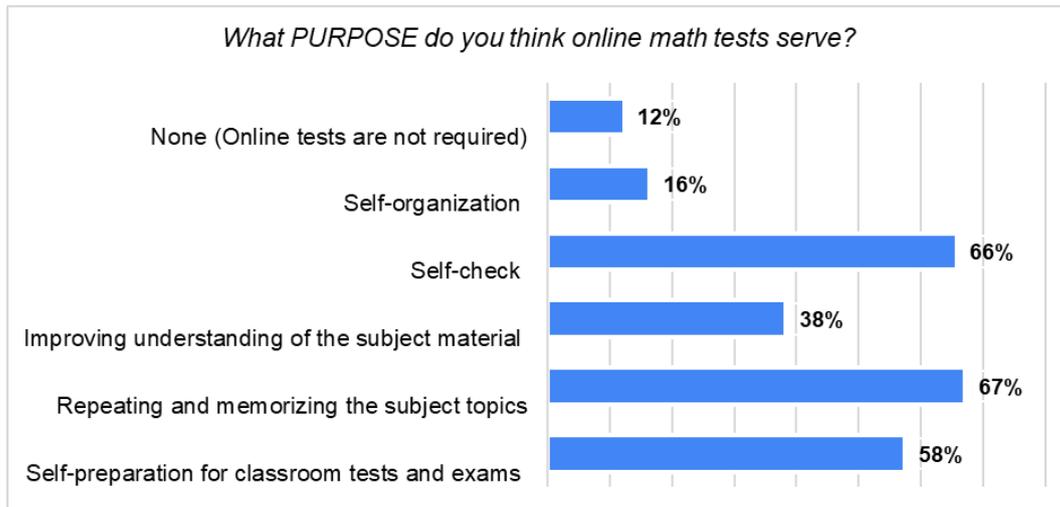


Figure 4. Purpose of online math tests.

The survey results show that the majority of students give priority to hand-written math homework (almost 60 %), because the hand-written homework completed on the paper helps students to learn the study material better and be better prepared for classroom tests and exams than online math tests (see Fig. 4). The other 30 % of the students think that it is better to combine hand-written math homework and online math tests, and only 7 % of the students consider that online tests are better than hand-written homework. Moreover, the majority of the students (60 %) consider that the checking and correction of a student's hand-written homework by a tutor is essential for the student to understand his/her mistakes and the study material, and this way, have better preparation for the exam (see Fig. 5).

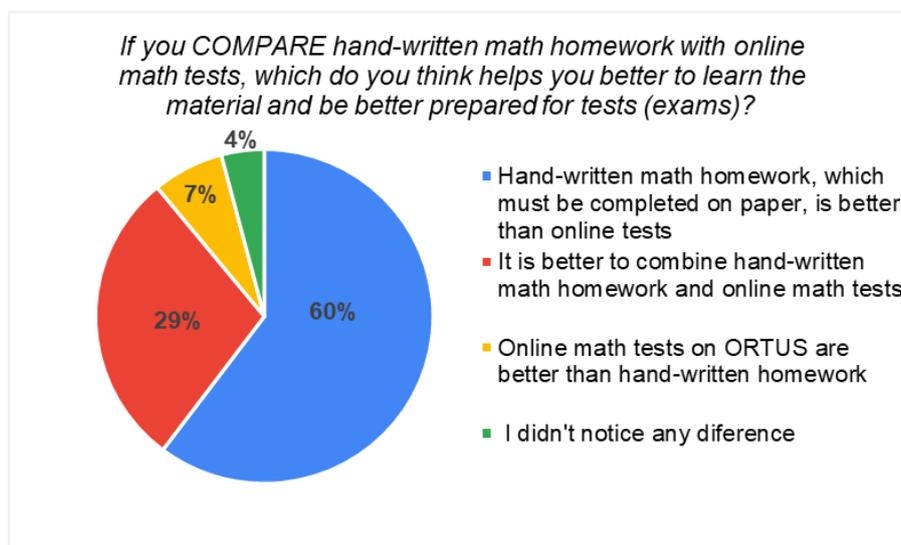


Figure 5. Hand-written homework vs. online tests in higher mathematics.

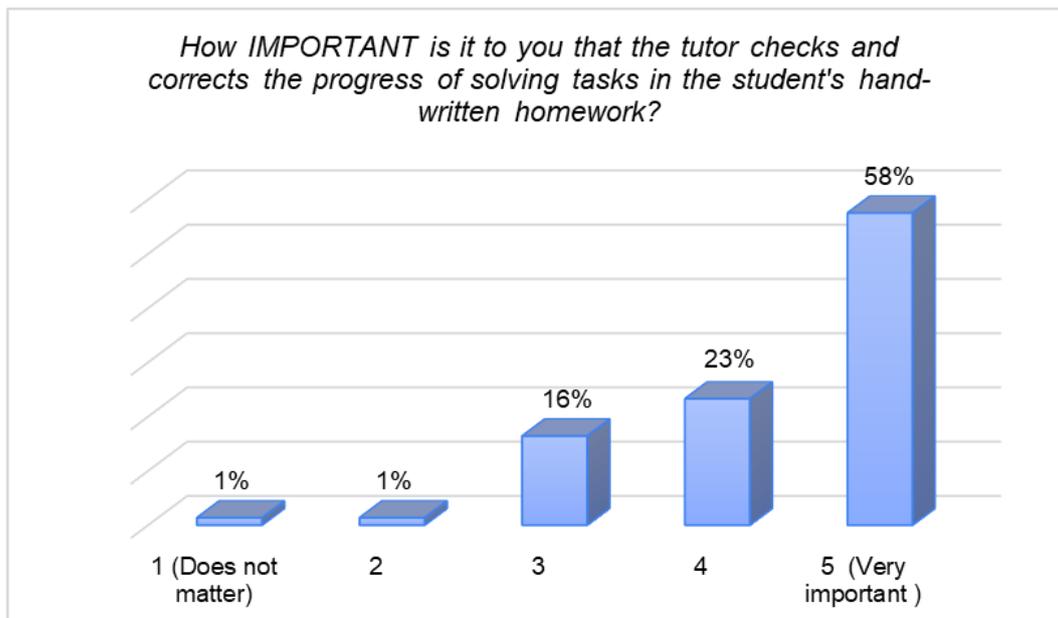


Figure 6. Check and correction of progress of solving tasks in student's homework.

Let us present some comments from the surveyed students:

- “Hand-written homework helps to prepare for classroom tests very well, especially if the tutor checks for mistakes and helps to correct incorrect tasks”;
- “Students cannot learn mathematics with online tests”;
- “In online tests, students definitely need explanations as to why the answer is wrong, or what the steps of the solution should be - this would motivate me to take such tests more seriously”;
- “Taking online tests for training purposes must be optional”;
- “While online tests are faster, hand-written homework is more convenient and a student gains more understanding”;
- “Hand-written homework is more valuable”.

It is important that 47 % of the students noted that the assessment of a classroom math test was higher when, on a corresponding topic, obligatory hand-written homework was assigned, which they needed to submit before the classroom test. That is quite understandable, considering the above-mentioned. Another 7 % of the students answered that their assessment of the classroom test was better after only completing the corresponding online test and, 30 % - didn't notice any difference (see Fig. 7).

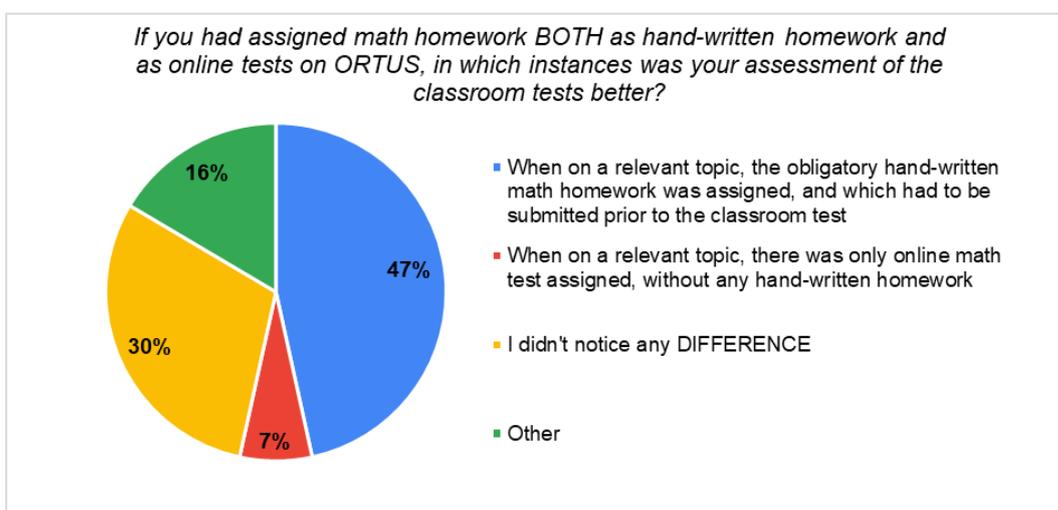


Figure 7. Score for classroom tests.

Since the 2017/2018 academic year, the student's academic performance for all mathematical subjects at RTU has been evaluated by means of the so-called "Evaluation Formula": a student's final grade of the course is based on 50 % of the mark obtained from the final exam, 35 % - from classroom tests, taken during the semester, and 10 % and 5 % - from hand-written homework and online math tests, respectively. In the question, of whether math homework is necessary provided that it does not affect the final grade of the semester, 42 % of the students answered that both hand-written homework and online tests are necessary, 36 % of the students think that only hand-written homework is necessary, and only 8 % of the students consider online math tests as necessary.

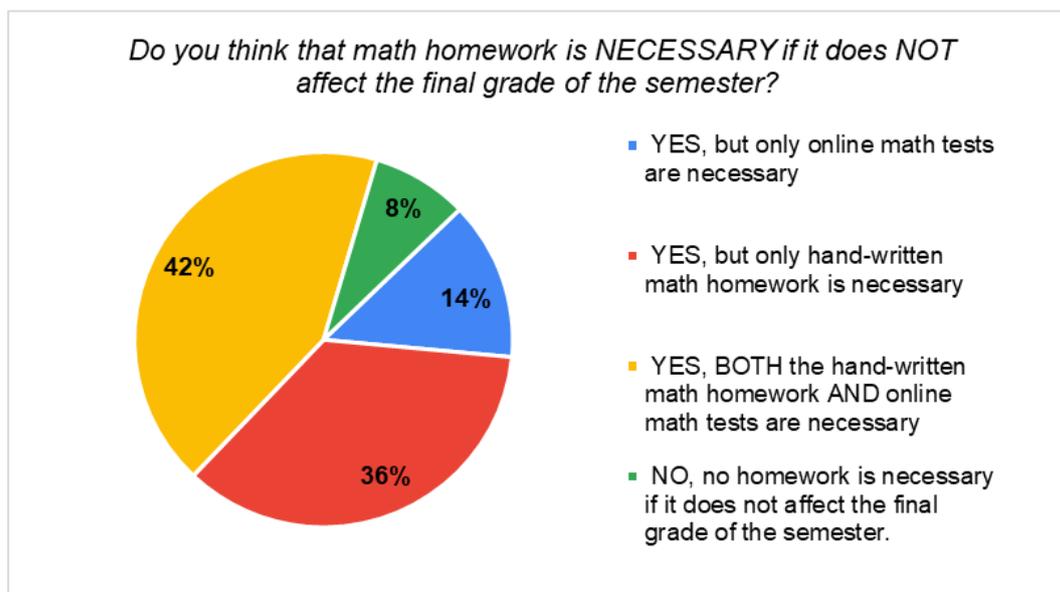


Figure 8. Necessity of homework if it doesn't contribute to the final grade.

As a conclusion, students need hand-written math homework or a combination of hand-written homework and online math tests. The hand-written math homework should be checked by a tutor, and this helps the student understand where the mistake is, which cannot be achieved by replacing hand-written homework with online tests. Both students and teachers need feedback, which can only be achieved through hand-written homework. According to the authors, online math tests are good as complementing tools for additional training and self-testing.

In mathematics, a crucial point is that the more a student solves tasks, the better his/her understanding of the material and, as a consequence, his/her academic performance is better. The online mathematics tests do appear to be a good tool for training and self-assessment for students. However, the answer to a complex problem of an online math test doesn't provide much information for both the teacher and the student. From the test we can understand only whether the answer is correct or incorrect, but it is impossible to understand whether the solution of the problem is correct.

There are no theoretical questions in the mathematics exams at RTU. The theoretical questions are given to students in the form of online tests, which students must complete at home by the day of the exam. These tests' results contribute 5 % to the final grade for the semester.

Students were asked the following two questions: "Did you complete theory tests?" and "In your opinion, do the theory tests reflect the real level of knowledge of theory?" The students' answers can be seen from Fig. 9.

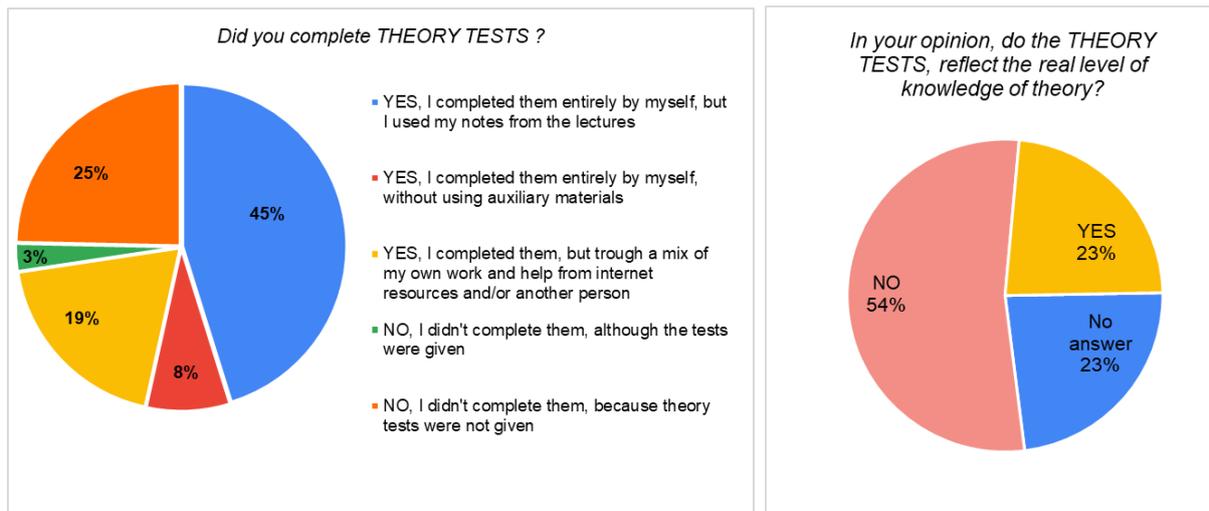


Figure 9. Importance of theory tests for students.

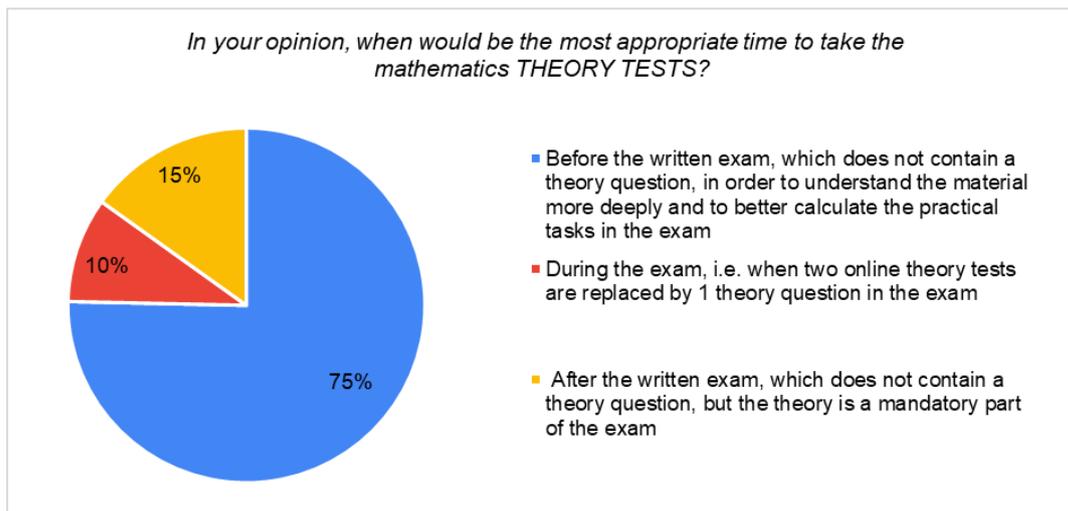


Figure 10. Preferred time for taking theory tests for students.

75% of the students noted that the most appropriate time for taking mathematics theory tests is before a hand-written exam, which does not contain theory questions, in order to understand the study material deeper and to solve the practical tasks in the exam better (see Fig.10).

For students, theoretical tests seem to be important as a way of repeating and understanding the study material deeper and, therefore, be better prepared for the exam. Although, 54 % of the surveyed students answered that computer-based theory tests, normally taken at home, do not reflect the real level of knowledge of theory.

## 4 CONCLUSIONS

The current research provides a detailed study on the effectiveness, specificity, advantages and disadvantages of using online tests in teaching higher mathematics at universities for engineering specialties. This research is based on the RTU students' and professors' surveys, and is also complemented by reviews of recent publications in this area.

- In higher mathematics, due to the specificity of the subject, online tests must be used very carefully, with restrictions and precautions, and they should not substitute traditional methods of teaching and evaluating student knowledge, rather, they should be used as an additional tool in the study process to achieve better academic performance for students.

- For a higher mathematics course, an online brief theory quiz would be very useful and even recommended to be given to students at the end of each lecture to motivate students to be focused on the lecture and be better prepared for mathematics tutorials.
- The online mathematics tests do appear to be a good tool for training and self-assessment for students. However, the answer to a complex problem of an online math test doesn't provide much information for both the teacher and the student. From the test we can understand only whether the answer is correct or incorrect, but it is impossible to understand whether the solution of the problem is correct.
- Substitution of handwritten mathematics homework by online mathematics tests is not acceptable. It worsens students' academic performance. The main functions of hand-written math homework are teaching, educating and only then diagnosing, while for online tests the educating function becomes minimal.

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