ON ONLINE SELF-CHECKERS OF KNOWLEDGE FROM THE INTRODUCTORY MATHEMATICAL SUBJECT IN THE 1ST SEMESTER OF UNDERGRADUATE PROFESSIONAL STUDIES IN ELECTRICAL AND CIVIL ENGINEERING

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Abstract

From March 2020 to February 2022, due to the COVID-19 pandemic, classes at the Polytechnic of Zagreb were organized in whole or mostly synchronously online. Such an organization required additional involvement of teachers in the preparation of online content intended for the independent work of students. The paper describes the authors' own teaching experience in the preparation and implementation of knowledge self-verification from the introductory mathematical subject in the 1st semester of undergraduate professional studies in electrical and civil engineering. The performance plan of the course provides for 120 hours of independent work of students, so every week students are given at least one self-check quiz (usually behind each lecture). All quizzes were implemented in Moodle using different types of exercises (multiple response, short-response, numerical, formulas, etc.), resembling those given in official exams. These exercises served as feedback for students, indicating that the class material needs to work more thoroughly, and for teachers as an indicator of which types of tasks need further practice in (online) group teacher-student conferences due to the perceived errors and difficulties in students' solutions.

Keywords: online self-verification of knowledge, types of exercises, introductory mathematical subject.

1 INTRODUCTION

Due to the outbreak of the COVID-19 pandemic, all educational institutions in Croatia had to switch to online teaching in March 2020. Before the outbreak, only a fifth of Croatian higher education institutions conducted classes online [1]. Therefore, 80% of institutions had to adapt to the situation in a very short time in order to preserve the continuity of the educational process. This included procuring the necessary IT equipment and educating teachers on the use of LMS systems. During June and September 2020, courses on the use of LMS systems and MS Teams were held at the Zagreb University of Applied Sciences [3]. In addition to other higher education institutions and faculties providing such courses internally, the University Computing Centre SRCE at University of Zagreb has organized a series of workshops and lectures on the use of technologies and tools for e-learning since the beginning of the pandemic [4]. Also, lectures related to work in LMS systems have been held regularly within the professional section of the Croatian Mathematical Society [5], in which teachers shared their experiences related to online lessons and tests, pointing out the difficulties and shortcomings they encounter.

At the time of this writing, the epidemiological situation in Croatia is very good, permitting a more-less normal social life. Almost all restrictions have been suspended, which enabled educational institutions to switch back to the traditional (contact) way of teaching. However, considering the unpredictability of the COVID-19 virus and a relatively low vaccination rate in Croatia, it unclear whether such organization of classes will be possible in the next academic year as well. Regardless of the current status and further development of the pandemic, the latter has permanently changed the way of teaching. Various studies have shown that LMS systems are a useful tool which should be considered as a supplement to classical teaching [5-7]. Providing reliable communication tools and promoting IT-supported learning at educational institutions is especially important because, in the long run, ignoring digital transformation in higher education is simply not affordable. To develop multimodal approaches to achieve course content objectives for better learning outcome can be a better idea to deal with the complexity of online education [8].

In this paper, the authors describe their experiences in using the LMS system to create teaching lessons and test knowledge in mathematical subjects. Although the presented experiences are related to the field of mathematics, they can be applied to other subject areas as well.

2 ABOUT LECTURE ORGANIZATION AND STUDENTS' MATH PRECOGNITION

2.1 Lecture organization

The implementation plans of the undergraduate professional studies of electrical and civil engineering envisage that the introductory mathematics course Mathematics 1 is conducted in the first semester with a total of 45 hours of lectures, 45 hours of auditory exercise classes and 120 hours of independent student work.

During the first semester 2020/2021, all teaching and tests were conducted online. MS Teams was used as a platform for giving lectures, auditory exercises and for meeting students during office hours. Moodle was used as a platform for in-semester tests and exams.

During the first semester of 2021/2022, all lectures were conducted online using MS Teams. Auditory exercises and exams were held in the classroom. Students could consult their teachers either traditionally, during office hours, or online via MS Teams.

Due to such organization of teaching, the corresponding e-course was created in Moodle in September 2020 containing teaching materials presented in lectures and exercises, as well as online tests and quizzes for self-assessment and examination. Based on the students' feedback received during classes and meetings, these materials were finalized and supplemented throughout the semester. The materials thus obtained were also used in 2021/2022 regardless of partially switching back to classroom teaching.

2.2 Students' math precognition

In each academic year, a total of 170 students (40 of whom are part-time) were enrolled in the study of electrical engineering and a total of 190 students (of which 80 part-time) were enrolled in the study of civil engineering. When enrolling full-time students, the success achieved by passing the higher-level mathematics exam at the state graduation exam was scored.

The second and third co-authors of this paper were members of the Commission for enrollment in the undergraduate study of electrical engineering. By assessing the enrollment documentation of students, they determined that in each academic year the mean grade of the state graduation mathematics exam is C. This sample of grades refers to approximately 25% of all students enrolled in the first year of undergraduate studies at Zagreb University of Applied Sciences, so the authors consider valid the hypothesis that C is the mean grade for all enrolled students.

Taking the above into account, the authors expected the students to have difficulties when trying to recall and use the high school mathematics knowledge necessary to understand the course. The hypothesis proved empirically correct in both academic years. The rather extensive curriculum of the Mathematics 1 course does not allow for adequate repetition of the required high school material within lectures and auditory exercises, so such repetition was mostly done during teacher-student conferences and through tasks intended for independent work of students.

A special teaching challenge in both academic years was working with part-time students. Some of these students did not take mathematics at the state graduation exam, and some graduated from high school before the introduction of the latter. Their mean grade in mathematics during high school was also C. However, in these students, significantly lower prior knowledge of high school mathematics material was observed in comparison with full-time students, mostly due to the larger temporal gap between high school and current studies. Hence more time was spent on repeating the necessary material of high school mathematics during the group teacher-student conferences.

3 STRUCTURE OF ONLINE SELF-CHECKERS OF KNOWLEDGE

The curriculum of the course Mathematics 1 in the undergraduate study of electrical engineering consists of a total of 21 thematic units. At the beginning of the semester, complex numbers arithmetic is taught, followed by the basics of matrix and vector calculus. Most of the semester, the basics of differential calculus and some of its standard applications are studied (function flow testing, modeling of simple optimization problems, etc.). This part of the material also includes the repetition of basic concepts about functions, definitions and basic properties of some types of elementary functions (polynomials, exponential and logarithmic functions, trigonometric functions), etc.

The first official knowledge test during the semester includes processed material from thematic units: complex numbers, basics of matrix calculus, basics of vector calculus and basic concepts of functions.

Students were provided with a total of 10 self-tests of knowledge, the last of which is the so-called "trial 1st test". Although all official knowledge tests held in the period from 2010 to the present are available to students in detail, the author's personal experience shows that such "trial" tests are additionally useful because they are solved within the same time interval (60 minutes) as "real" knowledge tests. Thus, each student can simultaneously check their own level of mastery of the material taught in class and their own ability to solve the set tasks within a given time interval.

The second official knowledge test includes the processed material from the differential calculus basics and applications. Students were provided with a total of 13 self-tests of knowledge, the last of which is the so-called "trial 2nd test". Its purpose is analogous to the purpose of the "trial 1st test".

At least one self-test was created in each week of the semester. The deadline for solving each self-test was not defined, so students could use them when preparing for the written exam. The time interval within which each individual self-test should be completed was set mostly at 60 minutes, which proved to be sufficient in practice.

Each self-test typically included five different types of tasks. Each task brought 1 point. The solving procedure is not scored, i.e., only the final answer of the student is scored. There were no negative points. A self-test is solved successfully if the student achieved a total of at least 2 points.

When compiling self-assessment tasks, the authors decided to use the following types of tasks implemented in Moodle:

- Multiple choice,
- Numerical,
- Formulas,
- Essay,
- Essay – science.

The latter type was used mainly in official online knowledge tests during the 1st semester of 2020/2021 because in these tests it was necessary to review and score the work as well as the solution for each task. Other types were used exclusively in self-tests of knowledge for the already mentioned reason of scoring only the final answer of the student.

Although the authors were aware of the shortcomings of this method of self-assessment of knowledge (copying, group assignments, etc.), they decided to reward students who solved self-tests as part of their independent work. For this purpose, they used the implemented functionality of the Moodle system, which provides one with information about the participants, including the time taken for each test and the scores of individual questions. Based on their own teaching experience, the authors assumed that there always will be students who will pass both official knowledge tests during the semester and who will lack 1 or 2 points to achieve a higher grade. For each such student who successfully passed the majority (at least 5 self-tests related to the first test and at least 7 self-tests related to the second test) the grade obtained by passing both official tests was increased by one.

Due to the epidemiological situation in which the classes took place, and especially the relatively large daily number of infected people on certain days, the authors did not insist on the regularity of solving self-checks. However, the authors are convinced that by normalizing the epidemiological situation, it will be possible for students to set the condition that to gain additional points, they must successfully solve one self-test each week. The purpose of this requirement is to facilitate continuous learning.

4 FEEDBACK

Online self-tests, together with solved exercises from classes and previous official tests, are available to students and are intended to assist them in preparations for the planned tests. In addition, the course syllabus prescribes the literature required or recommended for taking the exam. However, given the economic situation of a significant proportion of students and their families caused by the COVID-19 pandemic, the authors took the view that their own published teaching materials should be sufficient for students to prepare for their exams. Such an attitude is additionally justified by the facts that Zagreb University of Applied Sciences does not have its own library and that the number of users of reading rooms within the National and University Library in Zagreb is limited due to the still ongoing pandemic. Based on the feedback of students obtained by conducting both introductory and closing student surveys on the course, as well as spoken comments of students expressed in classes and teachers' office hours,

the authors conclude that this approach is indeed beneficial for students. There were no negative comments in the closing survey regarding the online teaching materials. Moreover, existing comments indicate that these materials, together with group teacher-student conferences intended for task practicing, were very useful to students for reviewing the material and preparing for knowledge tests during the semester.

The authors, on the other hand, used the results of self-tests to improve group teacher-student conferences in a way that types of tasks being perceived as more difficult for students to master are practiced more thoroughly. Several task examples illustrating these types are singled out in the rest of this section.

4.1 Example 1

Compute the volume of the three-sided prism spanned by vectors $\vec{a} = \vec{i} + 2 \cdot \vec{j} + 3 \cdot \vec{k}$, $\vec{b} = 2 \cdot \vec{i} + 4 \cdot \vec{j} + \vec{k}$ and $\vec{c} = 2 \cdot \vec{i} - \vec{j}$.

Solution: 12.5 cubic units.

This task belongs to one of the standard task types that are given in the first knowledge test. The authors expected that the most frequent incorrect answer in self-tests would be 25 cubic units because, by the previous experience, students tend to overlook the fact that they are dealing with three-sided prism. However, most of the incorrect solutions were not equal to 25. Talking to students revealed that the main difficulty was in fact the computation of the determinant of order 3. In class, such determinants were computed in two ways: by using adjunct and by Laplace expansion (with the help of elementary transformations), with the latter method being preferred. Three tasks of this type were solved in detail in one two-hour group teacher-student conference.

Note: The authors estimate that a maximum of 20% of students can compute determinants of order 3 on their calculators.

4.2 Example 2

Compute $f'(0)$, where $f(x) = \cos^2(4 \cdot x) + \ln^3(x+1) + \sqrt[3]{6 \cdot x - 1}$.

Solution: 2.

This task is one of the standard task types that are given on the second knowledge test. More than 80% of students failed to provide the correct solution in self-tests. In the conversation with students, it turned out that most mistakes were caused by applying the chain rule incorrectly, e.g. differentiating the first term in $f(x)$ as $2 \cdot \cos(4 \cdot x) \cdot 4$. The authors therefore organized group teacher-student conferences to practice using the chain rule in task examples. As a result, most students applied the chain rule correctly in exams.

4.3 Example 3

What is the maximum volume of a rectangular box, constructed from a piece of cardboard with area 972 cm^2, which has a square base and no upper lid?

Solution: 2916 cm^3.

Tasks of this type are solved in classroom exercises within the teaching unit Mathematical Modelling of Simple Optimization Problems. Generally, most students have significant problems solving these types of tasks. Moreover, based on their own teaching experience, the authors claim that most students have significant problems with mathematical modelling of practical problems like the one above. According to some students, they usually give up solving such tasks in advance because "they do not know where to start." The example above was used by the authors to determine the percentage of students who decided to solve this type of task within a self-test. It was solved by less than 10% of students who took the corresponding test. Therefore, the authors demonstrated solving several examples of such tasks in a group teacher-student conference.

The percentage of students who solved this type of task during the exam was approximately 20%, with about half of these students arriving to the correct solution. The emerging fact that only 10% of students can solve a problem task in univariate optimization correctly is not encouraging. Nevertheless, the authors believe that solving simpler optimization problems should be included in the prescribed learning

outcomes of the course because it encourages the understanding of the course material and creativity of students.

5 RESULTS

Based on the described implementation of self-assessment in combination with group teacher-student conferences, the authors believe that they have managed to shape and facilitate the independent work of students with sufficient quality within the given (primarily epidemiological) framework. Until the summer semester 2019/2020, none of the authors had any experience in online teaching. In other words, all components of all courses conducted by the authors were designed exclusively for the contact mode of implementation before the COVID-19 outbreak.

It should also be noted that the authors held group teacher-student conferences – as a kind of support for independent work of students – even before the pandemic. However, the concept of these meetings was based solely on the teaching experiences of the authors, i.e. on the subjective assessment of which types of tasks students find more difficult to master. Online self-tests of knowledge offered exact indicators of such types for the first time and enabled the implementation of "trial exams" which students could take at any time.

A particular component worth mentioning here is the transition from the high school system to the higher education system. From authors' experience, students have certain problems in adapting to the new teaching system which typically splits courses into lectures and auditory exercises. It has already been pointed out that study performance plans and programs do not provide for repetition of material prior to an official knowledge test, as is done in high school. A significant part of students has poor learning skills, so the role of self-assessment and group teacher-student conferences becomes even more important.

By comparing the results of in-class and online knowledge tests, the authors found that the pass rates are nearly equal. It therefore seems that creating additional teaching content intended for independent work of students was in fact not necessary. However, the authors believe otherwise. Namely, in the period when some of the components of teaching were conducted online, the accompanying life and social circumstances were significantly worse than in the period before the pandemic. The authors are convinced that these circumstances have left a mark on students and that pass rates in the pandemic period, without guiding and monitoring students' independent work, would ultimately be significantly lower than the respective rates before the pandemic. The student attitudes expressed in official surveys conducted during the pandemic period confirm the authors' belief.

6 CONCLUSIONS

In Croatian academic circles, one often encounters the view that online teaching in all its components should be abandoned as soon as possible, i.e. that the entire concept of study should continue to be maintained as it was in the pre-pandemic period. An argument to such standpoint is that a very small number of accredited studies in the Republic of Croatia have a permit for online teaching.

The authors believe that the traditional method of conducting the standard components of teaching (lectures, tutorials, etc.) of mathematics courses is significantly better and more appropriate compared to the online way. However, the authors do not agree with the view that no online component has a place in the teaching process. Moreover, the authors believe that students' independent work is much more focused and productive if being moderated by using e-learning systems such as Moodle (in addition to traditional teacher-student conferences) and that such methods could be used regardless of the (non)existence of an official permit for online learning.

Therefore, the authors intend to continue using online self-assessment of knowledge in the future, considering it to be an important tool for evaluating, monitoring, and encouraging independent work of students. Inevitably, a whole generation of students who have spent half of their secondary education online is going to be enrolled to studies in the following academic years, which will pose additional methodological challenges for teachers. The authors are convinced that combining contact and online components will be optimal in such situations.

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