Three-Level System for Teaching Mathematics in Engineering Education

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Abstract

Mathematics is the foundation on which the engineering studies are built on. Therefore, it is important to transfer the skills and the understanding of mathematics to the students in engineering in the very beginning of their studies. These courses are commonly known as 'service math courses', and teaching these courses provides challenges. Selected educational approaches as solutions for these challenges will be presented in this paper. The teaching method is divided into three levels of weekly exercise material, as well as three tests that need to be covered. Comparisons to the results of the same course a year before without the three-level system will be discussed. We will report on heuristics and show some results of the trail phase of this format. Examples of each level will be presented. A statistical analysis of the results and the student's engagement will be performed.

Introduction

In this contribution we present a new approach to constructing teaching and learning to increase student's motivation and at the same time offer support for the needs of groups with different mathematical backgrounds. One of the most common obstacles lecturers face while offering the so called 'service courses' is that the students of engineering discard the introduction to higher mathematics as not interesting, and partially unnecessary since the topics are not closely related to the subject of their studies. The second obstacle is that these courses are bound to deliver very complex materials in a short time and make sure that the content is understandable for the undergraduate students, which can be challenging at times.

We focus on the introductory mathematics course offered to students of physics, electrical engineering and geodesy and geoinformation. This will further be referred to as Mathematics 1. This course consists of lectures and complementary exercise sessions. In keeping with the concept of constructive alignment, the aim of the lecture is to impart definitions, concepts and relations between them, while during the exercise course students have to apply the knowledge they have acquired. The set of requirements for passing the exercise session course consists of weekly assignments and tests during the semester (Mid-Terms). The lecture course is completed by a final exam. The exercise materials, together with some materials for visualisation in the lecture, are done in Möbius which is supported by Maple.

Due to the COVID-19 pandemic, the importance of distance learning increased during the last year which made the students engage more with the electronic learning materials, and we can see grade improvement in the summer term 2020.

Structure of the course and first observations

Mathematics 1 in the summer term is a course that can be attended by the students of three different majors, and must be suited to their different interests, as well as different focus of their studies. The course is designed to be in three levels, in order to support students from different backgrounds and provide continuous assessment, as well as a lot of exercise material. The three – level assignments are provided on a weekly basis.

The first level must be completed by every student, and they need to score at least 90% of the available points. These examples are providing information and preparation on the topics and materials they should already know in order to follow the current material in the class. It consists mostly of problems and topics that are already, or should have been covered in school, or later during the term, in previous lectures. They can repeat these assignments as often as they want in a given time frame, and their best submission is graded. Each time they start an assignment again, they get a randomised version of the assignment, which provides necessary basic exercise material that is otherwise not available.

Only after they have completed the first level and refreshed or learned the necessary topics for the current exercise session, can they start with the regular exercise, or the second level. This is a traditional exercise, that is also covered in exercise sessions. Here, they have two attempts and need to obtain at least 60% in order to pass the course. These examples are given as homework and are also presented in by the students in a weekly exercise session. This requires deeper understanding of the topic and prevents the students from cramming the very broad material of this course short before an exam. Also, multiple solutions are discussed and explained, as well as some underlying questions that are clarified by a teaching assistant. After the start of the COVID-19 pandemic, these courses switched to online sessions with the use of Zoom. In summer term 2019 the students would present their solutions on a blackboard, whereas in 2020 they had distance-learning and presented their written solutions over a screen share. This unfortunately reduced the attention of the students that were not presenting, but on the other hand, more questions were asked, and the attendance increased. As already mentioned, they do not need to solve all of these examples in order to pass the class, but it is necessary to connect the skills they already obtained by solving the questions of the first level and new skills gained from the lecture. For each chapter covered in the lecture, a set of randomised exercises is provided as a practice for the test.

The third level is the so-called master class, and two to three examples are provided to the students each week, where a certain idea is presented, and they need to construct their own examples. Those problems are used to broaden the understanding of the subject and provide connections between seemingly different topics of the course. The students can gain bonus points if they solve these examples correctly, and this is not obligatory. In the next section, we will compare the final grades of the students who attempted these master class examples at least once, with the students who did not.

We will also observe some results from the summer term 2019 and compare it to 2020, to make a statement about the impact the exercise course has on the examination of the lecture. In 2019 the three-level system was not introduced yet, and the students only had weekly homework, which corresponds the current level two.

Our main goal in this system is to close the gap between the students of different backgrounds by providing enough exercise and preparation material for each of them, so they can successfully pass the course.

Presentation of Data

In this section grade distributions of the exercise session and the lecture are presented. In the summer term of 2020 particular attention is paid to the grade distribution between students who submitted at least one example of the last level and students who did not participate in the master class.

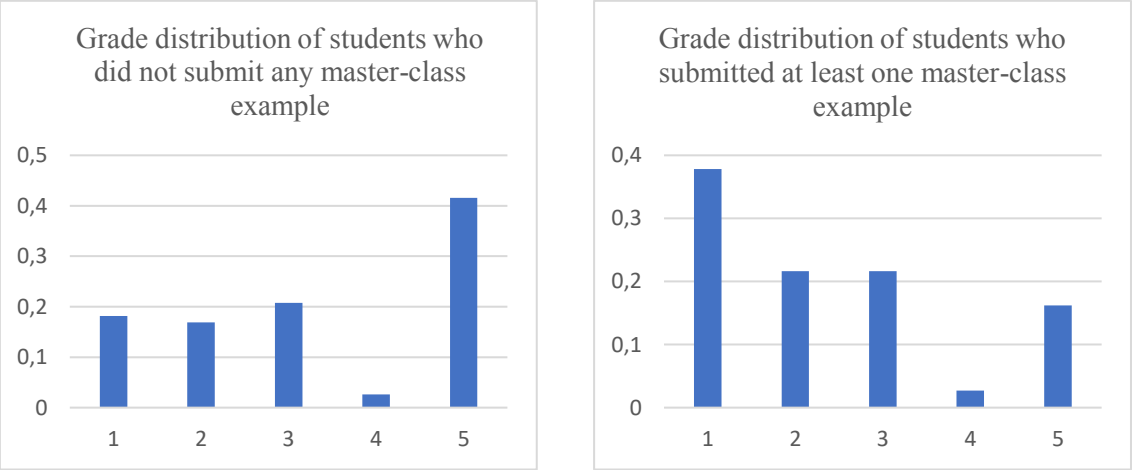

Figure 1. Grade distribution of students who did and did not participate in the master class in summer term 2020 in percentage terms.

In Figure 1 two histograms showing the grade distribution of the exercise session in 2020 are presented. In this term 37 students participated in the last level of the three-level system while altogether 114 students attended the exercise session. In this context a student is counted as a participant of this level if she/he submitted at least one example of the masterclass and presented it in the accompanying exercise.

The two histograms show that students who attempted last level examples showed significantly better results of the overall grade of the exercise session. About 37.8% of these students finished the course with the best grade, while only about 18.2% of those who did not attempt these examples managed to achieve the highest grade. The percentage of students who failed the course and did not participate in the master class is about 41.6%, which is more than two and a half times the percentage of those who did so. The share of grades between the best and worst grade is almost the same in the left

and the right diagram of Figure 1. For example, the percentage of students who got the grade 4, which counts as sufficient, is about 2% in both categories.

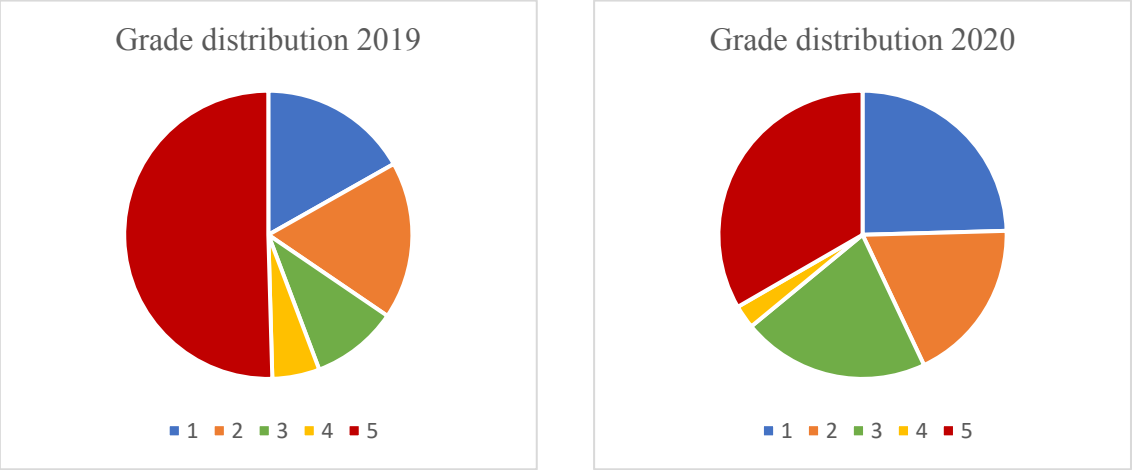

Figure 2. Grade distribution of the summer semesters of 2019 and 2020

Figure 2 shows the grade distribution of the summer semester of 2019 and 2020. This is of interest because in 2020 the three level-system of teaching mathematics was first introduced in engineering courses. In 2019 there were 113 students participating in the course, in 2020 there were 114. As we can see in the left diagram in Figure 2 the share of students, who failed the course, meaning they finished with the grade 5, is about half of the participants. The right diagram shows a smaller red region, in 2020 only one third of the participants could not successfully complete the exercise course. In contrast to 2019, where only about 17% finished the course with the highest grade, in 2020 this share is about a quarter of the students participating. The percentage of students, who finished the course with the second-best grade, is almost equal in both years with a total number of 20 students in 2019 and 21 students in 2020.

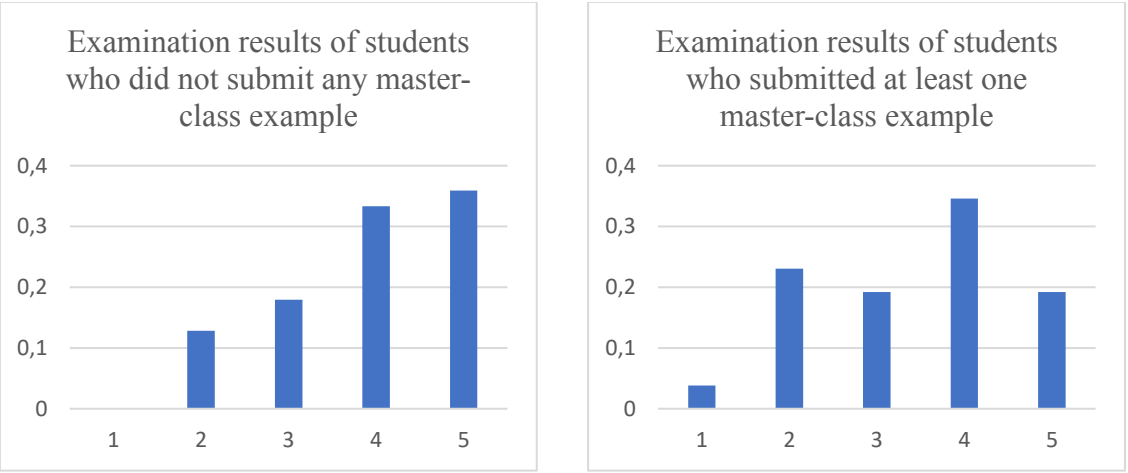

Figure 3. Grade distribution of the examination of the lecture of students who did and did not participate in the master class in percentage terms.

Altogether 65 students, who participated in the exercise session in 2020, took the exam of the accompanying lecture at least once. Figure 3 shows the grade distribution of the examination results of those students, divided into participants and non-participants of the master class. For this study, if a student took the exam more than once, the best grade was considered. About 20% of students, who submitted at least one master class example, and about 35% of the other participants of the exercise session could not pass the exam of the lecture. The ratio of participants, who passed the exam with the best or second-best grade and attended the master class, is more than twice as big as the ratio of students who did not.

Discussion of Results

The histograms in Figure 1 and Figure 3 both show that students, who submitted at least one example of the master class, are more likely to pass not only the exercise course, but also the examination of the accompanying lecture. Especially the grade distribution of the exercise course clearly suggests that also a higher ratio of participants of the master class managed to finish the course with the best or the second-best grade. Concerning the grade distribution of the examination of the lecture it must be considered, that only about half of the participants of the exercise course in 2020 took the exam. This is not unusual, since the lecture and the exercise course must not be completed during the same semester.

To check the influence of the introduction of a three-level-system in mathematical courses on the grades of the exercise course, the grade distribution of the summer semester of 2019 and 2020 was compared. In contrast to 2019, where only half of the students finished the course with a positive grade, about one third of the participants could achieve a positive result in 2020. Figure 2 clearly suggests that the introduction of a three-level-system has a positive impact on the grade distribution of the participants of the exercise course.

Conclusion and outlook

Based on the results of this study, it seems that the presented three-level system influences the grades of the exercise course and the lecture that goes with it. While Figure 1 shows, that participants of the master class also managed to finish the course with better grades, Figure 2 points out, that the number of students who completed the course with a positive grade increased with the introduction of the three-level system. Figure 2 also suggests, that since the exercise course was split in different parts with a clear evaluation in 2020, the scoring was more comprehensible, and therefore more motivating, than in 2019.

As shown in Figure 3, students, who submitted at least one example of the master class, were more likely to pass the exam, than those, who did not participate in the last level of the system. Hence, it can be concluded, that the introduction of the three-level system does not only have a positive impact on the exercise course, but also on the accompanying lecture.

This three-level system was further developed in the summer term 2021, but since the semester is not over yet, there is no data to evaluate. The exercise materials in Möbius and clear communication of requirements for the course got positive feedback from the students, so it is planned to introduce similar methods to other courses taught by our group. One of these courses is Practical Mathematics for Technical Physics, which is to be done in the winter term 2021.

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