Technology-supported Teaching of Modeling and Simulation in Inverted Classroom Format

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Abstract. Modeling and simulation is an interdisciplinary field requiring several competences. Due to this interdisciplinary nature and diverse set of skills that it imposes, teaching modeling and simulation in a university setting poses specific challenges. To confront this issue and contribute to the ongoing discussion on alternative methods of teaching, this paper proposes an inverted classroom approach, combined with a digital training system, as a means of teaching modeling and simulation.

The proposed approach aims to address this challenge of teaching multiple aspects in the right quantity and pace for all participating students. The paper presents a teaching concept for a lecture and exercise on modeling and simulation and evaluates the effectiveness of different tools in various settings of the course from the lecturer's perspective. The importance of appropriate technology integration and an engaging learning environment as the means of supporting the students in independent studies is also discussed

Introduction

Modeling and simulation is a field that uses mathematical and physical methods to derive and build structural models based on equations and physical principles (known as first principal modelling).

The interdisciplinary nature of modeling and simulation makes it challenging to teach in a university course. It typically takes several semesters for students to learn the basics and even then, there is still much to do before in-depth teaching can begin.

Modeling and simulation have long been used to teach STEM (Science, Technology, Engineering, and Mathematics) subjects, emphasizing the significance of applied mathematical methods. In this context, alternative methods to teach modeling and simulation in these subjects were discussed at the beginning of this century; see, e.g. [6] and [7]. It is noted that, when teaching basic courses in modeling and simulation, several aspects should be covered: mathematical methods, physical principles and programming. However, teaching all these subjects in the right quantity and at the right pace to meet all the requirements of the participating students is challenging. One possible solution is to change the teaching style from a classical lecture and exercises to an inverted classroom, also known as a flipped classroom, combined with an accompanying digital training and testing system.

While the integration of technology has been shown to be effective at all ages and can be beneficial for students with special learning needs [1], it is important that it is used appropriately and not simply transferred from one medium to another [2].

Seeking to address these findings and encouraged by the proven effectiveness of the inverted classroom approach, we present the teaching concept in a lecture and exercise on modelling and simulation for mathematics students at TU Wien.

We will specify the use of different tools in different settings of the course and discuss their effectiveness from the lecturer's perspective. Another objective of this approach is to increase the support for independent learning typical of the inverse classroom environment and address the negative influences in the inverted classroom setting in a university context, as reported by [8].

1 Course Structure and Educational Components

Courses in the curriculum of mathematics at TU Wien are divided into lectures for theoretical foundations and exercises for independent application of methods. Modelling and simulation is an elective course taken by students at the end of the Bachelor's program and the beginning of the Master's program. The course instructors are confronted with an inhomogeneous variety of students' knowledge.

Prerequisites for following the course are basic knowledge of analysis, linear algebra, differential equations, and programming - preferably MATLAB©. Analytical aspects needed to understand modeling approaches, such as behavioral models and transfer functions, can be effectively presented in the lecture. However, solving differential equations and programming in MATLAB requires a more hands-on approach. To equip the students with the tools to gain a comprehensive understanding of the matter and allow them to progress at their own pace, the exercises have been enhanced with eLearning tools.

1.1 Technology-enhanced Exercises

The traditional exercise setting consisted of homework and project work that students had to complete. Starting both aspects in parallel with the lecture was not possible due to the lack of programming skills for the project work and some missing skills related to differential equations. Incorporating eLearning tools to cover the training of differential equations and MATLAB programming in the first part of the semester enabled students to equalize their knowledge and receive higher-quality teaching.

For MATLAB training, the TU Wien license offers an online academy for students and staff. This academy consists of webinar lessons on various topics, and lecturers can decide which lessons are necessary for the course.

By providing only these academy lessons, students will benefit significantly.

For evaluation of students' skills and timely provision of feedback MATLAB Grader is used, see [3]. Handily, the grader environment can be connected and integrated into established learning management systems, e.g. Moodle, by learning technology interface (LTI).

MATLAB Grader puts us in a position to support students' learning by providing them with relevant examples. The tool manages randomization, automatically grades students, and provides feedback to help them improve their skills in a targeted manner. In the typical setup for an example specified in the MATLAB Grader environment in Moodle, the task specification is located in the upper part, the middle part is reserved for the student's MATLAB code, and the lower part provides automated feedback and assessment.

Enforcing students' skills in handling differential equations requires another eLearning system. Möbius, a testing and assessment system based on the computer algebra system Maple, with its randomization and grading capabilities, was our tool of choice. Importantly, for modeling and simulation education, the system allows instructors to select and create assignments on the pertinent chapters of differential equations that students need to understand in order to pass the course. The system's randomization capabilities allow for a continual offering of new exercise material on demand. It also provides immediate feedback and enables a more personalized and active learning environment. In [4] an in-depth instruction on the use of Möbius, formerly named Maple T.A., and its application in engineering education at TU Wien is presented.

1.2 Inverted Classroom Lecture

Since the COVID-19 pandemic, more non-classical teaching strategies have been adopted at TU Wien. One such format is the inverted classroom approach, which allows for a different approach to teaching in higher education, exemplarily see [5]. This concept was deemed suitable for addressing a diverse group of students and enabling them to progress through the lecture material at their own pace.

In line with this idea, video streams of the different lecture content modules were provided to the students.

The distribution was managed through the Moodle system of TU Wien, where a plug-in called “lecture tube” was developed for this purpose. The in-person lectures turned into Q&A sessions for the videos being provided. To give a link to the exercises, the specifications of the future exercises were also discussed and questions from the students were answered live.

The Q&A sessions were used to support the students with use cases of MATLAB examples in preparation for their project work. The specification of the project work was handed over after the MATLAB academy and grader sessions, and the submission and presentation of the project work were at the end of the semester. During the semester, the small examples given during the meeting sessions guided and instructed the students latently.

2 Discussion

The proposed didactic approach of an inverted classroom for modelling and simulation courses at TU Wien addresses the challenges that the teaching of interdisciplinary university courses poses. It extends the conventional inverted classroom approach by incorporating a digital training system in the domain-specific context.

Digital training systems offer immediate feedback to students, which helps them to better understand the material and become more engaged with the subject matter. This approach allows for a more active, hands-on learning experience in an inverted classroom setting, while still allowing students to equalize their knowledge and learn at their own pace. Additionally, instructors can provide personalized guidance and support in form of Q&A sessions.

Over the years, student feedback has been very positive, particularly regarding the effective use of time to better link lecture content with exercises. The on-demand availability of resources for interactive exercises is another appreciated feature of this approach. Its scalability makes it a suitable solution for a wide range of courses, allowing for a greater number of students to benefit from it. With this teaching approach, lecturers have a reliable tool to effectively instruct students and provide a more personalized and effective approach to teaching complex concepts.

Nonetheless, it is important to continuously evaluate and refine the approach so that it remains responsive to the changing needs of students and the academic landscape. Our goal for the future is to analyze the students’ results from the MATLAB Grader and Möbius assignments and examine the correlation between these results and examination scores. This will allow us to better assess the effectiveness of the proposed approach and identify potential areas for improvement.

If we look in detail at the questionnaire and the answers given by the students, they consider the application to be easy to use and helpful in teaching the subject, and they recommend it for use by other students.

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