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Educational Course Concepts for Applied Modelling and Simulation

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Abstract

Modelling and Simulation is an important aspect of developing new technologies. Therefore it is a valuable subject in every technical university, as well at the TU Wien. In this contribution we present two different courses regarding mathematical modelling and simulation to compare both concepts. One of these courses is offered in electrical engineering and the other in applied mathematics. In these courses different modelling methods, dealing with discrete as well as continuous models, are taught to enable students to apply them for the problem based simulation tasks provided. We will motivate and describe both concepts in detail to discuss its advantages and disadvantages.

Keywords: Modelling and Simulation; Problem Solving; Education Concepts; Applied Mathematics; Engineering Education

1. Introduction

Nowadays various applications are going through a prototype phase which often includes analysing a corresponding computational model. Regarding advanced state of the art technology, the included software mostly consists of a models to determine predications and calculate parameter settings. Focusing on future developers of such technologies, it is important to provide them with a fundamental but also problem based education to enable creative and independent solutions (Boud and Feletti (1997); Dolmans et al. (2005)). The main difference between applied universities and technical universities lies within the focus of their courses . At the TU Wien for example, undergraduates are mostly confronted with courses developing the fundamentals and theoretical background. Especially in mathematics practical applications are often neglected due to the theoretical focus. In engineering studies the number of applied courses such as laboratories and exercises is higher.

Hence, the course concepts we present in this work are designed to activate students and enable experimenting with given methods to find an independent solution to the given task, combining example study and problem solving effectively (Renkl et al. (2002)). In the following section we will motivate and describe both concepts in detail. Hereby we will focus on the practical hands on problem solving aspect and its implementation. In the end we share the evaluation of the courses.

2. State of the Art

In modelling and simulation, similar to other courses dealing with programming, practical components are essential to enable students to develop their own model simulation. Although the problem-based approach is a controversial method with inconclusive implication for knowledge-increase, it is said to improve student's skills with respect to application knowledge, as discussed in Dolmans et al. (2005)). The work of Dolmans et. al also states, that learning should be constructive, self-directed, collaborative and contextual. In the context of the problem based approach this can be achieved by the following actions:

- students have to formulate questions to what they need to solve the presented problem (*constructive*),
- students have to play an active role in planning and evaluating the solving process (*self-directed*),
- students are encouraged to interact with each other to share problems and experiences (*collaborative*) and
- problem-based examples provide the preferred professionally relevant context (*contextual*).

Additionally, due to the fact that modelling and simulation includes state of the art computational tools and requires a certain amount of programming skills, a modification of the agile manifesto alignment as mentioned in Isong (2014) can be applied. In this work, the important points to enable agile processes are the following:

- enable working in pairs of groups,
- avoid passive listeners and engage students actively,
- support the learning progress with teacher's active involvement, and
- respond to changes accordingly.

In the next section we will present the two course concepts and elaborate which of the aspects, described above, are tackled.

3. Course Concept

TU Wien provides the possibility to use Moodle as Learning Management System (LMS) to support a more interactive learning and teaching approach. For the enrolment in the university and in each course another administration system is used, which is obligatory. Our research group, called Mathematics in Simulation and Education, is responsible for various courses including basic as well as advanced mathematics for engineers and applied courses in modelling and simulation for the following fields of studies:

- Mathematics
- Electrical Engineering
- Mechanical Engineering
- Computer Science
- Business Informatics
- Data Science

In each of these courses we implement a blended learning structure to enhance students' learning experience, as discussed in (Poon (2013)). We believe that a certain amount of face-to-face meetings enhances the motivation to stay on track but also enables students to connect to the lecturer and other colleagues. Additionally, it enables direct and immediate questions if something is not clear.

```
function [optimum] = calibrate(scenario)
...
while notFinished
    ...
    [distanceToHole]=masm(angle,speed,scenario);
    if isOptimal(distanceToHole+speed/10)
        optimum=[angle,speed];
        break;
    end;
end;
...
end
```

Figure 1. Function Template

In this contribution, we lay our focus on the two courses "Methods in Mathematical Modelling and Simulation" (MMMS) for students of the electrical engineering faculty and "Applied Modelling and Simulation" (AMS) for undergraduate students from the mathematics department. The two modelling and simulation courses are both based on three fundamental components: lectures, case studies and hands on experiences including feedback. In the following, both concepts are described in detail.

3.1. Methods in Mathematical Modelling and Simulation

This course is included in the curriculum of a master in electrical engineering. Its goal is to provide students with the tools to design solutions for problems for continuous systems, empower them to implement their ideas in MATLAB and analyse the performance of their own algorithms. The course consists of a three hour lecture and a two hour exercise. In the lecture different methods for modelling and simulation of continuous systems are presented in a more or less frontal teaching situation. In contrast, the goal of the exercise is to maximize the involvement of the students. For this purpose there is a problem-based task defined for each topic presented in the lecture. The problem motivation uses real world scenarios to enable the connection between the learned methods and their application and provides the necessary context. The problem definition requires students to create their own MATLAB function to solve the given task, typically a well specified question (see Figure 1) solved by a numerical algorithm which can be chosen freely. The students have to work self-directed and constructive to decide which or which combination of the algorithms discussed in the lecture might solve the task (best).

To support the evaluation process of their exercise, the predefined structure of the resulting function enables additional features. Each task comes with a corresponding so-called "score-function", such as depicted in Figure 2. By executing this file, the student's solution is tested for different case studies resulting in a detailed feedback for the students. Additionally, a final score value is displayed, which compares the student's implementation to a predefined teachers solution with

Score-Funktion *Für die Scoreberechnung wird der Kalibrierungsalgorithmus für alle 6 verfügbaren Bahnen (Szenarien) $s \in \{1, \ldots, 6\}$ jeweils 5 mal ausgeführt $i \in \{1, \ldots, 5\}$ (um stochastische Schwankungen abzufangen). Für jeden Durchlauf flißen die Rechenzeit des Kalibrierungsalgorithmus $t_{s,i}$ und der Fehler $err_{s,i}$:=distanceToHole+speed/10, der aus den kalibrierten Parametern resultiert, in den Score ein:*

$$score := \frac{1}{15} \sum_{s=1}^{6} \sum_{i=1}^{5} \frac{1}{1 + err_{s,i} + t_{s,i}}.$$

Der Score wird manuell auf 0 gesetzt, sofern diese Prozedur länger als 5min rechnet.

Figure 2. Score Function

respect to different target values, relevant for these kind of algorithms in real applications, such as numerical accuracy and speed. Hence, the course instructors are able to provide students with immediate feedback as well as an additional competitive aspect for motivational purpose. If applicable the score file additionally provides a visualisation for the comparison. Since the student can adapt the implementation with respect to the specific task, their solution can and typically does exceed the performance of the comparison file.

Attending students are mostly at the end of their bachelor program or at the beginning of the Master program. Hence, most of the students attend the course with other colleagues and use different channels to exchange their experiences and scores. This communication also requires them to develop specific questions whos answers are feasible for their progress. After uploading the finished MATLAB function, the teacher starts evaluating each contribution separately. In the following face-to-face meeting, students have to present their solution and explain their motives for the chosen method. The latter helps not only the presenting student but also the other students in the class to understand which methods are applicable and their advantages and disadvantages. Looking back at the important aspects of learning and the agile manifesto, one can see, that the exersice covers all of this points.

3.2. Applied Modelling and Simulation

In contrast to the elective course presented above, the AMS course is offered to undergraduates in mathematics and focuses on the modelling and simulation aspects of discrete models. This course does not separate strictly between lecture and exercise, but it intertwines both aspects. Each week there is a lesson, consisting of a mixture of lecture, case studies and hands-on tasks. The topics are of different length and for each of them, a problem-based task is formulated. If a method is presented in one single lesson, the second part of this lesson contains a short hands-on exercise. For topics which require multiple lessons, a more complex task is defined to enable the application of each aspect mentioned.

Each of the given tasks results in an executable MATLAB function. Compared to the exercise definitions of the MMMS course, there is no score function included

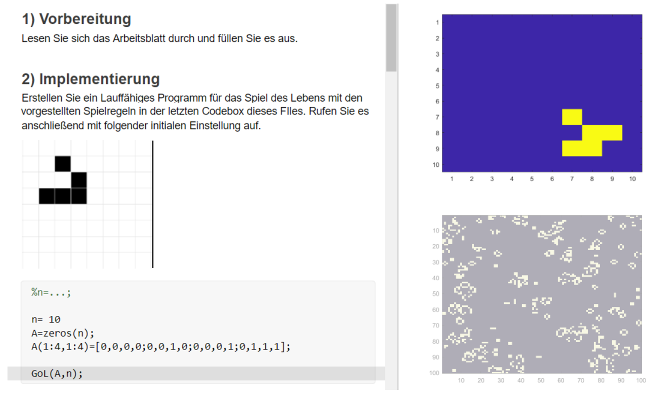

Figure 3. MATLAB Live Script

as the tasks are too diverse and the quality of the solution cannot be measured fairly. Instead it is possible to use visual output to verify and validate the simulation results. To support the students in the development process, the tasks are embedded into a so-called live script, as depicted in Figure 3. This file starts with a questions they have to answer in the course of developing their routine using the materials from the lecture. This script defines the context of the example and contains a specific structure to enable building a main implementation and add small routines to answer the different tasks of the exercise. Compared to an ordinary MATLAB file, the live script provides the visual response embedded into the layout. Additionally, students can add their own documentation and hence, generate a protocol-like file. This enables students to explain their idea not only by using commented code but by creating a small presentable document.

Comparing this concept with the bullet points regarding the aspects of good learning, one can see, that the constructive aspect is supported by the leading questions in the file and the contextual facet is given by the actual problem definition. Similar to the concept before, the students are encouraged to interact with each other to find their personal problem solution. In doing so, their work is self-directed and collaborative. If the communication with peers is not sufficient, the teacher is available and can be bother with any additional questions.

3.3. Distance Learning Changes

The courses are eager to adapt and improve the concept after each course. In 2020, the outbreak of the COVID-19 pandemic resulted in changes during the semester. Hereby, the basic idea of the two course structures were not changed, yet there were minor adjustments to recreate the face-to-face sessions and converting them into online meetings. The lectures as well as the regular feedback meetings in MMMS were done with Zoom. We also made an attempt to recreate hands-on experiences by providing small tasks, and defining a meeting time after one hour to follow up to remove any obscurities. Even in this mandatory distance learning scenario, we believe that it is important to enable face-to-face interactions, even if only possible via online meetings.

Compared to the courses held the years before, we experienced a rising number of enrolments since we immediately started conducting teaching not only with material distribution but also with online lectures and exercises. The concept enables an easy transition to distance learning. In the following section we summarise the students feedback.

4. Feedback Evaluation

Compared to the usual number of enrolments at approximately 12-17 students, the MMMS course jumped up to 30 students. Therefore the time effort for evaluating the exercises and prepare the feedback increased accordingly. The feedback questionnaire contains 5 scaling questions (2 totally applied, −2 does not apply) und 5 open questions. The results of the students' feedback at the end of the course can be summarised as follows:

- The students attended the lecture quite frequently (mean 1.6786).
- After completing the course, the students are able to decide which method is appropriate for a given task (mean 1.4543).
- The exercises are helpful for understanding and applying the taught methods (mean 1.8214).
- The effort necessary to solve an exercise was sometimes too much (mean 0.5357).
- The number of exercises was sufficient (mean 0.1667).

When asking openly to comment on the lecture and the exercise, the possibility to record the lecture due to Zoom lectures in 2020 as well as the used online tools were very much appreciated. The structure and combination of lectures and exercises was successfully coordinated. Some the exercises are related too time-consuming. But apart from that, the chosen context and task as well as the score function are mentioned as motivational factors. When asking for changes for the next year, a desire for even more detailed feedback for each student was raised. Additionally, students were asking for the best routine for each exercises. After discussing the feedback in the last lesson, we ask everyone for their permission to share all contributions in Moodle so that they can look up other solutions whenever they are confronted with similar problems. In the AMS course the number of attendances was ten (last year: six) and so only an oral feedback was gathered. The overall time effort was rated to high, so next years' exercises will be reviewed to minimise its efforts. It was stated, that the live scripts in MATLAB provided a supporting structure, especially for novices in programming. Even for the last exercise, where the format was open, some of the students chose the structure of a live script. Again, the format of lecture and exercise as Zoom meeting was complemented.

5. Conclusion

In 2020 the enrolment in both courses has risen significantly since they were one of the first offered in an online format. Both courses are elective subjects, and therefore there are usually no drop-outs in the exercise. If students decide to attend the course they usually finish it if the are willing to invest time into the exercises. Even more so due to the great engagement of both, teacher and learner.

Year after year we adapt and improve specific aspect of the course. Also the content and the problem definitions are adapting to include past feedback and current research topics. In both courses we added a module about machine learning and created according problem tasks. By the same token, a topic about COVID-19 modeling has been included as part of the lecture and embedded in the exercises in 2020.

In conclusion, the combination of lectures and immediate corresponding exercises is a motivating concept. To avoid standard minimalised approaches, tools, such as the score-function, result in very positive feedback. A format, such as the live script, can be an important support structure for students with no prior programming experience.

In the future we are thinking about combining the approaches of both courses to benefit from the advantages of the live script as well as the score-function.

References

Boud, D. and Feletti, G. I. (1997). *The Challenge of Problem-based Learning*. Routledge, 2nd ed edition.

Dolmans, D. H. J. M., De Grave, W., Wolfhagen, I. H. A. P., and van der Vleuten, C. P. M. (2005). Problem-based learning: future challenges for educational practice and research. 39(7):732–741.

Isong, B. (2014). A methodology for teaching computer programming: first year students' perspective. 6(9):15–21.

Poon, J. (2013). Blended learning: An institutional approach for enhancing students' learning experiences. 9(2):20.

Renkl, A., Atkinson, R. K., Maier, U. H., and Staley, R. (2002). From example study to problem solving: Smooth transitions help learning. *The Journal of Experimental Education*, 70(4):293–315.