Reflections on flipped classroom and digitized laboratory concept in building automation courses

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Abstract. In the last decade, innovative digitized teaching concepts were developed to improve the learning environment of students. Also due to actual restrictions concerning classroom teaching during the corona pandemic, these concepts are increasingly spreading in daily university life.

This article describes our experience of the last five years with digitized lecture and laboratory based on the flipped classroom concept. A comparison to the classic teaching form is difficult to achieve in daily university practice. Thus, the paper reflects the applicability of flipped classroom format for control engineering and building automation based on subjective experiences of students and tutors, as well as lecturers.

Keywords. Digital education, flipped-classroom, blended learning

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1. Introduction

Many of us can still remember the following scenes from a basic lecture: a crowded lecture hall, a seat on the stairs, the professor writes formulas on one of the three blackboards at an incredible speed, while his assistant is already cleaning the blackboard just described. Questions are not asked, only a few dares to interrupt this process - or have time, because the next board threatens to be cleaned.

To the advantage of today's students, the number of such lecture formats has decreased significantly, also due to increasing didactic training of professors. In addition, many innovative teaching concepts to improve the learning environment of students have been developed in the last decade, which - also due to the restrictions on classroom teaching during the Corona pandemic - are increasingly spreading in everyday university life.

2. Flipped Classroom

In lectures based on the flipped classroom concept [1,2], students independently develop teaching topics or competences that they apply and deepen during presence phases in small groups under close guidance of lecturers. This format is particularly widespread in basic lectures with a large number of students in order to counteract attitudes of students towards reception, to activate them for teaching content and to extend the learning process to the entire semester.

Flipped classroom goes hand in hand with a competency orientation in teaching, i.e. sub-competencies of a teaching module must be identified and their achievement over the semester must be timed. The application and deepening of these sub-competencies take place in presence phases, which are characterized by intensive supervision of the students.

In the self-study phase, students are provided with teaching materials via online media. These are videos for lectures and exercises, but also introductions to laboratory experiments and instructions for the operation of laboratory hardware and software can be offered digitally in preparation for lab experiments or projects. Even during the self-study phase, the students are closely supervised by lecturers and tutors, who discuss exercises or problems that arise in office hours or forums.

A flipped classroom format combines different learning processes of students: an individually shaped self-study process, a peer learning process during tutorials, and group work process during presence phase. To check the preparation and performance of the working groups, a test before starting the presence phase is a good idea.

3. Building automation courses

3.1 Principles of control engineering

The lecture principles of control engineering are offered to students of the Renewable Energies and Energy and Building Technology courses in the 3rd semester (about 350 students) – in combination with

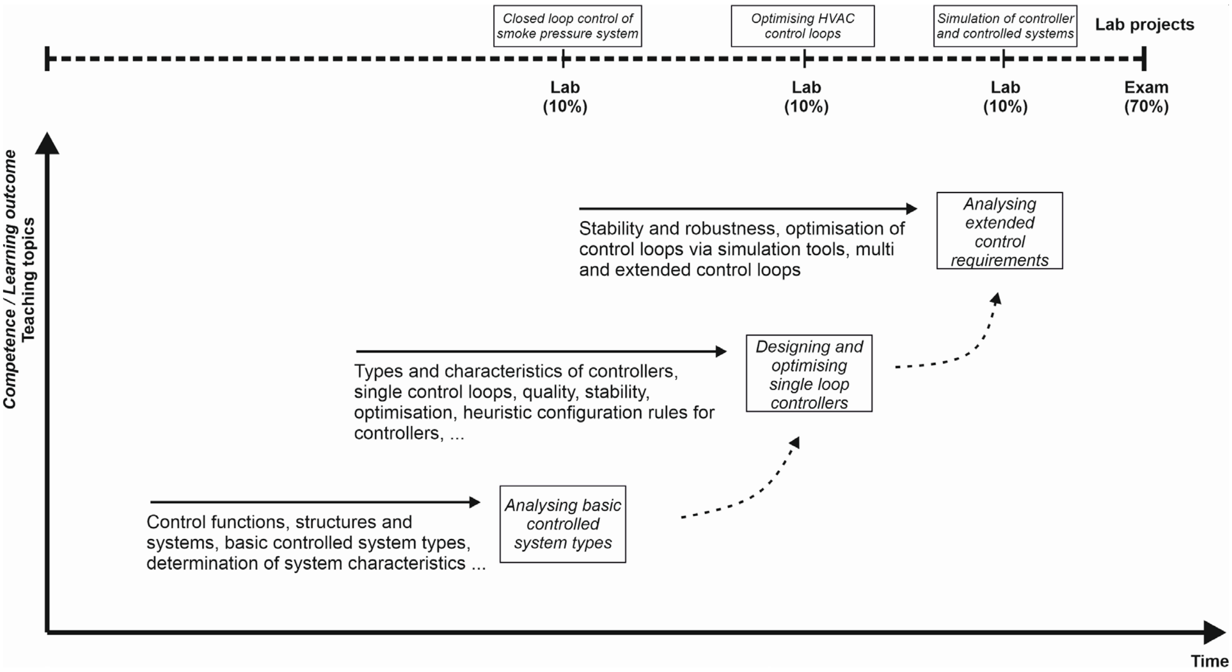

Fig. 1 – Learning outcomes and structure of control engineering

the basics of measurement technology in one module. The measurement part of the module follows a classic teaching format, 2017 the flipped classroom concept has been implemented for the control engineering part. The final competence in control engineering is the analysis of a building technology system from a control engineering perspective and the design and commissioning of a stable and optimized control. For this purpose, the students understand the means of describing control engineering tasks, characteristic curves, variables and behavior of control circuit components, properties and behavior of continuous and discontinuous controllers, control circuits and their stationary and dynamic behavior (Figure 1).

In control engineering, the aim is to achieve the expected final competence in three steps. Focus of the first learning phase is an introduction to controlled systems and the ability to analyze those. Building on this, the students develop competences to design and optimize a simple control task based on heuristic setting rules. This competence is deepened in the third learning phase through stability analyzes of control circuits and the use of simulation programs to optimize them.

The preparation for the presence phases is checked by means of a certificate by means of Ilias E-Assessment. After successful implementation, submission and debriefing of a laboratory report by the working groups, its result contributes to the overall result (10% each). An individual examination of the final competence is also carried out by means of a written exam (70%).

3.2 Principles of building automation

The desired final competence of the lecture principles of building automation (5th semester of Energy and Building Technology course, 100 students) follows a basic workflow of automation technology practice. It consists of the design, planning, implementation, commissioning and operation of an automation function in building technology. For this purpose, the students understand the means of description of building automation functions, function and functionality of the fundamental system components in the field, an at automation and management level, as well as methods for programming automation functions and apply this knowledge to their implementation. The students analyze basic problems and aspects of building automation and independently design solutions in terms of sustainable and optimized building operation. Prerequisites for the module are competences acquired in the modules plant hydraulics, control engineering and building system technology, basic system engineering (heating and cooling systems, air conditioning and sanitary technology), as well as the introduction to digital data transmission and information technologies.

The teaching of the topics in the self-study phases currently follows the classic teaching format for lectures and exercises (a flip is planned for the upcoming winter semester). Introductions to laboratory experiments and instructions for handling laboratory hardware and software are available in the form of instructional videos. The

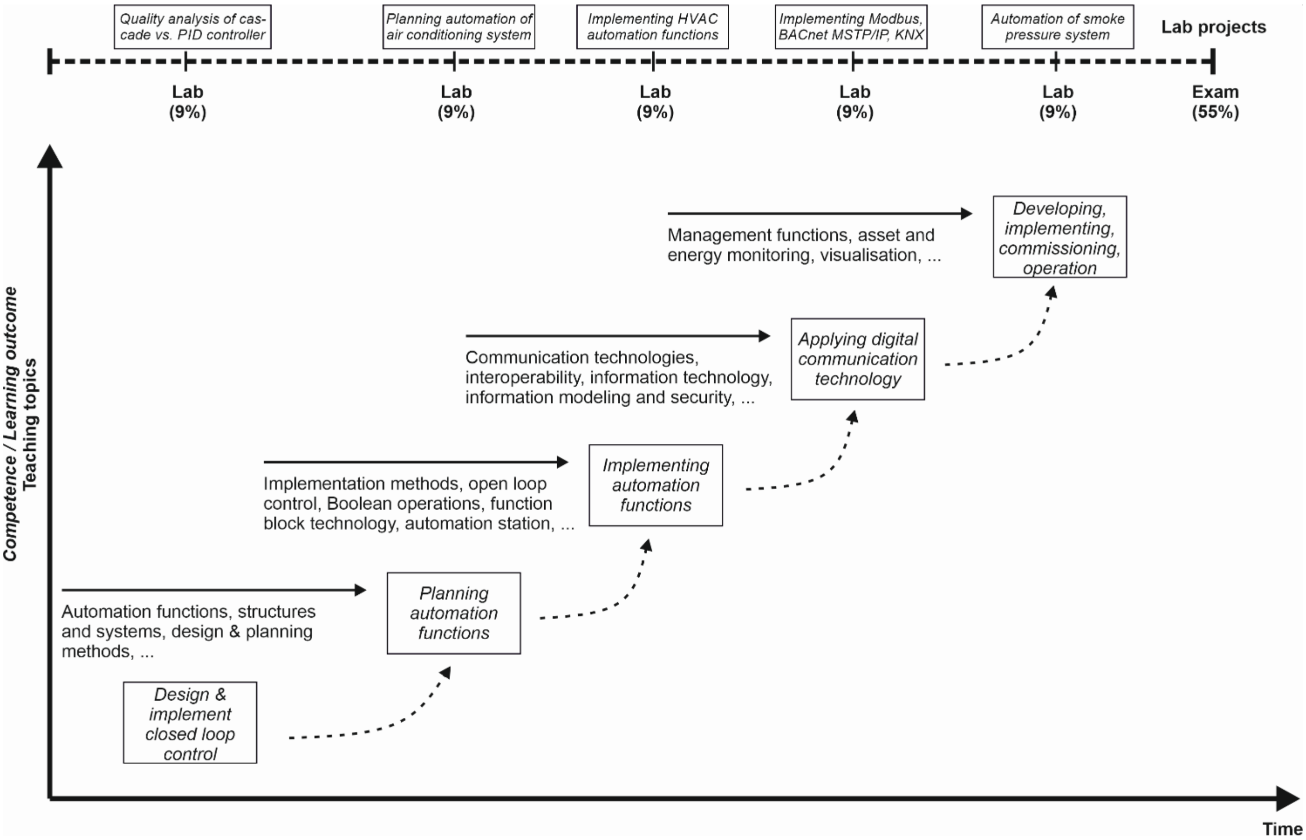

Fig. 2 – *Learning outcomes and structure of building automation*

competency orientation of the module, the application and deepening of partial competencies in presence phases, as well as the structure and sequence of the presence phases correspond to the flipped classroom concept (Figure 2). As in control engineering, lecture content and exercises are discussed individually by students and tutors during office hours. The teaching content developed in preparation for the presence phases is also checked in building automation in the form of certificate (9% each), and achievement of the final competence is assessed in a final examination (55%).

The final competence of principles of building automation is achieved in five steps. At the beginning of the module, control engineering skills are checked in a first presence phase, the subsequent step generates competences for the creation of planning documents of a HVAC system. These serve as the basis for the configuration of an automation station and the implementation of function block networks for the automated operation of the HVAC system. A deepening of skills for the use of digital communication technologies and the analysis of interoperability is the focus of the fourth competence step, the final level brings together all previous competences for the automation of a smoke pressure system and adds the skill for design and implementation of technical building management applications.

3.3 Teaching infrastructure, laboratory facilities

Teaching videos on YouTube are available for the self-study phases of the students [3].

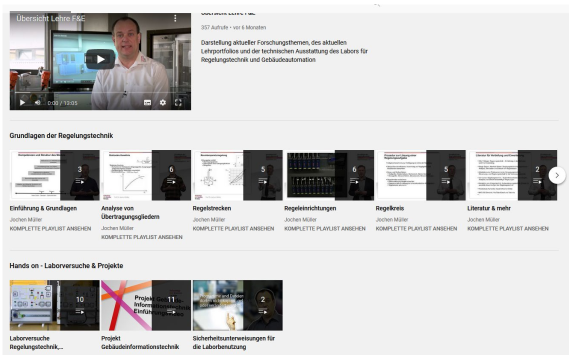

Fig. 3 – YouTube channel with teaching videos for lecture and laboratory experiments

Teaching videos are provided in a structured way for the self-study phases via links in the central teaching platform Ilias. To deepen the teaching topics, interactive exercises are integrated into the teaching videos via an Ilias-H5P [4] integration (Figure 4). An individual discussion of the exercises takes place in daily office hours, its content is individually designed by the students via forum contributions.

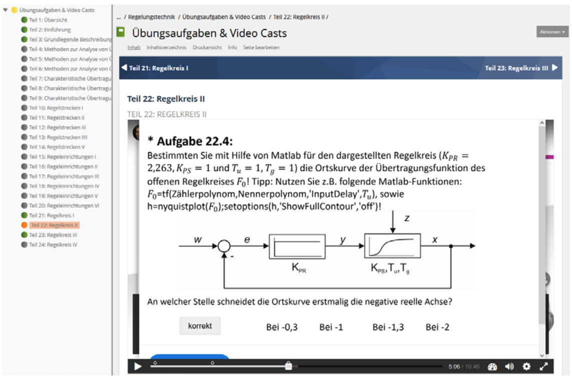

Fig. 4 – Teaching videos with embedded exercises in Ilias-H5P

Focus of the technical facilities [5] of the laboratory are in the areas of control engineering, digital communication technologies, automation of building systems and optimization of operational processes in technical building management. The automation of technical building facilities in the laboratory is integrated into lab experiments, in addition training systems are also available. Around twenty automation stations from different manufacturers are currently in use. Widespread digital communication technologies of building technology are used for information technology networking. Local and cloud-based solutions are available for the visualization of plant information in technical building management applications (Figure 5).

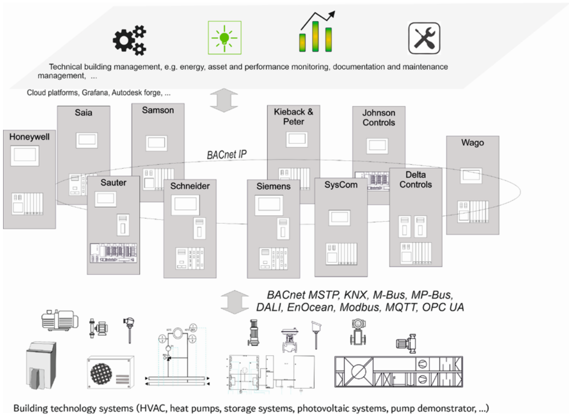

Fig. 5 – Technical facilities of the laboratory

Laboratory experiments within the principles of control engineering and principles of building automation are carried out simultaneously on six experiment facilities. The working groups of up to maximum five students are led by three lecturers resp. tutors. Under corona conditions, laboratory experiments take place via a zoom conference or in a hybrid form - by sending one student to the laboratory and a parallel zoom connection of the remaining group members.

A virtualized 360° laboratory [6] (Figure 6) serves as a central access point to laboratory experiments and the experimental rigs.

Fig. 6 – Tour in the virtualized 360° laboratory for building automation

Students enter the virtual laboratory, explore it, determine at the experimental setup (Figure 7) and receive videos explaining tasks and implementation of the experiment, as well as how to operate the hardware and software used.

Fig. 7 –Virtual exploration of laboratory experiments

In addition, direct access to teaching materials in Ilias is possible via links in the virtualized laboratory (Figure 8).

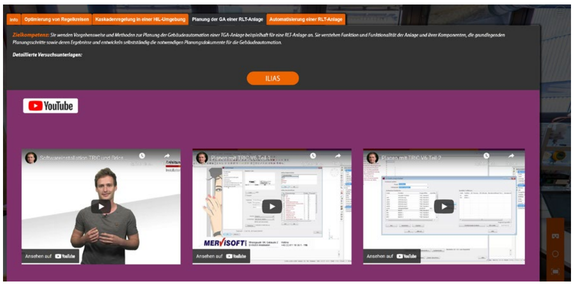

Fig. 8 – Central access to teaching materials via virtualized laboratory

4. Reflections

An objective comparison of courses in different teaching formats is not possible at this point. Conclusions about the performance of a course, analyzes of teaching quality, the desired target competences vs. the feasibility of the module etc. are affected by the individual characteristics of students and their annually changing composition. Analyzes based on a targeted compilation of comparable students and a parallel implementation of a teaching module in different teaching formats are not available. Therefore, the following reflection on the applicability of the flipped classroom teaching format in modules of control engineering and building automation is based on the subjective experiences and feedback of the students and tutors as well as the lecturers in comparison to the classic teaching format.

The flipped classroom concept is suitable for activating students in courses. Working in small groups during the presence phases reduces the inhibition threshold with regard to questions about problems of understanding. The peer learning process through tutoring also lowers this inhibition threshold. Many difficulties or ambiguities can thus be clarified before the presence phases. The concept is therefore particularly useful for courses with a variety of students, e.g. for basic lectures. For elective modules with a small number of students, the great effort involved in creating teaching materials must be weighed against the benefit. This analysis should also include the stability of the teaching content, e.g. in the case of special elective modules related to research.

The self-study phase considers the individual learning characteristics and capacities of students. They can fix the scope, but also the time and place of acquiring teaching content themselves. The distribution of the presence phases over the semester, as well as the verification of the required teaching content and competences through certificates, extends the learning process of the students to almost the entire semester. This is also reflected in increased efficiency in the implementation of laboratory experiments or projects.

Overall, the failure rate has fallen in both modules in recent years (with stable learning outcomes), which is attributed to improved activation of the students and an expansion of the learning and examination process.

Critical to the successful implementation of the flipped classroom teaching format is a sufficient number of face-to-face phases and an intensive supervision of the students by lecturers. For example, three presence phases are to be regarded as insufficient for the desired final competence in control engineering. Close tutoring of the students during the self-study phase is also very important. Communication channels must be established for the short-term solution of problems of understanding. Fundamental to the success of a flipped classroom teaching format is the quality of teaching videos. They should always have a clear reference to the desired competence of the following presence phase. By embedding exercises in teaching videos, a sense of achievement is created, which additionally motivates students during the self-study phase. The participation of students in teaching videos or the creation of videos by tutors also resulted in positive feedback.

5. Conclusions

Are universities still needed when teaching materials are available via YouTube? Sure, because the key to flipped classroom is the teaching and deepening of subject-specific competences through intensive support of the students during the presence phases. Flipped Classroom does not replace lecturers or save staff, the use of resources remains the same or is increased. The improvements in the quality of teaching justify these investments.

The high effort involved in creating attractive teaching materials motivates closer cross-university cooperation between professors. Because a legitimate question is certainly whether a large number of these experts should devote a similar amount of effort to creating similar instructional videos, e.g. about common function block technology.

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

6. References

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