Evaluation of a Learner-Centered Activating Learning Situation with Large Cohorts in the University

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***Abstract*—This Research to Practice Full Paper presents the evaluation results of a didactic concept for activating a large cohort of students in a classical lecture hall. The aim of the concept is to reduce factors that lead to study drop-out. The didactic concept is based on problem-based learning and flipped classroom approaches and enables the control of problem solutions via a remote laboratory. Developed according to the design-based research, the concept is tested in information technology courses in 2019 and 2020 and evaluated with a SOLOMON design. The activation of the large cohort basically worked, but the majority did not work on the problem-based tasks without extrinsic motivation. The results show that variables of the factors study motivation (interest in future jobs $p < 0.001$) and application orientation ($p = 0.002$) can be significantly improved by the didactic concept. The factor performance problems (e.g. workload $p < 0.001$) is rated significantly worse by the experimental group students, while their examination results in problem-oriented tasks, however, improved significantly by more than $50\,\%$ ($p < 0.001$).**

***Index Terms*—student-centered, active learning, large cohorts, remote lab, learning system, university drop-out, problem-based learning, flipped classroom**

I. Introduction

Drop-out rates in engineering subjects at German universities are high (approx. $40\,\%$) [1]. Therefore, universities are challenged to adapt teaching concepts to the students' needs and to the necessary qualifications of future engineers. In a literature analysis, the authors in [2] state that especially programming skills, process understanding, analytical skills, creativity, problem-solving abilities as well as communication and teamwork skills count among the key competencies of future engineers [2] due to Industry 4.0. This term is understood as a comprehensive networking of production components, from the customer order to delivery [3].

Furthermore, the Centre for Higher Education Research and Science Studies (CHERSS) has been investigating the causes of academic dropouts at German universities for more than a decade [1]. The CHERSS records the reasons for dropouts in a questionnaire that is continuously adapted. In the survey of 2016, $6,029$ dropout students from 60 different German universities were interviewed. Nearly three quarters of all dropouts are caused by one of the following three factors: "performance issues" (F1), "motivation to study" (F2) or "the unfulfilled wish for application orientation" (F3). The factor "performance issues" is assessed by using the variables "exam quantity", "requirement level", "performance pressure", "personal suitability for the subject" and "lack of prior knowledge". The factor "lack of motivation to study" is valued by the variables "false expectation of studying", "disinterest in professions that are accessible through studying", "waning interest" and "poor labour market opportunities in the field of study" as well as "scientific working methods". The third factor, "application orientation", is recorded by the authors using the variable "lack of professional and practical relevance in the study programme" [1].

Based on the requirements for future engineers as well as the fact that a teacher has an influence on the dropout factors F1-F3, we have designed a didactic concept to reduce these factors. The concept enables learner-centred activating teaching in a classical lecture hall with large cohorts (more than 100 students). The concept, following the design-based research approach, was implemented and evaluated for the first time in 2019 and in an optimised form in 2020. The following theses will be investigated:

1) Learner-centred activating teaching in a lecture hall with large cohorts is possible using digital media and appropriate methods together with a learning system.
2) The more learner-centred and activating the courses in university education are organised, the lower is the risk that students will experience failure in their studies.

II. Related Work

A. Activating Teaching

Activating Teaching is a didactic principle in which learners inform themselves independently or in a collaborative form about content and work on tasks. They also plan and realise problem solutions controlling, presenting and reflecting on their results [4]. Research shows that by activating learners, especially higher learning goals (analysis, synthesis and evaluation) can be achieved. Activation should take place holistically (head, heart, hand), as better learning performance can be obtained in this way [5], [6], [7]. Likewise, the authors in [8] observe better learning performance highlighting that learners can thus apply their knowledge appreciating the practical significance for their later work as engineers. Motivation through practical relevance is crucial for learning performance [9]. [10] state that learning achievements, independent of ability, can be predicted from interest in the subject as well as performance motivation. Furthermore, information and communication technologies, together with appropriate methods, software tools and interactive experiments, contribute to motivating and activating learners [5], [11], [12].

In addition to positive research results, there are also reports of challenges and conflicts that arise in activating teaching. Based on several studies, the authors in [13] summarise these observations as follows: In a course on real-time systems, students were asked to solve complex problem tasks in individual groups and to present the results a plenary session. The students strongly criticised this course because, in their opinion, they only learned teamwork and presentation skills. Students mentioned in the course evaluation that they expected a lecturer to teach them concepts and terminology. Moreover, the examination method, which consisted of a presentation and a reflection discussion, was also criticised. In another course, in the field of human-computer interaction, students worked on a project with the further incentive that the best project group would be allowed to present its results to an audience of economic representatives. The lecturer reports that this had no positive effect on the students' performance motivation and that, in the evaluation, the presentation was criticised as an additional workload which was not necessary to pass the course. These two examples show that the teacher's extracurricular (learning) goals do not always match those of the students and learning activities are avoided by some students [4], [13].

B. Problem-Based Learning

Problem-based learning (PBL) is an activating method in which students independently identify, model, solve and review problems in a learning situation [14]. Therefore, they are at the centre of the learning situation. In comparison, the traditional teaching method often only imparts content knowledge. Especially critical thinking and problem solving skills are not promoted [15] [16] [17]. In contrast, the PBL approach encourages professional [15], personal and methodological competences [18].

The PBL approach has been studied in different disciplines [19], with the result that a learning situation with PBL approach has an influence on factors related to the reasons for dropout. Various studies demonstrate that PBL has a positive influence on learners' motivation, curiosity and information exchange [18], [20], [21]. Furthermore, PBL can have a positive influence on student performance. However, this depends on gender, ethnicity, socio-economic status and language proficiency [22], [23]. In [20], student performance is compared between an online PBL course and an online instructor-led course showing that PBL course students achieve better exam results in terms of critical thinking skills. However, there are no significant differences regarding content knowledge. The authors in [21] came to a similar conclusion. They formed a control group (CG) and an experimental group (EG) with the EG being taught using the PBL approach and the CG using the traditional teaching method. Both groups were tested with the same written exam, whereby the examination results (total score) of the EG were significantly better than those of the CG.

C. Flipped Classroom

The flipped classroom approach, like the traditional approach, has two learning locations. In the flipped classroom approach, however, they are reversed, so that the learners familiarise themselves with a topic at home in a self-directed and asynchronous way. For this purpose, they use various materials such as books, scripts, videos and presentations [25], [26]. The time in the lecture hall is used to deepen the content. The students are active and solve problems in a collaborative form [24]. They also discuss their results and reflect on the learning process. The time spent together in the lecture hall is thus better used for interactive activities [27], [28].

In [29], [6], the authors demonstrate that, by using the flipped classroom approach, student performance can be increased depending on the target group. For advanced students, this approach may not be suitable. Depending on the specific subject area and abstraction or complexity, it is more difficult for students to acquire content basics themselves [30]. A disadvantage of the flipped classroom approach is that students often do not prepare for the course, though pre-tests can remedy this [31].

III. Learner-Centered Activating Teaching

A. Didactic Concept

The didactic concept developed by the authors aims to actively engage a large cohort of students in a classical lecture hall. The main goal is to reduce the factors that lead to students dropping out of their studies. The requirements for future engineers should be equally taken into account, which is why our concept is based on the PBL approach (cf. II.B). In the following, the concept is first presented and then substantiated.

The learning situation is centred on a problem that relates to an end product (e.g. a manufacturing plant) according to action-oriented learning (fig. 1). Further, it is assumed that the cohort of students is inhomogeneous. Therefore, the students prepare for the course individually at home (home setting). This structure follows the flipped classroom approach (cf. II.C). The students first *inform* themselves about the problem and the end product. For this purpose, the lecturer provides work and information sheets as well as video tutorials via a learning system (LS). This LS is a self-developed learning management system and further described in the next chapter. The students then *plan* possible solutions to the problem, e.g. a timing chart. Afterwards, the students *decide* between different solution approaches enabled by a checklist or quiz in the LS. The students receive feedback on their planning from the automatically evaluated quizzes.

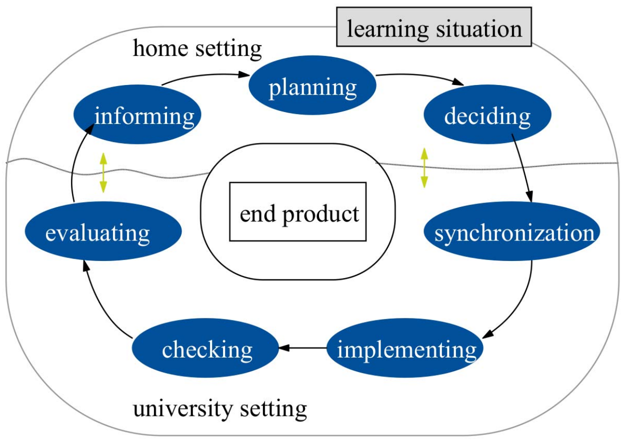

Fig. 1. Didactic concept

The course (university setting) begins with the *synchronisation* phase. The lecturer discusses in plenary problems that occurred in the home setting and uses quiz question statistics from the LS for this purpose. Furthermore, students and teacher discuss different planning options. Next, the students *realise* their solution in groups, using their planning or the planning option selected in plenary. The lecturer supports the learners in case of problems. Afterwards, exemplary solutions are presented by students in the plenary. To *check* and evaluate the results, the teacher brings a model of the end product to the lecture hall where the students' solutions (e.g. a programme) are directly applied to the end product. By observing the reaction of the end product, the solution is controlled in a real environment. The students discuss the solutions in plenary and suggest improvements, if necessary. The university setting closes with a reflection phase. The students *reflect* on the problem solving process. They also evaluate the learning situation and provide feedback to the lecturer (e.g. with a target) using tools in the LS.

Due to the large cohort of students, not every student can test their solutions on the end product in the lecture hall. Therefore, the concept includes the end products as part of a mobile remote laboratory. This enables the students to check their solution on the end product from home. Access is granted via a remote lab management system, which is part of the LS.

Furthermore, it may not be possible to complete the realisation and control it in one university setting because of the complexity of the task. Thus, it is conceivable to shift steps of realisation or control to home setting or steps of preparation into the university setting. In Fig 1, this flexibility is illustrated by the vertical double arrows.

The learner-centeredness of the didactic concept results from the consideration of the students' prior knowledge, interests and learning styles. In addition, the concept is activating, since the students carry out all work steps independently in all phases and thus creative individual problem solutions arise. The didactic concept presented enables the consideration and implementation of these two characteristics, especially with a large cohort.

We have chosen the PBL approach, as the activities of an engineer emerge from complex problems (e.g. from a set of requirements and specifications). This has been already proven in other studies [32].

In addition to the PBL approach, the learning situation process is based on action-oriented learning. Action-oriented learning is a holistic form of teaching, in which the learners are at the centre of the learning situation. The actions of the learners in all steps are related to an end product as well as to their later work as an engineer or natural scientist. We have chosen this approach in order to create a stronger application orientation of the contents, a major wish of the students and often mentioned by dropouts. The use of an end product, which exemplifies a real model, clarifies this reference and also promotes intrinsic motivation [18], [20], [21].

Moreover, we have included flipped classroom in our didactic concept, since the auditorium in university lectures consists of students from different study courses and thus previous knowledge is often inhomogeneous. By individual preparation, the students can familiarise themselves with the topic in a self-directed way. Furthermore, the provision of multimedia learning materials (texts and videos) takes different learning types into account. In addition, the time spent together in the lecture hall can thus be used for collaborative learning [24].

The quiz system is used to automatically transmit feedback to the students. Through early feedback, misconceptions can be quickly identified and avoided. Feedback on correct answers is also important so that the students can be sure that their performance is correct.

B. Learning System

In the previous chapter the didactic concept is described. Due to the large cohort, the implementation of the concept is not possible without a LS. The LS is web-based and can be accessed with any internet browser. It consists of several subsystems described below.

One important subsystem is the remote lab management system. Via this system, the students have the possibility to upload their results from the step realisation and apply them to the end product. The execution of the uploaded programmes takes place according to the first-in-first-out queue principle. After completion, a video and error message file is available to the students. With this data, students can check their solution and identify errors. The lecturer has the possibility to control access to the Remote Labs, manage queues and run diagnostic programs for the end products. A more detailed explanation and specific examples of remote experiments can be found in [33], [34], [35].

The auditorium system (fig. 2) supports the lecturer in the lecture hall. The students can mark their seat on a virtual lecture hall seating plan and draw attention to problems using a traffic light. For this purpose, they can choose the colour green (no problem), yellow (small problem, but I can continue to work), red (I can't get any further without help). Moreover, the students can set their work progress on a scale. The lecturer can see all the students' current problems in an overview and thus support them in a prioritised way. In addition, he can view statistics on the processing progress to better estimate the required processing time.

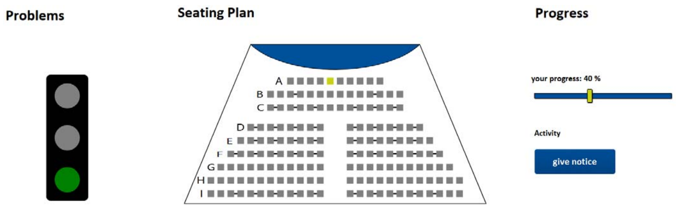

Fig. 2. Lecture hall system

With the quiz system, students can participate in quizzes that are automatically evaluated. The quizzes can be single or multiple choice, matrix or sorting tasks. Students have multiple attempts to take the quizzes, can see their own answers and sample solutions, as well as a top 20 list. The lecturer has the possibility to create and manage quizzes and view anonymised quiz statistics.

Furthermore, there exists a feedback system with which the students can reflect and evaluate the learning situation. Students can view and answer reflection questions of the same type as in the quiz system.

C. Course and Exemplary Learning Unit

In 2019 and 2020, the concept was tested with more than one hundred students in the course "Industrial Control Systems and Real Time Systems" at "Leibniz University Hannover" in Germany. The participants studied electrical engineering, mechatronics, energy technology, (technical) computer science or industrial engineering. We estimate that there was an average of about 50 students in attendance during the 2019 summer semester and significantly more in the 2020 summer semester with 102. They were at least in their fourth bachelor's semester or already in the Master's programme and had previous knowledge of at least one programming language (e.g. C or Java). The relevance of integrating the didactic concept into courses in electrical engineering and computer science at our university is evident from the dropout rates. In these courses, about $40\,\%$ of first-year students drop out of their studies.

The course content included both the characteristics and programming of industrial control devices as well as selected aspects of task management. Programmable logic controllers (PLC) and microcontrollers were used as control devices.

The above-mentioned contents were explained theoretically in a 90-minute lecture using a presentation with examples. After each lecture, there was a 90-minute practical course in which the contents were deepened in an application-oriented way according to the concept presented. In accordance with the concept for the practical course, suitable end products were selected and realised for application in the course as a remote laboratory.

Below an exemplary learning situation is described based on the subject didactic concept. The aim is for students to learn the storage and retrieval process in a high-bay warehouse by controlling a stacker crane and conveyor belt via PLC.

At the end of the previous learning situation, the teacher motivates the students for the home setting by explaining the problem (control of a high-bay warehouse) and the tasks. In the home setting, the students inform themselves about the end product, the process and the PLC programming language sequential function chart (step informing). For this purpose, the students use information and worksheets, video tutorials from the LS and the lecture material. The students then plan the process for the conveyor belt subsystem on the basis of a state graph (step planning) checking their planning in a quiz in the LS (step deciding). During the university setting's synchronisation phase, the lecturer first addresses frequently wrongly answered quiz questions. Furthermore, 1-2 students present their state graph in plenary. Afterwards, the students implement the control programme for the conveyor belt (step implementing). At the end of the university setting, 1-2 groups present their programme in plenary. The lecturer brings the high-bay warehouse (end product) into the lecture hall for all students to observe the control at the remote laboratory via its cameras and the beamer (step checking). Finally, the solution and the problem-solving process are critically discussed in plenary (step evaluating). In the subsequent home setting, all groups can check their solutions from home via the remote laboratory. Furthermore, the students plan the control programme for the next subsystem (stacker crane), which will be realised together in the next university setting. At its end, the learning situation is qualitatively and quantitatively evaluated by the students in the LS on the basis of guiding questions. Due to the Corona pandemic, all university setting in 2020 took place as a video conference and the students implemented the problem solution either alone or in a private videoconference as a group.

D. Optimisation of the concept

After the first implementation, the didactic concept has been optimised. On the one hand, we noticed that the remote laboratory was only used by a few students and also that not all students had completed the tasks in home setting [34]. On the other hand, there exists a significant positive correlation between the number of remote accesses and exam results. For this reason, the students of the second implementation could voluntarily collect bonus points for the final written examination. In groups of three, they were able to work on three learning situations (one each on the topic of "PLC", "microcontroller" and "task management") with problem-solving-oriented tasks including a remote experiment. The students were tested orally on their solutions and assessed individually. A maximum of three points (one for the remote experiment, two for the oral test questions) could be achieved for each task. They received a further bonus point if they had participated in

TABLE I
STANDARD UNIVERSITY QUESTIONNAIRES

no.	variable	1	2	3	4	5
Q1	The course is well-structured.	fully agree				disagree
Q2	The teaching methods are appropriate.	fully agree				disagree
Q3	Teaching content is taught in a comprehensible way.	fully agree				disagree
Q4	Questions and concerns of the students are addressed.	fully agree				disagree
Q5	I can describe and explain the covered content.	fully agree				disagree
Q6	Students were encouraged to ask questions.	fully agree				disagree
Q7	The presentation (use of media/chalkboard/slides) was good.	fully agree				disagree
Q8	The lecturer has spoken clearly and loudly enough.	fully agree				disagree
Q9	You find the required workload for this course to be ...	very high				very low

all quizzes during the home setting. In total, a maximum of 10 bonus points was possible which corresponds to a maximum bonus of 20 % for the final written exam.

In the evaluation, the students criticised the high workload. For this reason, some tasks have been adjusted in terms of their scope. The contents however, have remained the same.

IV. Evaluation

A. Research Design

The didactic concept and its optimisation according to the design-based research as well as the two theses above have to be evaluated. The students from 2019 (EG19) and 2020 (EG20) form the experimental groups. The control group consists of the 2018 course students (CG18), who had a passive role during the exercise.

In order to answer the first thesis from Chapter I, we consider the evaluation results of the didactic concept as well as the qualitative evaluations of the LS and the accesses to the remote laboratory. The concept's evaluation is carried out on the basis of standard university questionnaires after two-thirds of the lecture period. In 2019, this took place in the lecture hall, in 2020 via links sent by e-mail. Furthermore, supplementary questionnaires were used in the LS for the specific evaluation of the concept. The evaluation of both data collections was performed quantitatively according to quality criteria and is shown in table I. For the quality criteria, the arithmetic mean of CG18, EG19 and EG20 is calculated using the SPSS Statistics software and tested with the U-test for two-sided significance [36]. In addition, the teacher's observations are taken into account.

For the second thesis from Chapter I, a research method inspired by the Solomon design is used [37]. EGs and CG received a pre- and post-questionnaire on dropout factors F1-F3 on their first and last day of the semester. The first questions relate to their previous study experiences. In the post-questionnaire, the factors refer to this course. The alteration $(x_{post} - x_{pre})$ is calculated for all variables and tested for two-sided significance using the U-test. Table II shows the pre-test questionnaire.

B. Results Didactic Concept and Hypothesis 1

Fig. 3 shows the results of the evaluation ($n_{CG18} = 66$, $n_{EG19} = 10$, $n_{EG20} = 41$) based on the quality criteria of the university-standardised questionnaire. It can be seen that the mean value of structure, teaching methods, teaching competence and learning success has slightly, but not significantly decreased in EG19 compared to CG18. The criteria learning climate, activation, use of media, comprehensibility and workload were rated better by EG19 than CG18, the difference, however, is also not significant. In the second implementation, all criteria were rated significantly better by CG18 than by EG20. The criteria media use and comprehensibility were not included in the modified questionnaire (due to the Corona pandemic) used in 2020.

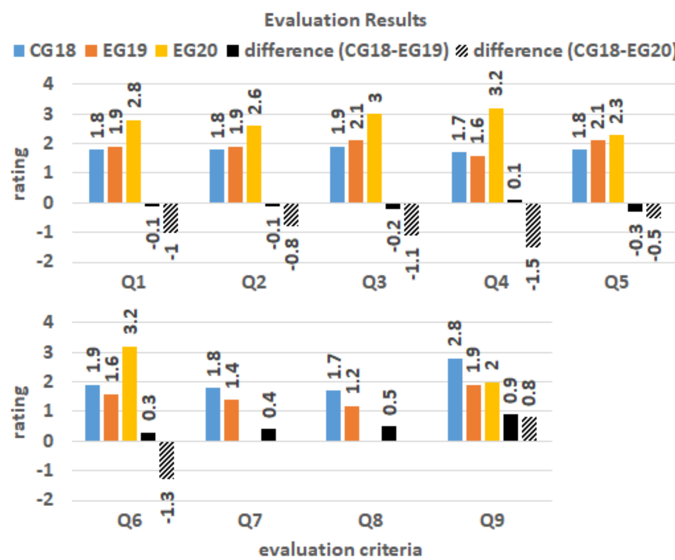

Fig. 3. Arithmetic mean of the evaluation questions Q1 to Q9

In addition, the students of the EGs ($n_{EG19} = 113$, $n_{EG20} = 182$) were asked via the LS which aspects of the course (problem-based assignment (PBL), control of the programmes on the remote laboratory (RL), video tutorials (VT), quizzes) were motivating for them. Table III shows the results of this multiple-choice question. More students of EG20 than EG19 find the problem-based tasks, the remote experiments and the quizzes motivating.

Based on other studies about flipped classrooms, which have shown that students do not always prepare for the course [31], the students were asked about their reasons for not doing so. In this multiple-choice question, the students had the following options: no time due to university workload (OP1), no time for private reasons (OP2), unable to complete the task (OP3), not knowing which task to complete (OP4), task not understood (OP5), no benefit for the exercise (OP6). Table III shows that

TABLE II
PRE-TEST QUESTIONNAIRE FOR THE FACTORS F1, F2 UND F3

no.	variable	1	2	3	4	5
F1.1	The workload during the studies (quantity of content, number of home exercises, examinations, laboratory tests, ...) I found	too little		just right		too much
F1.2	The performance level during the studies (complexity and abstraction of tasks) I found ...	too low		just right		too high
F1.3	The pressure to perform during the studies (15 ECTS per semester, limited number of attempts at examination, frequency of course and examination) I found ...	too low		just right		too high
F1.4	The courses I have taken during my studies have influenced my choice of subject ...	not all		unaffected		to agreat extent
F1.5	If I lack previous knowledge for a course, I can usually...	not compensate				compensate
F2.1	My expectations (content, independent study organisation, own ability to perform) with regard to the studies have been ..	not confirmed				confirmed
F2.2	My interest in future jobs available on the basis of my study course is...	low		unchanged		high
F2.3	My interest in the contents ... during my studies	decreased		unchanged		increased
F2.4	I estimate my job market chances after completion of my studies to be ...	very bad		unchanged		very good
F2.5	During my studies I discovered that science (e.g. mathematical modelling) ...	is not my thing				is my thing
F3.1	The teacher has established links between theory and practice.	strongly disagree				strongly agree

TABLE III
DISTRIBUTION OF MOTIVATING FACTORS

	PBL	*RL*	*VT*	*Quiz*
EG19	42 %	35 %	32 %	23 %
EG20	49 %	50 %	26V %	44 %

TABLE IV
DISTRIBUTION OF THE REASONS WHY STUDENTS DO NOT WORK ON ASSIGNMENTS IN THE HS

	OP1	*OP2*	*OP3*	*OP4*	*OP5*	*OP6*
EG19	45 %	38 %	25 %	15 %	12 %	7 %
EG20	52 %	36 %	18 %	18 %	13 %	10 %

there are no significant differences between EG19 and EG20. The main reason why students do not work on the tasks in the home setting is that they did not have time because of university and private appointments.

Furthermore, we asked the students how often they checked their problem solutions on the remote laboratory. Table V shows the results of the single-choice question. It can be seen that the real percentage of students, who use the remote laboratory always or often, has risen from 20 % to 46 %.

The evaluation results show that only a part of the students in 2019 actively participated in the course. The activation could be improved with the additional extrinsic motivation through the bonus points. Only 20 % (30 students) of the EG19 had ever done a remote experiment (141 experiments in total). The lecturer's observations show that the majority of students present in the lecture hall actively worked on the tasks and used the lecturer's support. The students rated the learning situation well and considered the problem-based tasks and the remote laboratory as motivating. However, the students' free text answers indicate that they did not see the need to do the remote experiments in order to pass the final exam. During the second implementation, over 140 EG20 students accessed the remote laboratory more than 3, 000 times. During

TABLE V
FREQUENCY DISTRIBUTION OF THE REMOTE LABORATORY'S USE

	always	*frequently*	*mostly*	*rare*	*never*
EG19	2 %	18 %	19 %	44 %	18 %
EG20	22 %	24 %	26 %	24 %	4 %

the university setting, only a few students took advantage of the lecturer's support in the video conference. Also, only a few, sometimes none, presented solutions. Furthermore, the learning situation was also rated significantly worse. The students criticised especially the high workload, the teaching competence of the lecturer, planning uncertainties due to the Corona pandemic and the waiting times for the remote laboratory's execution.

The first thesis cannot be answered with certainty due to the facts presented above. In principle, it is possible, but intrinsic motivation alone does not seem to be sufficient to activate the majority. Finally, it should be noted that, strictly speaking, the 2020 implementation cannot be used to evaluate the thesis, as it did not take place in a physical lecture hall but exclusively virtually.

C. Results Hypothesis 2

Table VI shows the evaluation of the U-test for the factor performance problems (F1) from Chapter I. Only participants will be considered ($n_{CG18} = 34$, $n_{EG19} = 19$, $n_{EG20} = 24$), from whom both pre-test and post-test are available and who have attended at least two participated in at least two university setting as well as spent at least one minute to answer 17 evaluation questions. The variables "workload" (F1.1) and "pressure to perform" (F1.3) are significantly better rated by CG18 than by EG19 and EG20. The "performance level" (F1.2) is rated significantly better by CG18 only for the first implementation and the "compensation of missing prior knowledge" (F1.5) is rated significantly better by CG18 than by the corresponding EGs, but only for the second implementation.

TABLE VI
RESULTS OF THE QUESTIONNAIRE FOR F1

No.		M	SD	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
F1.1	CG18	-0.56	1.02	21.56	733		
	EG19	0.58	0.96	36.74	698	-3.59	< 0.001
	CG18	-0.56	1.02	21.63	736		
	EG20	0.67	0.82	40.65	976	-4.43	< 0.001
F1.2	CG18	-0.36	0.74	23.79	809		
	EG19	0.21	0.86	32.74	622	-2.32	0.026
	CG18	-0.36	0.74	26.85	913		
	EG20	0	0.72	33.25	798	-1.59	0.112
F1.3	CG18	-0.33	0.78	24.07	843		
	EG19	0.21	0.92	33.82	642	-2.33	0.019
	CG18	-0.33	0.78	21.71	760		
	EG20	0.96	1.04	42.08	1010	-4.67	< 0.001
F1.4	CG18	0.13	1.57	28.59	944		
	EG19	-0.47	1.07	22.87	436	-1.34	0.179
	CG18	0.13	1.57	31.65	1045		
	EG20	-0.46	1.18	25.35	609	-1.46	0.146
F1.5	CG18	0	1	4.5	23		
	EG19	0	1	4.5	14	0	1
	CG18	0	1	22.5	113		
	EG20	-2.33	2.14	13.44	323	-2.19	0.03

TABLE VII
RESULTS OF THE QUESTIONNAIRE FOR F2

No.		M	SD	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
F2.1	CG18	-0.1	1.31	27.54	964		
	EG19	-0.16	1.26	27.42	521	-0.03	0.978
	CG18	-0.1	1.31	31.64	1108		
	EG20	-0.37	1.72	27.6	663	-0.92	0,36
F2.2	CG18	-0.36	0.99	21.49	752		
	EG19	1.58	1.71	38.58	733	-3.89	< 0.001
	CG18	-0.36	0.99	24.81	869		
	EG20	1	1.84	37.56	902	-2,86	0.004
F2.3	CG18	-0.39	1.25	29.03	1016		
	EG19	-0.63	1.17	24.68	469	-1	0.315
	CG18	-0.39	1.25	34.37	1203		
	EG20	-1.17	1.37	23.63	567	-2.42	0.02
F2.4	CG18	-0.55	1.12	28	980		
	EG19	-0.58	1.02	26.61	506	-0.32	0.747
	CG18	-0.55	1.12	30.9	1082		
	EG20	-0.71	0.91	28.69	689	-0.51	0.61
F2.5	CG18	-0.03	1.08	28.67	1004		
	EG19	-0.21	0.92	25.34	482	-0.78	0.115
	CG18	-0.03	1.08	29.74	1041		
	EG20	-0.08	1.1	30.38	729	-0.15	0.884

Table VII shows the evaluation of the U-test for the factor "study motivation" (F2) from Chapter I. The variable "interest in future jobs available on the basis of the study course" (F2.2) is significantly better rated by both EG19 and EG20 than by CG18. The "interest in the contents" (F2.3) is rated better by the students of the CG18 than those of EG20.

Table VIII shows the evaluation of the U-test for the factor "application orientation" (F3) from Chapter I. The variable "links between theory and practice" (F3.1) is slightly better rated by EG19 and significantly better rated by EG20 than by CG18.

TABLE VIII
RESULTS OF THE QUESTIONNAIRE FOR F3

No.		M	SD	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
F3.1	CG18	0.34	1.26	24.6	837		
	EG19	0.84	1.07	31.29	595	-0.744	0.457
	CG18	0.34	1.26	25.01	850		
	EG20	2.63	0.93	35.85	861	-2.52	0.012

It is revealed that in the questionnaire the variables of the "performance problems" (F1) are significantly rated worse by EGs or do not differ from those of the CG. For this reason, a more detailed investigation is necessary. In addition to the results of the questionnaire, the exam results can also be used to evaluate the variables.

In order to ensure comparability between the exam results of the CG and the EGs, on the one hand, only the same tasks will be compared. On the other hand, the average is calculated and normalised to the pass rate of $80\,\%$ that is common in this course [34]. In problem-solving tasks, EG19 scored at least $50\,\%$ more points, but on average twice as much as the CG. In these tasks, EG20 achieved at least as many points, but on average $60\,\%$ more than the CG. For other tasks (e.g. reproduction) the EGs achieved at least as many points, in some cases twice as many points. Again, it can be seen that on average EG19 achieves more points than EG20.

The better exam results of the EGs, especially in problem-solving tasks, are related to the processing of the tasks and the control at the remote laboratory. This is shown by a correlation calculation of the points achieved and the number of remote experiments carried out. For both ECs, the correlation coefficient ranges between 0.3 and 0.45 (two-sided significant $p < 0.001$).

This correlation additionally emerges from the evaluation of the bonus points achieved by EG20. In total, 152 students achieved an average of 5.78 bonus points from a maximum of 10. The correlation between the total achieved points (without bonus) and the bonus points is $r = 0.484$ and two-sided significant ($p < 0.001$).

With regard to the second thesis, it can be stated that the variables of "study motivation" and "application orientation" have improved. The "workload" and "performance pressure" are perceived as being high as before. At the same time, the EGs achieved better examination results. Whether the active processing of the tasks in the home setting and university setting is its causal reason, will be examined in further studies.

D. Discussion

Based on the aim of activating a large cohort in a classical lecture hall, the results show that this represents a major challenge. In the first implementation, many students did not use the remote laboratory and did not prepare for the university setting or failed to even show up. The students justified this by claiming that the work was not exam-relevant or that they learned the content using the sample solution shortly before the exam. This attitude is in line with the findings of [13]. Furthermore, the lecturer's objectives (preparation for lifelong learning) did not coincide with those of the students (passing the exam with least effort). In contrast to the criticism expressed in [13], the students did not miss the presentation of basic contents and concepts. We think that this is due to the composition of the course consisting of an activating practical course and an additional traditional lecture.

In the second implementation, the course was rated significantly worse. There are several possible reasons for this. First of all, the change in evaluation participation should be pointed out. CG18 and EG19 filled out a questionnaire in the lecture hall, while in 2020 all students who registered for the course received a link by email. Assuming that mainly engaged students were present in the lecture hall in 2018 and 2019, this differs from the group of participants in 2020. In addition, regulations on the containment of the Corona pandemic have had an influence on the learning situation. The students were not able to solve the problem-solving tasks face-to-face in groups in the lecture hall. Furthermore, the communication structure was changed during the university setting, so that the students had to actively address the teacher in the video conference if they had a problem. Moreover, the changed learning environment has an influence on the learning climate. Some students have abused their anonymity and disrupted the learning situation. From our point of view, the quantitative results show the relevance of a face-to-face course in addition to e-learning elements or that e-learning has to be introduced consciously and accepted by all actors (students and lecturers).

Furthermore, the chosen approaches PBL and flipped classroom can have an influence on the performance problems. On the one hand, the chosen methods promote self-management and self-organisation of the learning process. On the other hand, these two important competences also constitute a challenge for more advanced students. We think that this is especially due to the fact that in many courses students take a passive role and thus these competences are not promoted.

We have seen that the examination results in both EGs have improved compared to the CG. This finding is consistent with those from other studies on activating teaching [5], [6], [7], [8], problem-based learning [15], [16], [17], [20], [21] and flipped classroom [6], [29]. The difference is especially clear in problem-solving tasks and confirms the conclusion from [5] that activating learners improves the achievement of higher order thinking skills. The examination results have slightly decreased in EG20 in contrast to EG19, although the students have worked much more actively. In our opinion, the examination results cannot be improved further without adapting the previous form of examination (programming on paper) to the learning situation (programming a real system) according to the principle of constructive alignment.

V. Limitations

The didactic concept presented in this paper has been developed specifically for electrical engineering courses and is only one way of activating students. We do not think it makes sense to align all study courses according to this concept, especially since the transferability has limits (e.g. existence and uniqueness of problem products) [38]. Furthermore, the implementation of the concept is associated with a high workload for the lecturer, requiring an adjustment of the personnel framework.

VI. Conclusion

In this paper we have shown that the activation of a large cohort is generally possible. Variables of "study motivation" as well as "application orientation" have significantly improved in the EG's compared to the CG. Variables of the factor "performance problems" have significantly worsened, whereby the examination results of the EGs are better than those of the CG. The link between the theoretical content and the application orientation is perceived as positive by the students. The activation of the majority of students to solve the problem-solving tasks does not seem to be immediately possible without extrinsic motivation and is perceived as unnecessary by the students. Therefore, further studies are needed that take a closer look at the increase in acceptance and the reasons for rejection.

VII. Future Work

Due to the fact that the majority of students can only be motivated extrinsically to actively solve the tasks in the home setting, the flipped classroom will no longer be a component of the didactic concept in further studies. Instead, a second practice session in the lecture hall will be introduced. In addition, it is planned to test the concept with first-year students, as they are not yet used to studying exclusively for an exam and we therefore expect them to be more accepting. Furthermore, it has been shown that with large cohorts, there are longer waiting times at the remote laboratory. Therefore, the usage of a virtual reality laboratory is to be tested [39].

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