Lecture Meets Laboratory

Experimental Experiences for Large Audiences: Results of a First Implementation and Recommendation

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***Abstract*—In this article, the inclusion of practical experiments in a large-scale engineering lecture will be discussed (both positive as well as negative aspects). Recommendations for how best to achieve a successful implementation will be given based on these experiences.**

***Index Terms*—active learning, hands-on experience, laboratory skills.**

I. INTRODUCTION

The discrepancy between the knowledge and skill set provided by the university and those which are required by the job market [1] is a crucial aspect of current discussions in the didactics of engineering field. According to this discussion, education must not consist solely of reproductive factual knowledge, but rather must also further the development of interdisciplinary qualifications in order to reduce the gap between possessing knowledge and its practical application [2]. In order to develop the necessary competencies, student must be provided with learning environments that offer the possibility to exercise and strengthen such types of competence [3]. One possible option to do so is described in [4]: the lecture-hall laboratory (LHL). The LHL supplements a traditional lecture course with lab units, during which students can carry out practical experiments directly in the lecture theater. The central goals are supporting the learning process, the reduction of difficulties in understanding, and the consolidation of thematic material – or at least, those are the theoretical goals as envisioned by instructors. An initial trial implementation of this method, however, revealed several points of criticism from the perspective of the participating students. These will be discussed after introduction of the method and will be used to offer suggestions for improvement when applying this tactic.

II. CONCEPT

The LHL was tested for the first time during winter semester 2013/2014 in the course "*Grundlagen der Elektrotechnik für Maschinenbau*" (Fundamentals of Electrical Engineering for Mechanical Engineers), which has some 400 students per year. The integration of practical lab units in the lecture is based on the "sandwich principle" [5]. This theory describes a learning environment in which purely instructional phases are systematically interrupted in order to actively involve students in the construction of the imparted knowledge. This switch between the phases makes it possible for students to situate the scientific theories being presented within their individual, subjective concept of said theories. Should these subjective phases consist of activating learning methods, then, according to the sandwich principle, can the course be said to fulfil the familiar demand to actively involve students in the learning process in order to ensure its success ([5], [6], [7]).

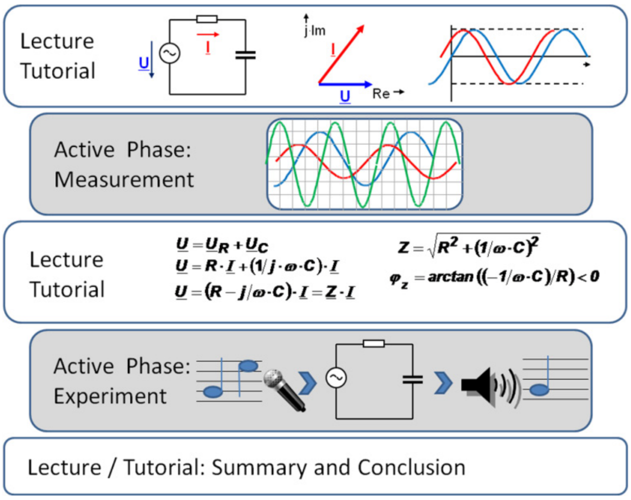


Fig. 1: Implementation of the Sandwich Principle

Figure 1 shows an example of a class according to the sandwich principle. In the plenary learning phase (here a lecture and a centralized tutorial), theoretical content such as phase diagrams and phase shift within the context of an RC circuit are presented. Following the explanation, students measure the individual currents on the components independently and examine the frequency dependence based on the changes in phase. Thus, they are able to directly apply the theoretically presented knowledge to a practical problem during the lecture. The class continues with a further plenary phase, which expands on content under discussion. In a second active phase, students investigate the functionality of an RC circuit (filter) using audio tones and their signals, aurally as well as visually (see Figure 2).

Fitting experiments make it possible for students to acquire subject knowledge, to recognize natural relationships, and to be able to reconstruct their derivation [8]. The lab units are constructed in direct relation to the lecture itself and follow various didactic goals, among which transfer between theory and practical application plays a central role. Based on these experiments, students are also expected to develop a working familiarity with the capabilities of the devices used. The experiments are carried out on the portable data sampling device NI myDAQ from National Instruments [9]. An additional goal is to create a connection to the industrial reality by offering students

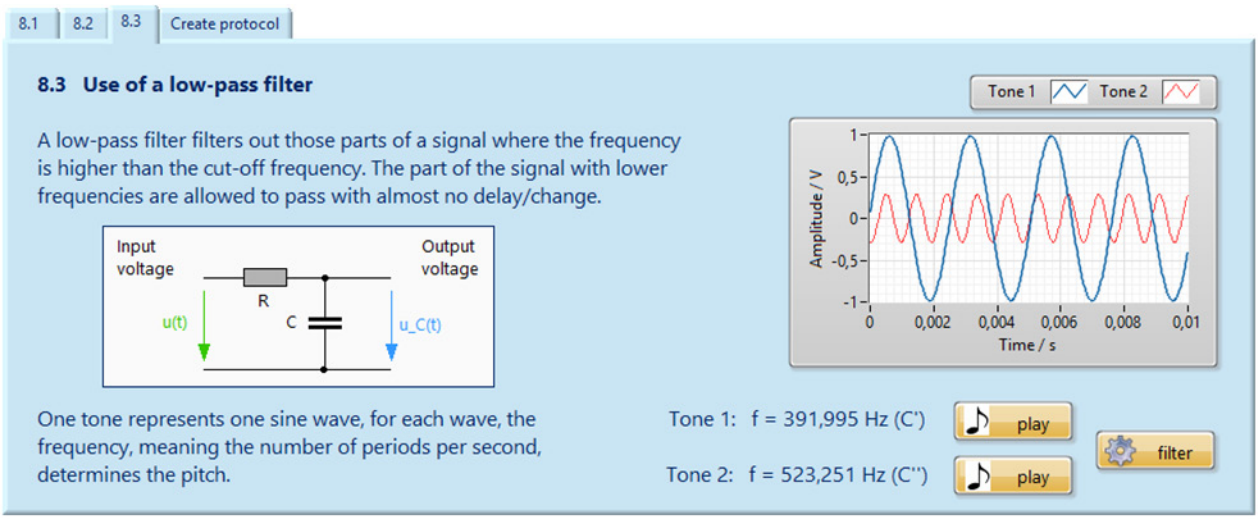


Fig. 2: Sample Task

real-world applications examples which underscore the relevance of the theoretical content.

III. Preliminary Implementation WS 2013/2014

A. Prior Considerations

Before implementing the LHL, various questions were considered, such as how to best regulate the lending of lab equipment. Arguments against giving students the equipment for the duration of each lecture were, among others, the sheer amount of time required, as well as the resulting tumult. More important, however, was the consideration that students should have access to the equipment for use at home as well. By lending students the devices for the entire semester, students are able to carry out or repeat the experiments anywhere they desire to do so – for example, as preparation for the final exam. Furthermore, considerations arose with respect to time management and motivation. Where in the curriculum can time be saved to use for experiments, and how long do the students need to complete them? Are students willing to actively participate in the learning process and how far can they be motivated with respect to a subject outside their chosen field?

To complete the lab units, students require at least one laptop per lab group, ideally one using Windows OS. A survey during the previous semester provided the information that ca. 70% of students own a laptop, ensuring that conditions can be met for all students to participate.

B. Results of Implementation and Re-Design

In the following section, student statements regarding the trial implementation will be analyzed and taken into account to adjust the implementation concept. The results offer suggestions for the introduction and effective implementation of practical lab units in courses.

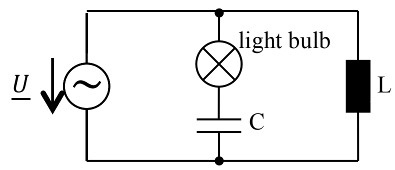
1) "I have no interest whatsoever to get involved during the lecture." "I liked it, because it causes you to think about the problems differently and it's a change." "More independent experimentation and less dry lecturing!" [1]

Among the students, a notable heterogeneity was visible in motivation levels and willingness to participate. While some of the students see themselves in a passive role, other students appreciate the active involvement and actually request more involvement in the learning process, above and beyond that offered.

In order to increase motivation and willingness amongst the students, the goals of the lab units will be made clearer to them.

In addition, following the ideas of Constructive Alignment [10], exam questions will be included whose solution will be easier for those who have taken part in the lab units:

The circuit shown below is fed with an AC $\underline{U}$ which has the frequency ω. The light bulb has the resistance R.



The light bulb is brightest for…

a) very low frequencies.
b) very high frequencies.
c) the frequency $\omega = \frac{1}{\sqrt{LC}}$

Explain your answer.

Fig. 3: Exam Question According to [11]

2) "A consistent division between lecture, tutorial, and lab units is desireable."

The tutorial is scheduled directly after the lecture, meaning that the entire scheduling block was used to intertwine the three elements seamlessly based on a given topic. However, a large proportion of the students preferred a time-based scheduling structure rather than a thematic one.

For the second course cycle, the lecture will be supplemented by lab units, while the tutorial will take place separately.

[1] All quotations here were taken from student evaluations and translated into English.

While the first two points relate to the concept in general, points 3-5 focus on concrete aspects of the trial implementation:

3) "Provide more background information."

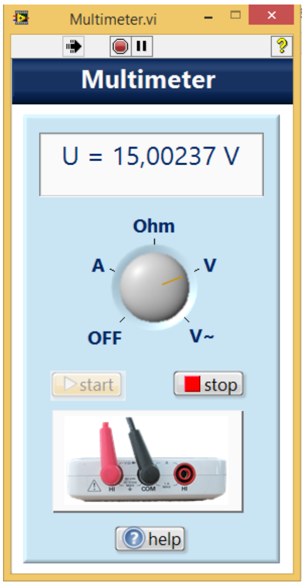


Fig. 4: Multimeter

It is important to the students to understand the reasoning behind the actual processes. Until now, the tasks have been designed so that, for example, the signal generation is done invisibly and students merely have to connect the appropriate circuit lines.

In addition to the tasks themselves, students will now also have access to programs specifically for the power supply unit, multimeter (Fig. 4), signal generator, and oscilloscope (Fig. 5), which they can operate themselves. The packages delivered with the NI myDAQ include various measurement tools, which, however, require a better driver. In order to keep the amount of work for the students as low as possible, these devices/ packages will be reimplemented.

4) "Creation of short summaries; otherwise, the results are forgotten too quickly."

The lab units can only be completed with the help of the equipment. During the semester, the students can repeat the experiments as often as desired; however, after returning the equipment, the information is often no longer available to them.

The tasks have been expanded so that students can export their solutions and results as an HTML-file. Thus, there is no central solution, but rather those values, system responses, data and even the signals from the oscilloscope are saved which students themselves measured and recorded.

5) "The results from measurement problems should be repeated and discussed in the plenary."

The heaviest criticism from students relates to the minimal or partially even neglected discussion of solution methods and results.

In future, the tasks will be briefly summarized live in the plenary using a document scanner. To do so, the task and the use of the necessary devices will be shown on the first of two available projectors. Simultaneously, a breadboard with the necessary electrical connections and current and voltage measurements will be shown on the second projector.

6) "I find the use of tools such as surveys to be disturbances and inappropriate in the context."

In order to be able to make statements about the influence and the sustainability of the new concept, differentiated evaluation is necessary. For this purpose, the survey tool BEvaKomp [12] was used at the end of the trial implementation period, which examines a self-evaluated increase in student competence. These surveys suffered from general unpopularity among the students. In addition, the surveys differentiated between various fields of competence, meaning that they attempted to measure increases in subject competence as well as in, among others, social competence. Several students reacted similarly to the following:

7) "Was the goal of the LHL to increase my social competence? If so → chair circle time!" "I could work well alone or in a team beforehand; I'm not here to learn social competence."

Many of the students seem to be unaware that the work and discussion in small lab groups is also a medium for training teamwork and communication abilities. As shown for the previous point, transparency, both regarding the concept and regarding its goals, is essential to ensure student acceptance of the concept.

For the next lecture cycle, students will be explicitly prepared for the evaluation by clear presentation of the purpose and intent behind the LHL and of the evaluation tools.

8) Further Aspects:

The trial implementation has shown that error-free software is also essential for student acceptance of such a program. All of the tasks and devices were tested and readjusted with regard to various possible errors. A lending contract containing a set return date is recommended for the distribution of the equipment. However, equipment return was completed with almost no issues, and with only a few exceptions. In future, the equipment will also be available for students taking the exam in summer (the lecture is offered only for the winter semester; students are free to take the exam in following exam period in summer as well, however).

Individual tasks took some 20-30 minutes to complete. To free up the time needed for this in the curriculum, the lecture content was adjusted.

IV. SUMMARY

Both the collective experiences from the trial implementation, as well as the results from the final exam at the end of the semester point towards a positive influence of the LHL concept on the learning process. Figure 6 shows the percentage of students who took advantage of the

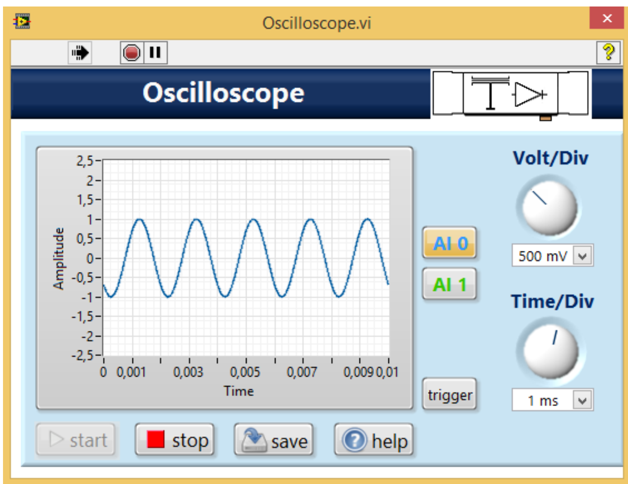


Fig. 5: Oscilloscope

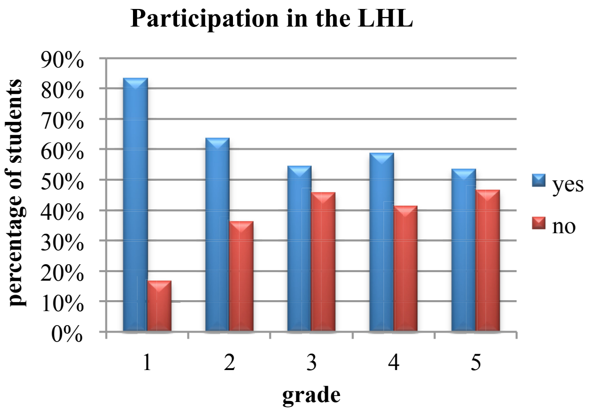


Fig. 6: Percentage of Students Receiving Each Grade Who Took Advantage of the LHL, Survey WS 13/14

LHL, divided according to the grade they received on the final exam. In particular, it can be seen that students achieving "excellent" or "good" results (1 or 2 on the German grading scale) clearly tended to be those who participated in the LHL. Certainly, there are other factors here which play a role and should be considered here, such as motivation or participation in tutorials.

An additional positive confirmation of the success and student acceptance of the concept is the presentation of a student-awarded honor for excellence in teaching, the "IGEL 2014".

For the winter semester 2014/2015, the LHL will be in its second cycle. Prior to the submission of this paper, no lab units had been carried out in the lecture; in comparison to last year, however, more students have chosen to borrow lab equipment, indicating an increased acceptance of the concept among students.

V. OUTLOOK

After the trial implementation and re-design, a differentiated evaluation will take place using various data collection methods. In addition to measuring self-evaluated competence increase and motivation using surveys, individual interviews will be carried out. In addition, the final exam will be analyzed with regard to the influence of the LHL on achieved results.

An additional task is also under consideration which students would complete during the lecture. Based on the resulting HTML-protocol, bonus points could be accumulated for the final exam.

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