Home labs – are they here to stay?

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***Abstract*— When teaching is now slowly returning to normal circumstances, it is time to think about what positive changes we will take with us from the pandemic. One such thing is that we realized that many laboratory exercises can be done in the comfort of the students' own homes. This is especially true for simulation labs, but can also work for experimental work by using what is available in the students' homes, sending smaller equipment with them or by providing them with prerecorded data. We hypothesize that this stimulates a more active and independent approach to solving the tasks and therefore improves learning.**

***Index Terms*— Laboratory exercises, Distance learning, Home labs, Computer simulations, Prerecorded data**

I. Laboratory Exercises Stimulate Deep Learning

A deep-oriented learning strategy is a prerequisite for good learning [1]. Students who have great interest, inner motivation and good prior knowledge often choose a deep-oriented learning strategy, while students who do not study out of curiosity or are driven by a strong ambition need support to adopt a deep-oriented learning strategy [2, 3]. These factors can vary for different courses so that the same student chooses different learning strategies for different courses and situations. The connection between learning strategy and interest is also reciprocal - lack of interest can lead to surface-oriented learning and a student with a surface-oriented learning strategy may have problems to become interested [1].

Laboratory exercises is a pedagogical tool to support in-depth learning strategies for important elements in a course, as laboratory work "forces" students to immerse themselves in the subject before, work practically with the subject during, and often summarize the topic in a report after the laboratory exercise. All these three elements support deep-oriented learning strategies [1].

Laboratory exercises are typically done in scheduled time slots in laboratories with teacher supervision. This has not always been possible during the COVID-19 pandemic due to social distancing requirements [4]. We here provide some examples of how laboratory exercises can be carried out by students from home using (1) what is available there, (2) material and equipment from the university (3) simulations or (4) prerecorded data. We also discuss benefits with these approaches that may make them interesting adopt even after the pandemic.

II. Computer Simulations at Home

The category of laboratory exercises that was the most straight forward to bring home was computer simulations. Many students already do them on their own computers, making the transition easy. Still, it is important not to assume that all students can do that, but to offer them to borrow a laptop or provide access to a computer room.

III. Experiments at Home

In some courses it is even possible to do experimental work at home. In our course on microfluidics, the students for instance studied capillary wicking in various materials, contact angles of different liquids on varying surfaces, laminar and turbulent flow in the tap and sedimentation of yeast cells. Most of the necessary material was already available in the students' homes, but yeast was provided by the university. According to the course evaluation a majority of the students thought the home labs improved their learning compared to not having the exercise at all, but that it would have helped even more if it would have been performed as an ordinary laboratory exercise (Fig. 1) [5].

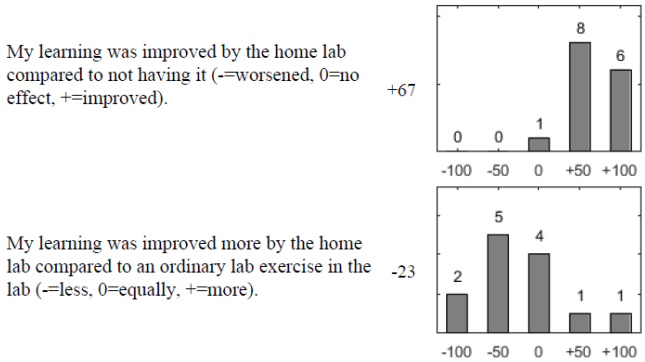

Fig. 1. Results from the course evaluation of the home labs described in section III, adapted from [5].

IV. Sending Equipment with the Students

As a complement to the on-site laboratory exercises in one course, a small project is made at home, typically done as a literature study. The project can also be done by borrowing smaller measurement equipment from the university, and rather unsurprisingly an alcohol sensor (alcometer) has proven to be a popular project topic for the students. Typically, it has involved consumption of alcoholic beverages while continually making and recording measurements (unlike the yeast mentioned above, alcohol was certainly not provided by the university). While the risk may seem obvious that the project could lead to overconsumption of alcohol, we have consistently seen responsible use and good discussions of measurement

accuracies. We have also seen requests for other measurement equipment, such as a radar- or laser equipment for speed measurements. In our experience, providing measurement equipment, such as the aforementioned alcometer, has given good outcomes and led to deep-oriented learning, leading us to consider purchasing a variety of sensors for use in future student projects.

V. Prerecorded Data

In this approach, the practical steps in the laboratory exercise are performed in advance by a supervisor. After the student has become familiar with the implementation of the experiment, the task is to analyze and present the data. In this arrangement, the students are never on site at the university's premises, but everything is done digitally at a distance.

These type of lab exercises were arranged in mandatory courses for first-year students as well as in elective courses for later year students. For the later year students, the supervisor initially discussed the laboratory work with the students in the respective lab groups via web conference. Then they went through the experimental setup and came up with suitable data series to collect and the data collection was shown via video. Then the students remotely logged in to the university computers where the analysis program was installed and then analyzed, plotted, and compiled the results. Ongoing and concluding discussion with supervisors was performed via video conference.

The setup for the first-year students had to be more structured, partly because they were less experienced but also since more than 100 students were registered for the course and the work thus had to be more streamlined. These laboratory exercises were kept in on-going zoom meetings that followed a regular schedule. Two types of instructions were provided for the students, one document with laboratory guidelines and one with more practical information on how the prerecorded data was generated. Such an arrangement allows the students to follow a story where they can contact the lab supervisor for questions and detailed discussions. This structure allowed the lab supervisors to ensure that all students were able to participate and move forward, similar to what can be achieved in laboratory exercise on campus. It should be mentioned, however, that development of such a well-structured online version of a laboratory exercise requires skilled lab supervisors, in terms of pedagogic, technical and administrative competence to ensure that all students can (1) do their lab on time, (2) finish it in time and (3) still learn how laboratory data sampling and analysis is done.

According to the course evaluation the later year students did not appreciate the adaptation of “Laboratory practice with pre-collected data” as much as, “Laboratory practice on campus with measures” (to prevent COVID-19 transmission), “Laboratory practice with one-way flow” (of students, also to limit transmission) and “Laboratory practice where parts are performed digitally”. This was probably partly because some of the students had problems to remotely log in into the university computer. Many later year students also commented that they preferred that a laboratory exercise is hands-on and that it was more difficult to swap duties and discuss with the supervisor via web conference during the online laboratory exercise than it would have been on site. Some students that took part in these elective courses still stressed that it was better with adapted laboratory exercises than no laboratory exercises at all.

The majority of the first-year students, however, liked the on-line arrangement according to the course evaluations and from feedback at the course evaluation meetings. This difference in attitude towards laboratory exercises with prerecorded data may be due to that the first-year students did not chose this course for the laboratory work, whereas the later year students had made a choice to take courses with where experimental work and analysis were an important part. Furthermore, the first year for an engineering student is rather streamlined and the students seem to appreciate teaching that can fit into their rather busy schedule.

Another benefit of laboratory exercises with prerecorded data may be that they may make it possible for the students to perform laboratory exercises that are otherwise not possible, e.g. if the equipment is not available locally [6] or too dangerous, complicated, expensive or heavily booked to allow use in courses.

VI. Teacher Support and Examination

For all these types of laboratory exercises made from home questions and examination can be handled over video conference, still having the exercises during specific time slots or by scheduling question hours. Examination can also be done through written reports or video clips recorded by the students.

Having teacher support less available stimulated the students to try to solve the tasks more independently and ask first when it was really needed. This type of supervision also typically reduces the time spent by the teacher, freeing resources to support the students in other ways. There was, however, also an increased tendency for the students to get stuck on technical details and to procrastinate the tasks until the last minute. An important aspect when designing online exercises may therefore be to remove hurdles for starting, since having less fixed time slots otherwise seemed to increase the risk of procrastination.

VII. Other Lessons Learned

One way to make quick changes possible when necessary, in this case exemplified by the fast adaptation when the pandemic hit, was to delegate responsibility to a teacher or group of teachers responsible for a specific laboratory exercise. This turned out to stimulate commitment and creativity, generated many good solutions and may be a good way to keep the laboratory exercises developing also after the pandemic.

Laboratory exercises at a distance turned out to have several benefits, such as increased flexibility for the students, less teacher and facility resources needed, making it easier to involve guest lecturers and to allow students taking the course from elsewhere.

One general lesson from the pandemic regarding laboratory exercises, especially when held on site, was that it is highly important that the students are reassured and

have confidence in that they will be given a new time for the exercise within reasonable time if they are sick on the day for their scheduled lab. Otherwise, there is a high risk that they show up anyway and put fellow students and teachers at risk for transmission of infection. This is an important lesson even after the pandemic, since it may reduce the spread of colds, flu and other diseases.

VIII. Conclusions

Our experience is that while practical experience from the laboratory environment and close supervision is an important component of many laboratory exercises, other laboratory exercises may advantageously be done from home. This is giving the students other benefits such as flexibility with when and where to do them, more incentive to solve the tasks independently and possibility to use lab data from equipment that would otherwise not be available to them.

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