INTEGRATED INTRODUCTORY PHYSICS LABORATORY COURSE ONLINE

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ABSTRACT

Introductory engineering physics has traditionally included some laboratory work either as own laboratory course or as a part of theory courses. Generally, students are interested in active doing in laboratory, but calculations and reporting are often seen as laborious and demanding.

Since 2015, challenges with reporting have been tackled in a bachelor level engineering education by offering an integrated course “Basics of measuring and reporting”, in which Physics-, Mathematics- and Communications teachers work together. The key idea of the course is to bring all necessary basic skills the student needs for measuring and reporting to one single integrated course. In spring 2019 an online pilot version of the integrated course was planned and implemented, followed by another in autumn 2019. Costly laboratory facilities are not necessary in the online implementations. Laboratory tasks, that are used as a basis of reporting, are possible to organize in such a way that equipment is available either at home or from local grocery store. In this way the course is also easy to offer in open university nationwide.

The online course itself, challenges and solutions of the online implementation are described. Students’ experience of online laboratory course is also reported, using student feedback data. The pros and cons from the teacher teams of the implementations was collected and reported. The results promising, so there are several online implementations running now on yearly basis.

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1 INTRODUCTION

1.1 The role, importance and challenges of lab work in Physics in EE

Traditional engineering curriculum includes introductory physics laboratories, either on their own course or integrated in the theory courses. Learning outcomes of the laboratory courses may include learning physics concepts more deeply (more conceptual approach) or learning measurements, data analysis and reporting (more engineering approach). Both approaches strongly support scientific thinking as a cornerstone of engineering. According to Holmes ad Wieman, laboratories that are designed to improve students' intellectual and experimental abilities offer great opportunities to improve experimentation, reasoning and critical thinking skills [1]. Students' experiences on introductory laboratory courses vary a lot and they depend on the goals an implementation of the laboratories. According to research, experiences in the laboratory can be negative or dull, because tasks, working and the solution methodology are pre-stated [2]. On the other hand, a survey from Australia have shown that students felt physics laboratory work useful, understandable, interesting and enjoyable. [3]

Typical difficulties that students encounter in introductory physics lab courses lie in understanding the measurements and interpreting the gathered data. Students may see the measured values as exact without any uncertainty [4]. The concepts and implementation of error analysis may be difficult for students even after the laboratory course [5].

One of the key learning outcomes in the introductory physics laboratories is the writing a technical, scientific report. According to student feedback it is often seen as the hardest part of the of a laboratory course. One good practice to reduce students' workload in reporting in "sElf" approach. In the approach students focus on different parts of the report on different tasks and only finally write a complete report with all parts included [6]. In Tampere University of Applied Sciences, the high step to scientific reporting has been smoothed with dividing physics laboratories in two courses. The first course, "Basics of Measuring and Reporting (3 cr)" is an integrated course in which students learn the very basics of measurement, data analysis, error analysis and reporting [7]. In the second course, "Laboratory Works of Physics (3 cr)", students practice their skills and finally the course ends to self-designed laboratory work which is reported either as a poster or a video [8].

1.2 Pressure and need for distance learning

Traditional way to implement introductory physics laboratory courses need reasonable laboratory facilities, that are often expensive and need more teachers per student group for safety reasons. In Finland, the national funding model of universities also encourages to open and distance learning, so there was a genuine need to arrange as much online teaching as possible. So "Basics of Measuring and Reporting was re-designed in a way that students are able to make the measurements at their homes with equipment that they find in their households or with low costs at the local supermarket. The CoViD-19 pandemic really proved the need for this kind of innovative online solutions, in which students are able to work hands-on at their own home.

2 METHODOLOGY

2.1 Design of the online course vs. the traditional course

"Basics of Measuring and Reporting" in traditional or online implementation is students' very first course for making measurements and reports in Tampere UAS. It is an integrated introductory physics course with elements of physics, mathematics and communication. Integration means that skills needed for measuring and reporting are not taught in different separate physics, mathematics or communications courses but in a single integrated course. The idea of the integrated course is presented in fig. 1.

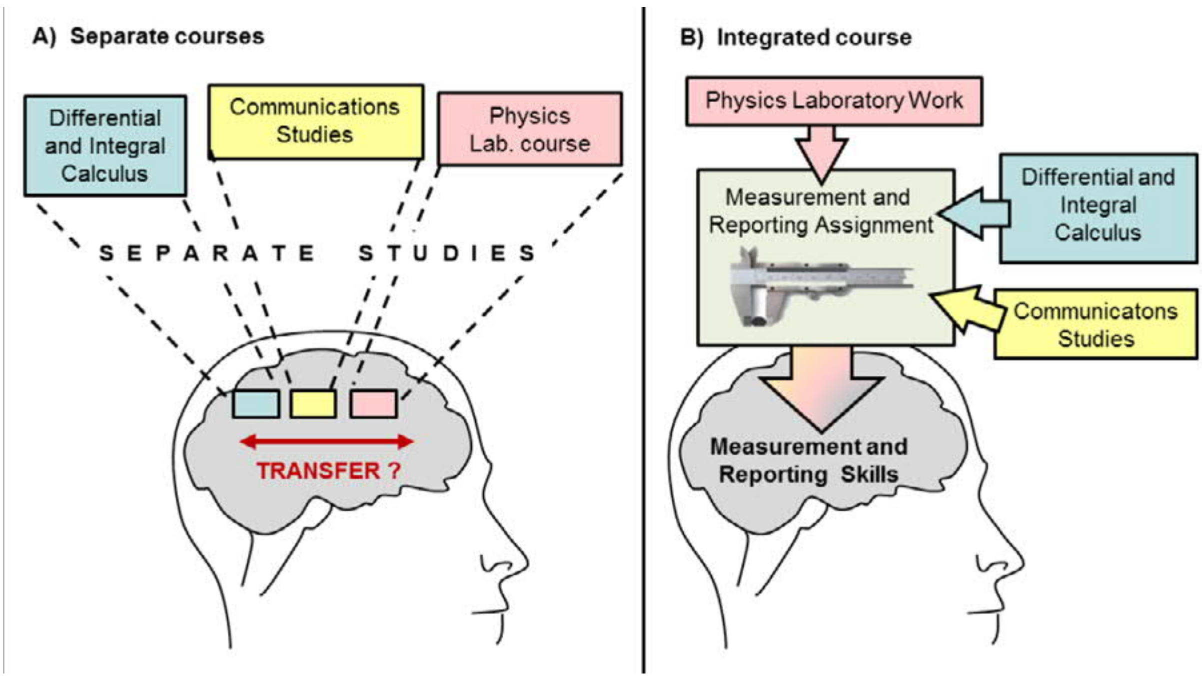

Fig. 1. The idea of the integrated course

"Basics of Measuring and Reporting" includes following learning outcomes:
Student can:

- make a measurement task under supervision
- make a data sheet under supervision
- calculate the results of the measurement task
- make a graph representing the results
- make an appropriate error analysis
- draw up a report in accordance with standards

From the learning outcomes it is seen that students get a lot of support for their studying. The support is arranged in a way that there are three teachers, physics, mathematics and communications teacher guiding students in "Just in time" throughout the course. This means that student makes measurements under supervision and guidance of a physics teacher. After completing the measurements, student gets guidance for data- and error analysis from mathematics teacher. Finally, a communications teacher helps with the reporting. The course includes three laboratory tasks to complete.
In a traditional course, the measurements are carried out in physics laboratory and they are followed with a workshop of mathematics and a workshop of communications. Each of these phases lasts one week so there can be three different student groups at the same time slot for a single teacher team (fig. 2.).

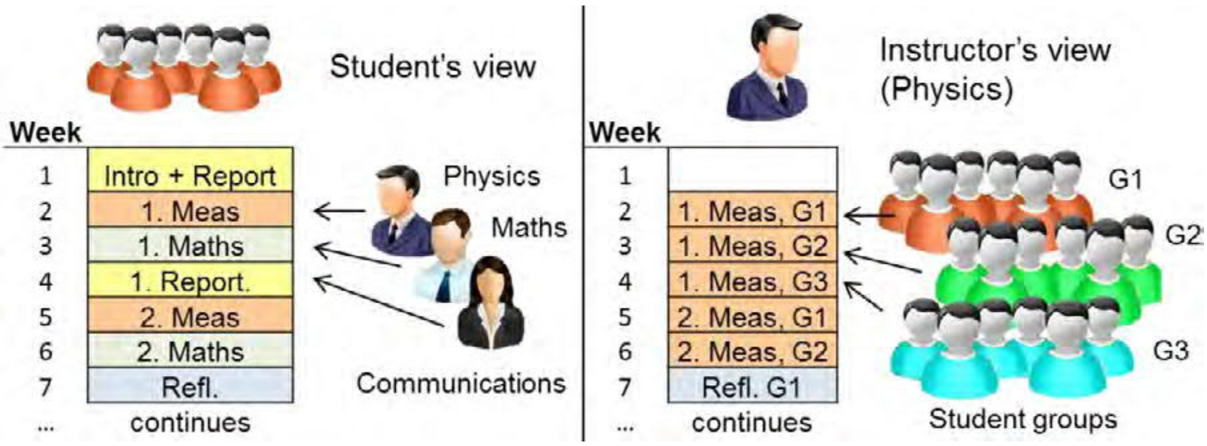

Fig. 2. Traditional course

The traditional version of the course is heavily scheduled with measurement tasks and workshops of mathematics and communications.
Online learning typically includes more independency for students in their time management. The online course follows the guidelines of the traditional course. First measurements, then data-analysis and error analysis, followed by reporting. But it is scheduled only with deadlines for measurement task and reporting task.
Measurements must be chosen in a way that the risk of injury of a student is minimal and the equipment needed is found from their households or with a low cost from a local supermarket. The guidance, "just in time", lies heavily on instructions and videos. Online live sessions of measurements, mathematics and communications are also available.

2.2 Implementation of the online version

Online version of "Basics of Measuring and Reporting" was built on Moodle platform. The structure of the course on the platform followed the design of the traditional implementation, three measurement tasks with mathematics and communications support. Each task included clearly the support for measurements, the support of

mathematics and the support of reporting. The support and instructions of reporting were also at their own section at the end of the course platform.
The measurement tasks of the online course included.

- The effect of the accuracy of the measurement device, density
- Spring constant of a rubber band
- Acceleration due gravity

In the first task students were asked to pick up an object, to measure its dimensions and weight with error estimations. Students calculated the density of the object with the error estimations using the relative uncertainty method. The equipment for measuring the dimensions is usually found at home and scale if not at home, at the closest supermarket.
In the second task students determined the spring constant of a rubber band. The students were encouraged to use a measurement setup described in fig. 3. The tension of the band is easy to adjust with water.

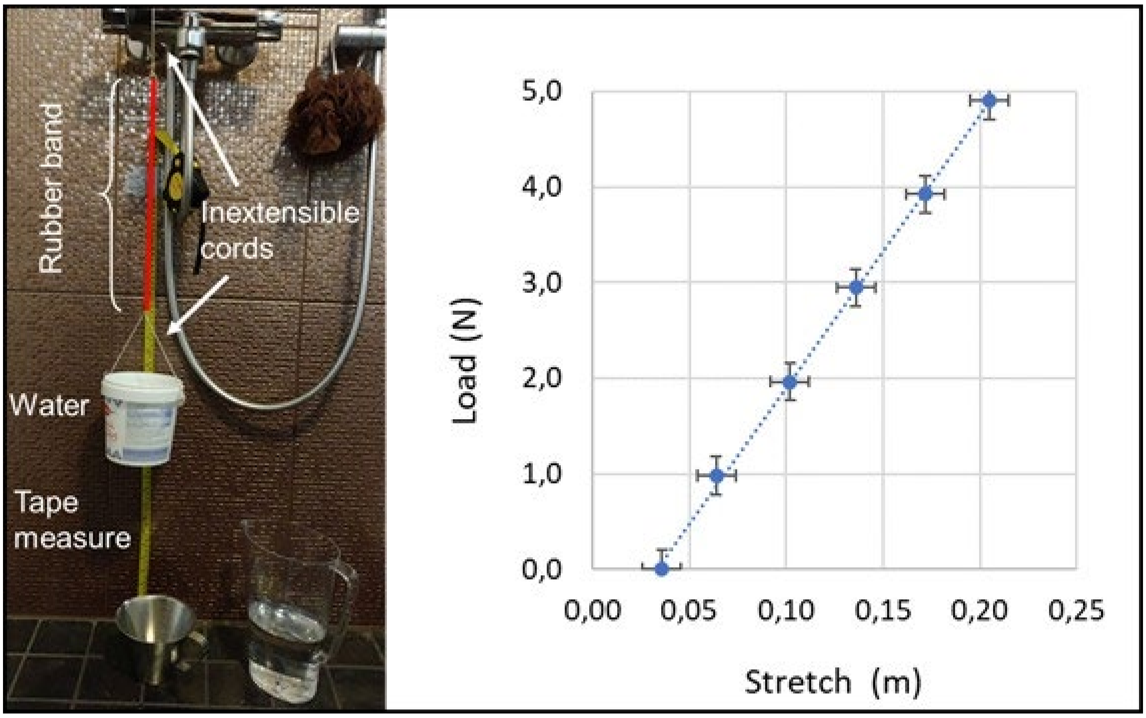

Fig. 3. Measurement setup and example graph

In the second task students were asked to draw an appropriate graph and to calculate the spring constant using linear fit to their data.
In the third task the students determined local acceleration due gravity by dropping object from different heights. Acoustic stopwatch of the PhyPhox app was used for measuring the falling times. Measurement setup is described in fig. 4.

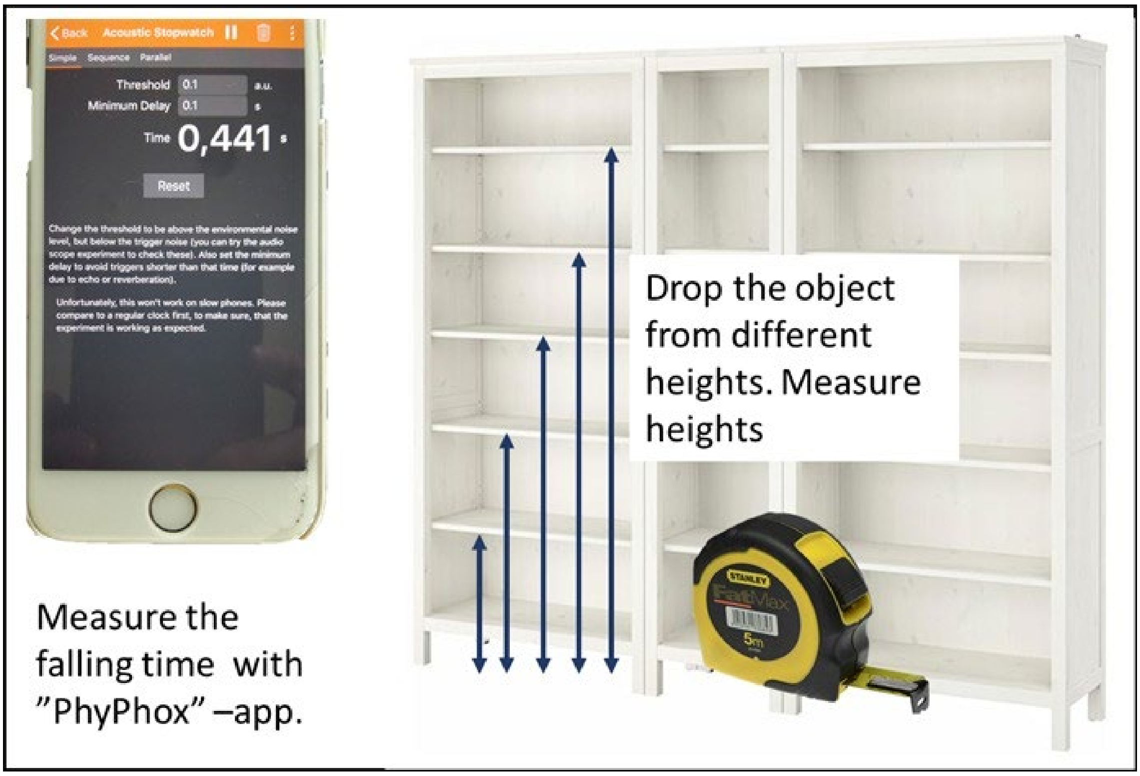

Fig. 4. Measurement setup for local g

The data analysis and the error analysis were made with two different methods, linear regression and calculations with partial derivations. A sample data with a sample graph is presented in fig. 5.

t (s)	y (m)	Δy (m)
0,32000	0,487	0,002
0,41550	0,808	0,004
0,48800	1,127	0,0035
0,54975	1,444	0,005
0,59825	1,718	0,002

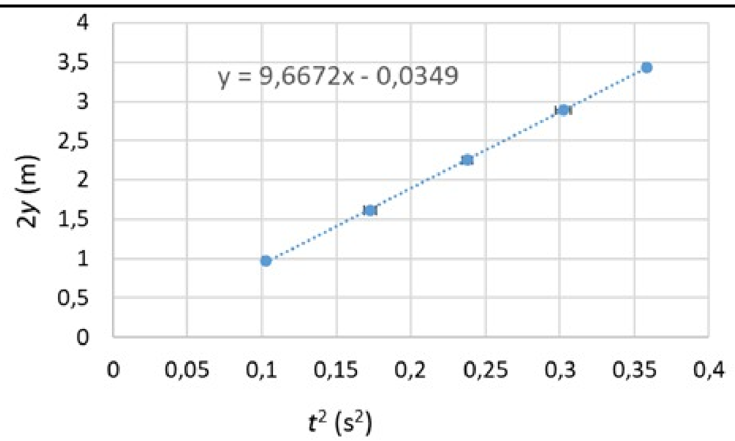

Fig. 5. Sample data and sample graph

2.3 Data gathering

Online version of the "Basics of Measuring and Reporting" has had three implementations. Teacher teams of the implementations (5 persons) were shortly asked to tell their pros and cons of the online implementation and their development ideas. Students' opinions of the online course were collected from student feedback and a short similar questions with ongoing implementation (13 answers).

3 RESULTS

3.1 Online implementation from teachers' perspective

Pros and cons from the teacher teams are described in table 1.

Table 1. Pros and cons from teacher teams

Pros	Cons
• Stronger time independency for both, students and teachers • Students' greater responsibility for their work	• More difficult to give feedback just in time if students don't ask for it • A lack of peer support and social pressure among students • Overall quality is poorer

Teacher teams described that the online implementation required more preparatory work compared to the traditional one. Student guidance was mainly based on written feedback, because the online discussions were in minor use. Therefore, the written feedback must be very accurate. In written feedback, discussion of different options is often missing, because the normal social contact is only online. In online implementation, students have to take more responsibility on their own work because the support is not pre-scheduled like in traditional courses. There were a lot of more dropouts in online implementations compared to traditional ones. Overall teacher teams strongly support the online possibility of the course.

3.2 Online implementation from students' perspective

Pros and cons from the students' perspective are described in table 2.

Table 2. Pros and cons from teacher students' perspective

Pros	Cons
• Stronger time independency • Necessary information is always available • Designing own measurements	• Measurements made at home may not be as interesting as in laboratory • IN traditional laboratory students get immediate feedback from their measurement • Live online support only at announced times • Lack of contact with other students

According the student feedback success in online course needs accurate following of instructions and independent time management. Students' development ideas for the course included some more time slots for online sessions and some improvements and examples for instructions available either on video or in written form.

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