Enhancing Learning in Integrated Physics Laboratory Course: Physics, Mathematics and Communications

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INTRODUCTION

At Tampere University of Applied Sciences, the bachelor's level engineering students are generally interested in active doing in laboratory courses. However, laboratory courses have been considered rather laborious and demanding - in many cases due to the scientific analyzing and reporting requirements. Data analysis skills and reporting skills can be considered as fundamental objectives of engineering laboratories [1] and concepts of error analysis are difficult to students [2]. To enhance student s' perception of their own reporting and analyzing skill level, self-assessment can be used [3]. Despite the clear need, mathematics and communication studies haven't always been well synchronized with the physics courses.

To enhance students' learning, the contents of the first physics laboratory course have been changed to an integrated implementation in which the course consists of equal amounts of physics, mathematics and communication studies, 1 ects each. These are instructed by a physicist, a mathematician and a communications teacher, respectively. The key idea is to bring together all the basic skills a student – and an engineer to be – needs related to measurements and their reporting to an instructor or to a customer, for example.

Course overview and its key concepts are presented earlier by the authors elsewhere in more detail [4] and they are only briefly reviewed in this paper. This study concentrates on the learning experiences and outcomes of the new laboratory course

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in comparison with those of previous implementations of physics laboratory courses. The evaluation of the new teaching method is based on interviews with the instructors and access to their assessment data, together with feedback from students. The new concept is also evaluated in course planners' perspective.

1 CHALLENGES IN PHYSICS LABORATORY TEACHING

Tampere University of Applied Sciences has always had physics laboratory works, either as separate laboratory courses or included in a physics theory course. Learning objectives are an important factor in any course. Feisel and Rosa [1] has said it in a nice way:

> "*If you don't know where you want to go, you won't know which road to take and you won't know if you have arrived."*

Understanding the physics is of course an essential learning objective in laboratory work. However, there are lot of other necessary engineering skills which need to be learned as well, including measurement technology, analysis of measurement results, uncertainty evaluation and scientific reporting. In general, physics laboratory work is reported to provide students with many important skills that they think they do need in the future [5]. At Tampere University of Applied Sciences contents and arrangements of physics laboratory courses have changed many times during the past years. According to the current curriculum, after physics laboratory course, a student should be able to:

- Carry out controlled measurements
- Use appropriate analysis methods
- Create correct graphs and visualizations of measurements
- Evaluate uncertainties
- Write reports in accordance with standards
- Communicate about engineering topics in a professional, understandable and assertive way
- Give, receive and evaluate feedback

In addition to the challenges emerging from physical phenomena themselves, students consider the interdisciplinary skills listed above as demanding. The students are not always well familiar with MS Excel or Word, let alone the standards of technical writing. Sometimes this makes student feel that they can't cope with all the requirements. In the past, it was not uncommon to hear students complain that the credit (ects) earned in a physics laboratory course was not in accordance with the amount of work it demanded. This led to new ideas how to arrange the first laboratory course in such a way that it would better support students to reach the learning objectives.

Even though the learning outcomes from physics laboratory courses are seen very important, some pressure is coming not only from the students, but also from the financing. Laboratory teaching is more expensive compared to classroom lecturing. It is much easier to arrange a resit of a theory course than offer opportunities to re-participate in a laboratory course. Therefore, it would be ideal to have high pass rates in laboratory courses.

2 THE NEW COURSE: "BASICS OF MEASURING AND REPORTING"

2.1 Pedagogic ideas

The synchronization of mathematics and physics laboratory courses weren't always perfect in the past years. In the worst case, the mathematics courses offering skills needed in uncertainty evaluation or in analysis of the measurement results were held after the first physics laboratory course. This put pressure on the physics teachers to teach also the necessary parts of mathematics. Moreover, the students didn't always see how the skills they had learned in mathematics could be used and should be used in physics laboratory assignments. Also the reporting skills were largely taught by physicists.

The lack of transfer, the need to improve written reports and physics teachers' need to concentrate on physics led to the idea of collecting all necessary skills within one course. This idea is illustrated in *Fig. 1.* The key idea is to bring together all the basic skills a student – and an engineer to be – needs related to measurements and their reporting to an instructor or to a customer, for example. First, the students carry out measurements in physics labs. Then, with their own logbook, they go to mathematics lectures during which they are able to calculate results based on their own measurement data. All necessary calculations are ready when the students participate communications workshop where they start to write the report.

With structure like this, it was rather natural to appoint different teachers to carry out different parts of the course: two physics teachers are responsible for measurements and equipment, mathematics teacher is responsible for analysis skills and communications teacher for document templates, writing and proper use of language, respectively. Accordingly, the course implementation has four teachers.

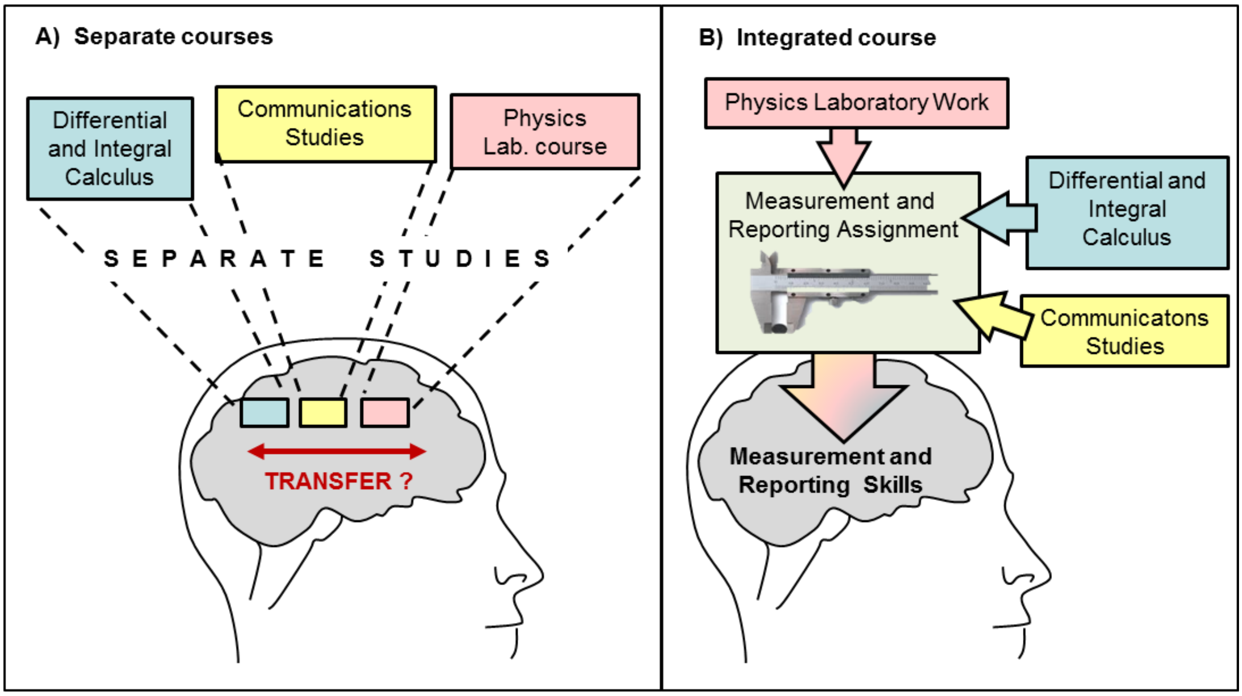

Fig. 1. The "traditional" way to organize teaching (A) and the new integrated way (B).

2.2 Course structure

Course structure was presented earlier [4] in more detail, but a brief review is written here to help the reader grasp the idea of the concept. Students have this new course scheduled at the same time every week, but the classroom, topic and the teacher changes as shown in *Fig*. 2 and *Fig*. *3*. The course proceeds as follows:

1. The concept, requirements and learning objectives are introduced (Intro).
2. The students carry out a measurement in physics laboratory working in pairs (Meas). The output is the measurement data, a log book. Time reserved for this stage is 3 h.
3. With the log book and data, the students go to mathematics lecture/workshop (Maths), which topic is related to the analyzing skills the students need for the laboratory work. Again, the reserved time is 3 h.
4. In reporting lecture and workshop (Report), the layout and structure of a scientific report is presented together with the standards for the text. All the calculations needed for the report are already done, and therefore students can concentrate on producing text. The deadline to hand in the reports is one or two weeks after the workshop.
5. Once the reports are ready, the instructror(s) read them and prepare collective feedback. During reflection (Refl) the reports are given back to students. They are also provided with a list of requirements for scientific text and reporting. With the help of the list, they go through their own report and mark, which aspect are already well done and which need further improvement. This way, they are aware of their skills and are able to improve their text and reporting during the next cycle in a cumulative way.

The teachers, on the other hand, repeat their topics three times to different student groups at the same time slot at his/her schedule in three consecutive weeks. In this way, it is possible to fill in the time table of a teacher without unnecessary gaps. The instructor's and student's perspectives to the schedule are illustrated in *Fig. 2*. Altogether, there are three cycles of measurement, mathematics and reporting in which the learning objectives became more and more challenging.

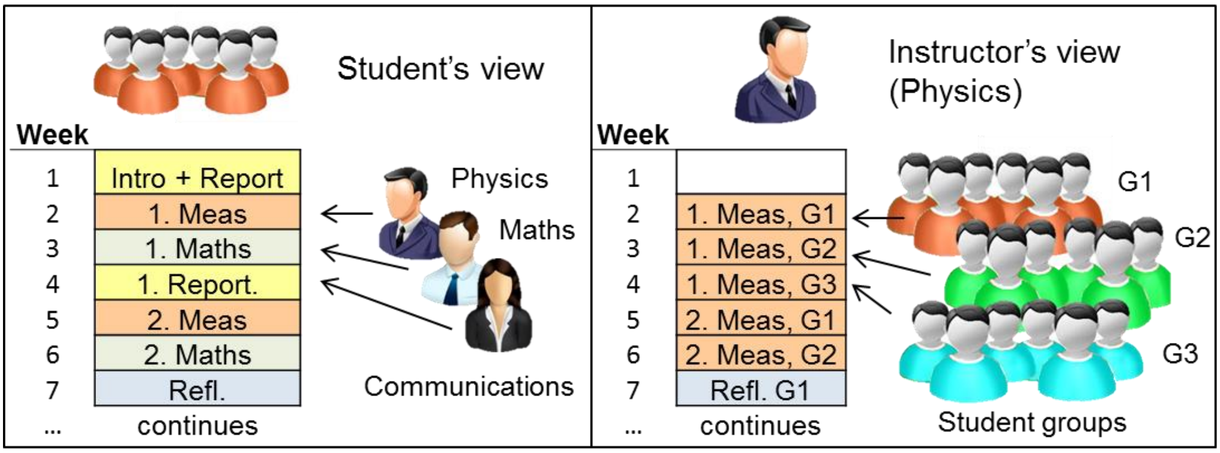

Fig. 2. The Student's and teacher's views to the course.

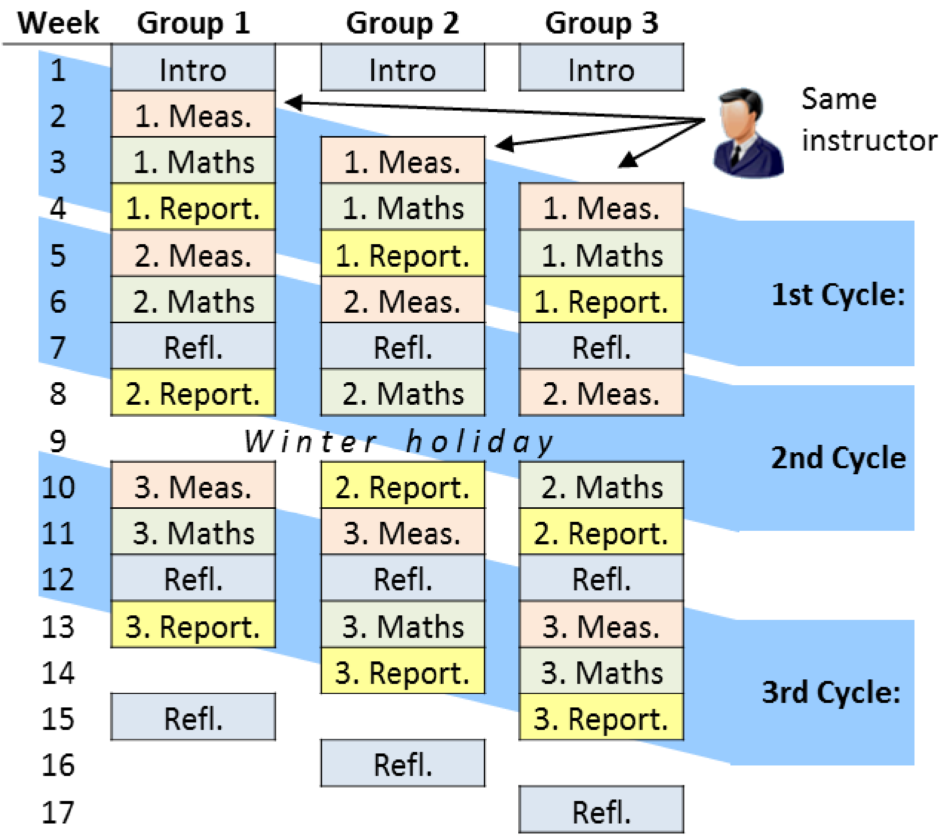

Fig. 3. Arrangements in the new laboratory course.

2.3 Assessment

The learning objectives for the first report were mainly related to the structure and layout of a report and uncertainty analysis. The physics in this assignment was rather easy. The first report was not assessed with a grade or points. During "Reflection" the students were asked to evaluate their own reports with the help of a checklist. The purpose was to make the students themselves find those aspects that needed further improvements in their reporting. Teachers skimmed through the reports and gave general, collective feedback to student group.

The second report was assessed by the communications teacher who concentrated on the language, naturally. The physics teachers commented each report individually about the physics content. No report with erroneous or missing results was accepted, even though physics teachers didn't otherwise grade them. Mathematics teacher had checked the calculations already during the math workshop.

The roles were reversed in the assessment of the third report. Physics teachers gave grades and communications teacher only commented on them. Now the emphasis was on the physics itself and how the student were able to present their perceptions of the topic. Also the evaluation of uncertainties was more demanding in this report.

3 EXPERIENCES AND RESULTS OF THE NEW COURSE

Effects of the new course on learning and reporting was studied by collecting feedback and examining learning outcomes. Students answered to online survey questionnaire and teachers were interviewed. The student feedback is largely already reported earlier [4]. The interesting questions are:

1. Are the learning outcomes better than before in terms of grades?
2. Is the number of dropouts reduced with the increased support to students?
3. Has the quality of the reports increased?
4. How well is the collaboration between teachers working?

Histogram of the final grades is presented in *Fig. 4.* The data consists of 902 students of which 536 had studied according the old curriculum (red) and 366 had participated the new course (blue). They were studying in different degree programs and had different teachers as well.

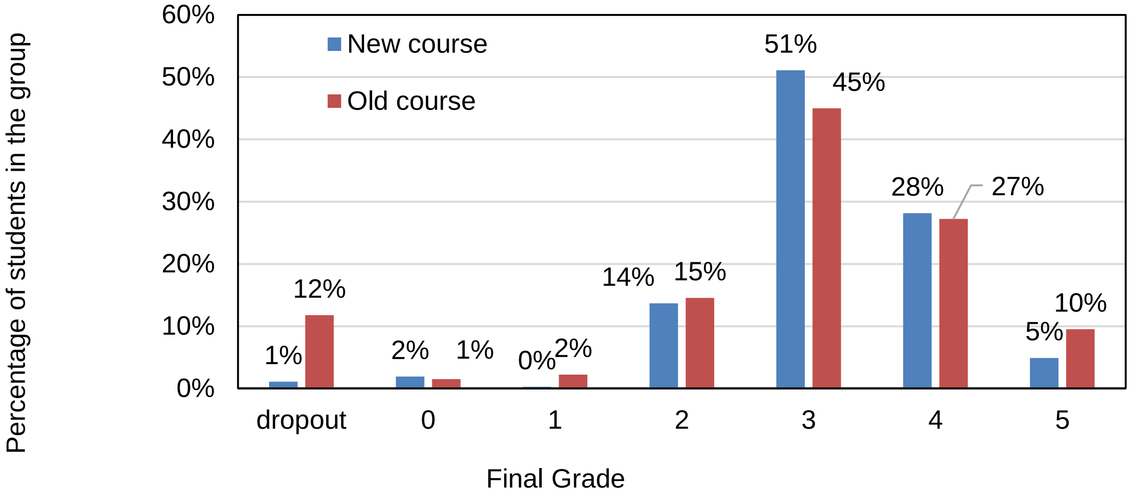

Fig. 4. The distribution of grades from dropouts and 0 (the worst grade) to 5 (the best grade) in students participated in old physics laboratory course (red) and in the new one (blue). Data consists of learning outcomes of 902 students.

It can be seen that the average grades are slightly lower in the new course. Especially the percentage of the highest grade 5 is remarkably smaller in the new course. One explanation can be that the communications teachers are better to evaluate the language itself and they concentrate on it – maybe more than physics teachers did in the past. There have been errors in the proper use of language even before, but physics teachers tended to ignore it and concentrated on the correctness of laws of physics and calculations. On the other hand, language was one aspect that needed to be improved in reporting [6].

The number of dropouts is reduced from 12 % to 1 %. This positive effect is likely to be the result of the much larger amount of support and guidance to the reporting they get in the new course. The workshops provide a scheduled, compulsory place and time for the students to continue and even finish their reports.

When a course has many teachers and many point of view to the same topic, there is a danger that the constituents remain separate, don't support each other and don't form an entity. Student experiences about this aspect were surveyed in one class (27 students) with a few questions and the results are shown in In *Fig. 5*. The results show that with the new curriculum it is possible to generate a more cohesive and concise view to measurements and reporting aspects and prepare the students to the studies to come. Moreover, physics teachers reported that especially last reports were better than before and, in general, they were submitted in time. Their layout and text properties also followed better the appropriate standards. Moreover, there haven't been students' complaints about the work load anymore.

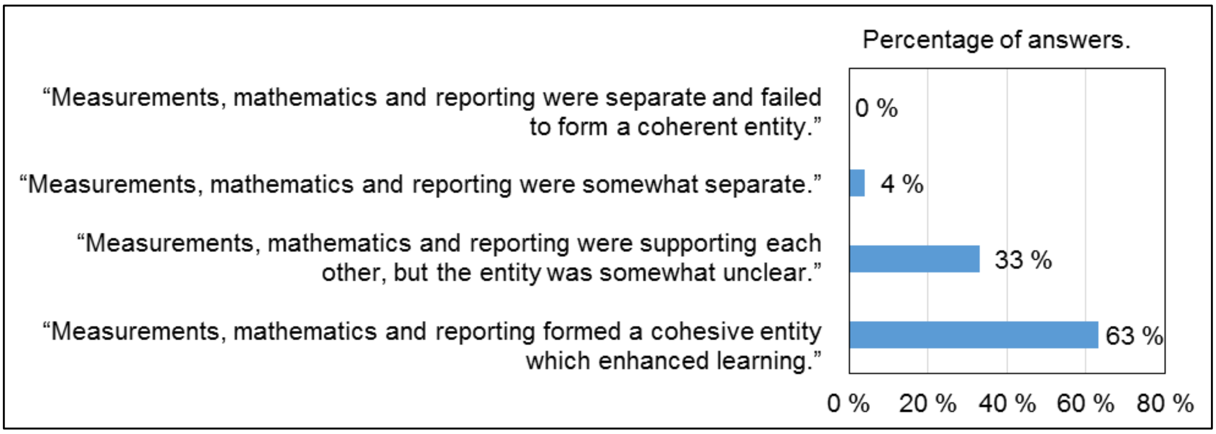

Fig. 5. The student answer distribution to questions related to course's coherence (N=27).

The main challenges in this type of a course are not in the implementation, but rather in the planning stage. The management and planning of time-table and classroom reservations are rather complicated. All three parts need to be handled: 1) the student groups should have a clear schedule, the contact hours every week at the same time (but in different classrooms), 2) Unnecessary gaps in teachers' schedules should be avoided and 3) classrooms booked only for needed usage.

The communications and mathematics teachers were working together with many physics teachers and it turned out that despite the same structure and rubric, the physicists had modified the laboratory work slightly in their own ways. This put extra pressure on the other teachers to be aware of these modifications. In the future, the communication between all teachers need to be even more intense.

4 CONCLUSIONS

The new laboratory course implementation has offered the students much more support in data analysis and scientific reporting than before. Course implementations had 3-4 teachers: 1-2 physicists, a mathematician and a communications teacher. According to survey results and learning outcomes, the teachers' contributions to the course were in line with the learning objectives and they were able to help the students to construct their knowledge and skills coherently. The number of dropouts was reduced and most students felt that they had learned a lot during the course. No complaints about the workload were heard anymore. The reports were better than before and they were submitted in time. Their layout and text properties also followed better the appropriate standards.

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