Enhancing scientific analysing and reporting skills - integrated physics laboratory course

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Abstract

Physics laboratory courses have always been included in the curricula of all engineering degree programs at Tampere University of Applied Sciences. Physics laboratory course is usually the very first course in which freshmen encounter not only measurements, but also uncertainty evaluation and scientific reporting. The versatility of the skills needed is large: laws of physics, measurements, uncertainty evaluations, reporting and yet skills in using MS Word and MS Excel. Despite the great interest the student have always shown in active doing in the physics laboratory courses, they have considered them as demanding and laborious. Therefore, the course contents have been changed to offer more support to analysing and reporting skills. Now the first physics laboratory course is called "Basics of measurements and scientific reporting" and it consists of equal amounts of physics, mathematics and communication studies, 1 ects each, instructed by a physicist, a mathematician and a communications teacher, respectively. The key idea of the course 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. Furthermore, now the students get much more support and guidance. Students have this course scheduled in the same time at every week, but the classroom and the teacher changes. First they go to physics laboratory to carry out measurements. Next week they bring their measurement results to mathematics workshop, which content is related to the analysis of their results. In reporting workshop they learn how to report them in a correct way. This three-week circulation is repeated three times. As the course proceeds, the learning objectives are varied and they get more demanding. It is possible to generate a more cohesive and concise view to measurements and reporting aspects and prepare the students to the studies and work life to come.

Keywords: Physics laboratory course; Measurement skills; Scientific reporting; Integrated course.

Summary

Laboratory courses are sometimes considered as demanding and laborious. Therefore, the course contents have been changed to offer more support to analyzing and reporting skills. Now the first physics laboratory consists of equal amounts of physics, mathematics and communication studies, 1 ects each, instructed by a physicist, a mathematician and a communications teacher, respectively. The key idea of the course is to bring together all the basic skills a student needs related to measurements and their reporting. It is possible to generate a more cohesive and concise view to measurements and reporting.

Introduction

Traditional physics curriculum in Bachelor's level engineering education at Tampere University of Applied Sciences (TAMK) has always included some laboratory work, either as its own laboratory course or integrated within a theory course. Physics laboratory courses develop engineering, scientific, and reporting skills of the future engineers. According to the student feedback, physics laboratory work and especially writing reports is considered very time-consuming, even compared to the ECTS credits of the course. Despite the feedback, students very much agree that they have learned a lot of important skills during the elementary physics laboratory course. On the other hand, as physics educators, it was seen that the quality of reports needed to be improved further. In order to react to the students' and instructors' feedback, TAMK's system of implementing elementary physics laboratory courses is going through a continuous developing process. This paper describes the latest step of the process, a change in curriculum, to form an integrated course in order to achieve enhanced measurement and reporting skills of first year engineering students.

Background and reported methods to improve laboratory courses

Even though the learning outcomes from physics laboratory course are seen very important, some pressure is coming not only from the students, but from the financing. Laboratory teaching is more expensive compared to the theoretical methods of teaching. This raises the danger of reducing the amount of laboratory courses in the name of reducing costs. In some studies, students have reported laboratory experiences to be negative or dull, mainly because the tasks, working and the solution methodology are pre-stated (Das, B., Hough C. L. Jr, 1986). On the other hand, student feedback and a survey from Australia shows the opposite result: physics laboratory work provides students with many important skills that they think they do need in the future. Laboratory work is also seen to be useful, understandable, interesting and enjoyable by the students (Blathal R., 2011). In order to increase the students' interest in physics laboratory work, the idea of self-designed, poster reported physics laboratory experiment was implemented in Tampere University of Applied Sciences (Tiili, J., 2012). In that study, it was shown that the quality of reporting needed further improvement.

In some cases, modern ICT has been seen as one tool to reduce costs of laboratory working. Laboratory experiments can be done hands-off using videos or live streaming from an actual measurement (Abdel-Salam *et al.*, 2006). All different methods of laboratory work have their own advantages. Traditional hands-on laboratory work is initially needed to bring the sense of reality in the remote and virtual labs (Ma, J., Nickerson, J. V., 2006). Traditional hands-on laboratory work brings the important aspect of a direct social interaction to learning. To increase the collaborative nature and social interaction to reporting, Google Docs is reported as a collaborative reporting tool in The United States (Wood, M., 2011).

Traditional hands-on experiments have their strengths. To improve students' motivation, the method of implementing and reporting may vary. Mainly to increase students' motivation, Greer has reported the method in which laboratory experiments' traditional tasks have changed to challenge laboratories. In challenge laboratories, students work first in a traditional way doing measurements and calculating results. After that students face a challenge concerning the experiment (Greer, A. J., Bierman, J. D., 2005). As instructors, the most important challenge is to make sure that students' learning outcomes are up to date and relevant to their future studies and professional needs, no matter the method used.

Evolution of the laboratory courses

Physics laboratory courses have been changed many times during the past decades. Most of the time, there have been two physics courses, both yielding 2 ects credits. In this study all data is for the first physics laboratory course, in which the students encounter measurement data analysis and reporting for the first time. Major, curriculum-level changes are summarized in table 1. The amount of classroom time for one laboratory work has increased from 4,5 h to 10 h, as shown in table 1. This increase includes workshops and theoretical lectures in mathematics and reporting to support the ongoing laboratory works and their reporting. Now all the necessary skills are taught within the laboratory course, not in separate mathematics lectures and writing lectures.

Until year 2005, classroom time was almost entirely used for carrying out measurements. At that time, there was only a three hour lecture of reporting and uncertainty evaluation. The students were supposed to learn the analysis and reporting autonomously by just reading instructions and doing it. At that time, the step from a freshman's basic skills to the skills needed to complete the first report was huge, which created discomfort among some students and not all of them were able reach the needed level. In addition to writing a report of all works, there was also an examination related both to the topics and to data analysing methods of various works.

Thereafter, from 2005 to 2013, scientific reporting workshops and peer reviews were included to course content to offer some support and guidance to the students. All this was carried out by physics teachers. The laboratory work final examination was discarded and the evaluation and assessment of learning outcomes was based on the reports and portfolio. Feedback about the reports was also given more continuously, not only by the instructors, but also as peer review.

At the latest step in 2013 curriculum development, the structure of the laboratory course was changed more dramatically, as described in detail in next chapter. The course contents have been changed to offer more support to analysing and reporting skills. The first physics laboratory course "Basics of measurements and scientific reporting" consists of equal amounts of physics, mathematics and communication studies, 1 ects each, instructed by a physicist, a mathematician and a communications teacher, respectively. This course is then followed by "Physics laboratories", which is extended to 3 ects credits and therefore the total amount of credits from physics labs is unchanged. The key idea of the new course 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. 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.

Table 1. Time usage of the first physics laboratory course.

Time usage	-2004	2005-2013	2014-
Total classroom time	27 h	33 h	30 h
Measurements	18 h	18 h	9 h
Intro, maths, writing, workshops	3 h	9 h	19 h
Feedback	2 h	6 h	3 h
Examination	3 h	-	-
Number of lab. works	6	6	3
Classroom time per work	4,5 h	5,5 h	10 h

Arrangements in the new laboratory course

The course "Basics of measurements and scientific reporting" has three measurement assignments, which each are followed first by a mathematics lectures and workshop and then by reporting lectures and workshop, as shown in figure 1. From the student's point of view, 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, typically in the form of a log book. If the students have time after measurements, they can continue calculating the actual results. Time reserved for this stage is 3 h.
3. With the log book and data, the students go to mathematics lecture (Maths), which topic is related to the analysing skills the students need for the laboratory work. Typically, in the first cycle, this means error calculations. The lecture part is rather short and it is directly followed by a workshop, during which the students are able to carry out the necessary calculations with the help of the teacher. 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. During this three hour period of many students are able to finish the report. The deadline is, however, one week later, before the first reflection time.
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.

One measurement-analysis-reporting set, or a cycle, lasts for three weeks plus one or two extra weeks for finishing the report. The three hour sessions are scheduled to the same time window in the timetable during successive weeks. After the second and third cycles, students have two weeks to finish their report. The learning objectives are getting more and more demanding as the course proceeds. For the second cycle, the objectives are linear regression and graphs in mathematics and the correct way in referencing in reporting. Again, students have the opportunity to write their reports in workshops with the help of maths and communication teacher, consecutively. During the third cycle the students learn how to use total differential method in error analysis.

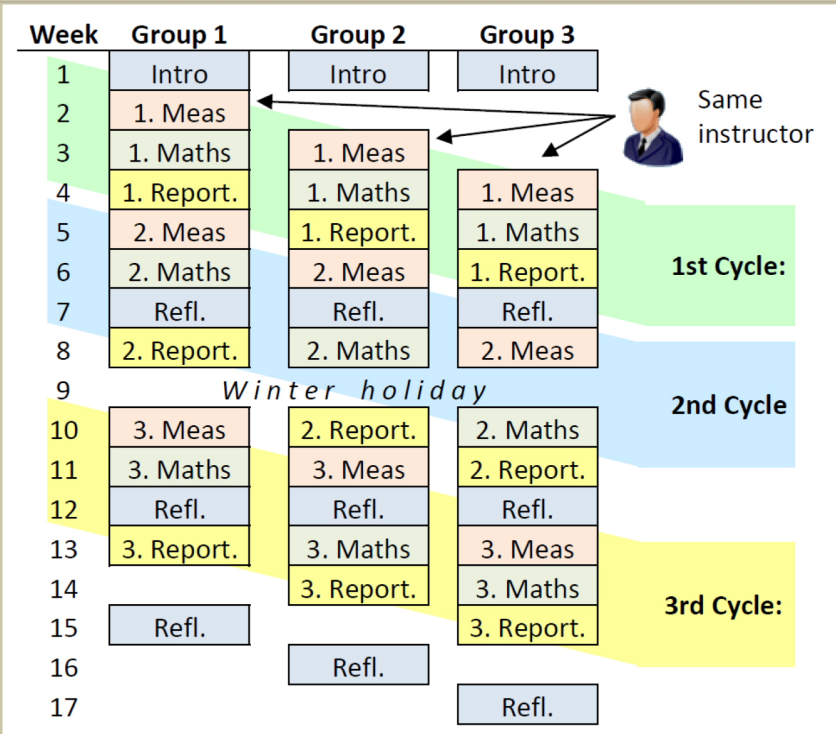

Fig. 1. Arrangements in the new laboratory course.

Like the student groups, the same time window is reserved for instructors every week. The difference is that a teacher has one group in first week, another in second week and yet third group in third week of a cycle. In this way, it is possible to fill in the time table of a teacher without unnecessary gaps.

Feedback and survey results of the new course

Feedback concerning experiences about arrangements and learning outcomes was collected from the students using questionnaires and some of the instructors of the course were interviewed. Figure 2 summarises the student feedback of their own learning outcomes. The students were asked how they experienced their skills to have increased during the course. The scale was from 0 (lowest) to 5 (highest). Most of the students rated their improvements as 4 in all other categories. In general, the feedback shows that most students feel that they have learned a lot during the course. The same conclusion can be made based on instructor experiences: physics teachers reported that especially last reports were better than before and, in general, they were handed out in time. Their layout and text properties also followed better the appropriate standards. Simultaneously, teacher's work load in reading and commenting reports has decreased.

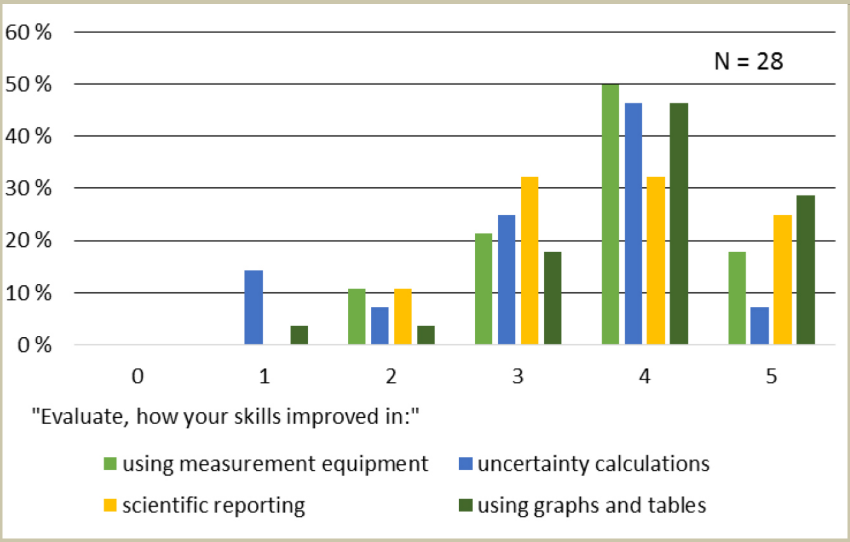

Fig. 2. Survey results of improvements in skills.

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 with a few questions and the results are shown in table 2. Majority of the answers (63 %) show that 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. Moreover, the students felt that measurement and reporting skills are relevant to an engineer to be, as shown in figure 3.

Table 2. Student feedback about course constituents, N=27.

Question:	No. of answers
"Measurements, mathematics and reporting were separate and failed to form a coherent entity."	0 (0 %)
"Measurements, mathematics and reporting were somewhat separate."	1 (4 %)
"Measurements, mathematics and reporting were supporting each other, but the entity was somewhat unclear."	9 (33 %)
"Measurements, mathematics and reporting formed a cohesive entity which enhanced learning."	17 (63 %)

At least in this piloted case, 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.

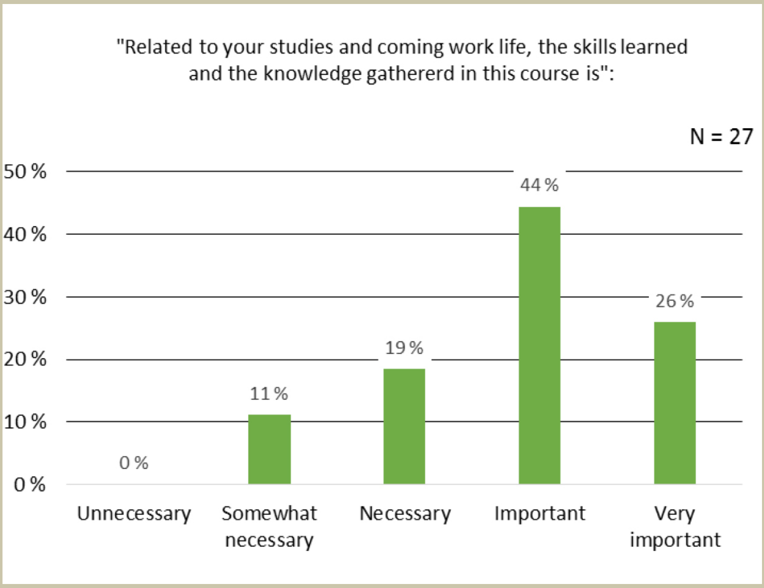

Fig. 3. Importance of the skills obtained in the course.

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, 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. Most students feel that they have learned a lot during the course. Physics teachers reported that reports were better than before and they were handed out in time. Their layout and text properties also followed better the appropriate standards. Simultaneously, teacher's work load in reading and commenting reports has decreased.

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