Laboratory Instructions as a Cause of Student Dissonance

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1 Introduction

In this paper, we aim to explain and remedy the major differences in pass-rates for a laboratory given to both electrical engineering (EE) and computer science (CS) students at the largest university in Sweden. Almost all EE students fail the lab, whereas nearly every CS student of the previous year passed. The EE and CS labs are given at different points in the education and have different course managers, but the labs are strikingly similar.

We performed a student survey in order to identify the problem areas. In particular, we asked about the level and quality of the lectures and laboratories. These are important issues, since the EE course has different managers for these two tasks. Previous attempts to get student feedback have been made by the lab session manager [1]. However, our survey was extensive, with answers from over 100 students. Unfortunately, we could not give the survey to the CS students, as this years' students have yet to take the lab.

In our analysis we identified the laboratory manual as the main cause of concern. The students felt that the lectures and lab were at an appropriate level. However, they were not able to understand the lab preparations and assignments properly. We explore many other reasons for the student performance, including the fact that the EE students were finally given the CS lab manual as a way to increase pass-rates.

The rest of this paper is organized as follows. Section 2 describes the problem background. Section 3 presents the theoretical view of laboratories in higher education. Section 4 details the student survey we used to determine the problem structure. Section 5 analyses the problem using our survey results. Section 6 gathers the conclusions of our research and suggests future improvements to the course.

2 Background

The core curriculums of both the electrical engineering and the computer science programs contain one mandatory electronics course each. The courses cover the same basic topics. However, the intention is to give the EE students a deeper understanding of fundamental electronics to encourage further studies, and to give them a solid foundation for their studies in electronics. This difference is motivated by a belief that the electrical engineering students should have a deeper interest in the subject of electronics since they chose that field of study. However, EE is one of the easiest programs to get accepted to, easier than computer science, which might mean that many of the people attending had EE as a secondary or tertiary choice.

The issue we are studying is a laboratory session given to the electrical engineering students. Almost all of the 120 students failed to complete the assigned tasks within the allotted time, and had to return for extra sessions. The corresponding laboratory is given to the computer science students, of which 80 % finished on time.

The EE students are given the basic electronics course in their first semester at university, whereas the CS students have had the chance to acclimatize to the workload of a university education when they take the course. The computer science students are given their electronics course in the very late autumn stretching until summer next year. Both electronics courses are given over two semesters, which roughly translates into five months. Traditionally, both the CS and EE programs are dominated by a male population, although the ratio has improved over the last few years. Both courses have the same course book and the laboratories cover the same topics. The two courses have different managers and therefore different lectures. However, half of the teaching assistants (TAs), two out of four, have given the laboratories to both CS and EE students.

The laboratory manuals for CS and EE differ significantly. One obvious difference is that the manual given to the computer science students has a simpler layout with plenty of figures and not very condensed text. The corresponding manual given to the electrical engineering students looks, at first glance, more "professional" and consists mostly of condensed text, see Fig. 1. Upon closer inspection, the CS manual clearly gives step-by-step instructions on what to do. In the case of EE, the assignments are more guides on what is to be achieved, rather than clear instructions on how to do so. Here, the students must use what they have learnt from the lectures and the text book in order to put their theoretical knowledge of the subject to practical use. This is quite a leap for many of the students, especially the ones that are coming directly from high school. Both CS and EE students have the same kind of preparations (assigned pages to read and related problems to solve) to complete in order to participate in the lab.

Another difference in the laboratory exercises is that the computer science laboratories take place on a robot, which for each lab has a new program that the students can examine and understand. Usually, the program will consist of "faulty" programming, causing the robot to malfunction. The task is to build a circuit to compensate for the "faulty" programming, making it, e.g., drive in a straight line instead of in a circle. The analogous lab for the electrical engineering students consists of building the same circuit on a standalone board, and simply measure their circuit and draw graphs (the computer science students also draw graphs but they have the "real" solution in front of them with the robot working as assigned). Hence, the computer science students apply their knowledge to the practical problem they are assigned. This allows them to see that their circuit actually makes a difference, rather than just seeing a graph changing its appearance on their measurement setup.

3 Laboratory Styles

There are several possibilities when constructing a laboratory for students. In [3], Domin presents a taxonomy of laboratory instruction styles. Domin focuses on chemistry laboratories, but the ideas can easily be transferred to labs in electronics, which is the subject of this paper. The laboratory styles are distinguished by their outcome, approach and procedure.

- **Outcome** The result of the laboratory exercises may or may not be predetermined. Moreover, it could be the case that the instructor knows the outcome, but not the students.
- **Approach** The approach could either be based on a general principle (deductive), or the general principle could be derived by observing particular instances (inductive).
- **Procedure** This determines how the lab should be performed. The procedure is either given to the students in the form of a manual, or they might have to determine the procedure to use themselves.

In the *expository* style, everyone knows the outcome, including the students. The task is simply to verify that the behavior is as expected. The approach is deductive and the procedure is given to the students.

Spänningsaggregatet

Utförande

Koppla upp dina filter på kopplinsplattan.

1. I brytpunkten har utsignalamplituden sjunkit till $1/(\sqrt{2}) \approx 0{,}7$ relativt insignalen. Bestäm brytpunkten genom att variera frekvensen på tongeneratorn och studera utsignalamplituden från nätet. Anslut båda probarna, en på insignalen och en på utsignalen.
2. Det asymptotiska bodediagrammet, amplitud och fas, är räta linjer med känd lutning samt brytpunkter. Det uppmätta bodediagrammet skiljer sig ytterst lite från det asymptotiska utom just i brytpunkten. För att kunna plotta diagrammet behövs då endast två till tre punkter på varje kurvdel samt brytfrekvensen. Gör mätningar och plotta diagrammen för både amplitud och fas. Angående fasmätning se appendix A.
3. Rita in det asymptotiska Bodediagrammets linjer i samma plot.
4. Belasta utgången med en resistans av samma storleksordning som R och bestäm brytpunkten. Förklara eventuella förändringar.
5. (*Obs! koppla bort en probe helt i denna mätning på grund av risk för kortslutning genom jordklämmorna*)
   Mät amplituden på insignalen, spänningen över R och spänningen över C med oscilloskopet (Multimetern klarar inte frekvenser över 1kHz). Det gäller att $v_{generator} = v_{resistor} + v_{kondensator}$. Stämmer Kirchhoffs spänningslag enligt din mätning? Förklara!

EXTRAUPPGIFT: Undersökning av "Svarta lådan"

Utförande

Använd dina kunskaper för att så långt det är möjligt karaktärisera innehållet i en okänd koppling utdelad av handledaren. Försök att göra en kretsmodell som beskriver uppträdandet.

EXTRAUPPGIFT: Karaktärisering av förstärkare med komersiellt mätinstrument.

Institutionen har ett audiotestinstrument *Audio Precision Mark II* som används kommersiellt i tester av audioförstärkare. Instrumentet styrs från en PC där det finns många färdiga testprocedurer och data kan lagras. En mätuppställning är förberedd för demonstration och en handledare visar möjligheterna.

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Uppgifter

Uppgift 1

I denna uppgift kommer du att studera frekvenssvaren från de låg- och högpassfilter ni designat och plotta motsvarande Bodediagram.

Uppgift 1.1

Koppla upp ditt lågpassfilter med brytfrekvensen 350 Hz på en Boe-Botens kopplinsplatta. (Robotens strömbrytare skall vara i läge 0.) Använd tongeneratorn för att generera en insignal. Koppla in den enligt förberedelseuppgift 2 till filtret. Plotta Bodediagrammet genom att mäta amplitud och fas för signaler mellan 100 Hz och 10 KHz. Tänk på att diagrammet har logaritmisk frekvensskala då ni väljer mätpunkter. För in era mätvärden både som en tabell i er labbdagbok, och i diagrammet längst bak i labbhandledningen. Glöm inte att gradera axlarna i frekvens, fas respektive dB så att det stämmer med era mätvärden.

Uppgift 1.2

Upprepa föregående uppgift för ditt högpassfilter med brytfrekvensen 1500 Hz. Anteckna mätvärdena och plotta bodediagrammet.

Uppgift 1.3

Jämför era plottar med de asymptotiska resultaten i Figur 6.15 i boken "Electrical Engineering". Kommentera skillnaderna. Anteckna dessa i er labbdagbok.

Uppgift 1.4

Belasta utgången av ditt högpassfilter från föregående uppgift med en resistans av samma storleksordning som R. Anteckna svaren på följande:

- Bestäm brytpunkten för det nya nätet.
- Förklara eventuella förändringar.

Uppgift 1.5

Koppla bort lasten.Mät amplituden på insignalen, spänningen över R och spänningen över C med oscilloskopet (Multimetern klarar inte frekvenser över 1kHz). Stämmer Kirchhoffs spänningslag? Anteckna era observationer.

Tänk på att jordförbindelsen på de bägge probarna är ihopkopplade i oscilloskopet. För att kunna mäta spänningen över en komponent mitt i en krets så används funktionen "Diff" hos oscilloskopet – fråga labbhandledarna hur man gör.

Figure 1: Laboratory manual for the electrical engineering students at the top and for the computer science students at the bottom.

In the *inquiry* style, no one knows the outcome of the lab, not even the instructor. The approach is inductive and the students have to determine the procedure themselves. In this style, no lab manual is given.

In the *discovery* style, the instructor knows the outcome, but the students in general do not. The approach is inductive and the students follow a given procedure.

In the *problem-based* style, the instructor knows the outcome of the lab, but the students do not. The approach is deductive, but no manual is given. The students have to develop the procedure.

Considering the different laboratory styles, it is clear that most laboratories at LTH are of the *expository* style, also known as the "cookbook" procedure. This is also true for the lab that we consider in this paper. Hence, we will focus on this style and not elaborate further on the other ones. Most tasks in expository labs are focused on verification of known results. The style also focuses on giving the students experience of practical work.

The expository style is the traditional and most common one at universities. Practical work is the most expensive part of an engineer's education [4]. One reason that expository laboratories are so common is the relatively low cost. This can be compared to lectures, another teaching form that is common at most universities, including Lund. Lectures also have economical advantages in comparison to other teaching forms. But when it comes to student learning, many other forms of teaching have been shown to be much better [5]. Another advantage of expository laboratories is that they are easy to organize, as space and equipment requirements are known beforehand. Moreover, the time span for a laboratory can usually be predicted and the students need minimal guidance from the teacher.

While being cost-efficient, the expository style has several drawbacks. Investigation and interpretation of results usually do not get enough attention. Moreover, there is no emphasis on thinking, a behavior which would stimulate a deep approach to learning [6]. In this paper we evaluate a laboratory session which almost none of the students finished on time. If students feel that they have to rush through a lab in order to finish it in time, there is no time for processing the information. Thus, it is likely that a surface approach to learning is predominant among the students, despite the intentions of the teacher. This is true for expository laboratories in general, and especially in our case. Relating this to Bloom's taxonomy [7], the students are likely to operate at the three lowest levels: knowledge, comprehension, and application. They are not given an opportunity to operate on one of the higher levels, analysis, synthesis and evaluation, even if they would like to. This is largely due to time constraints, but can also be attributed to the expository style of the laboratory.

4 Student Survey

In order to get a clear picture of the experiences and viewpoints held by the students, we decided to use a questionnaire. Interviewing seemed to be a viable alternative at first, but this option was discarded for practical reasons. We did not possess a priori knowledge regarding expected problem areas, hence, the questionnaire was designed as a broad spectrum survey. The development of the questionnaire was inspired by the design guide in [2].

We considered asking each question more than once, only reformulated, in order to improve the accuracy of the answers. However, fearing that a longer questionnaire might lead to a lower response rate and/or careless answers, we decided to keep the number of questions low. Hence, the effort required by the students was quite reasonable. We decided not to ask the students about their background before university, as it would be very hard to create relevant multiple-choice questions.

We performed our survey during the break in one of the course lectures. All the present EE students were asked to rate their opinion about the eight statements below on a scale from "do not agree at all" to "fully agree". By giving four possible answers, we forced the participants to form an opinion other than "neutral" or similar, hoping this would give better answers. There were three lab occasions and we recorded which of the three lab sessions each student had attended. In total, we received 104 answers, three of which were discarded due to failure to indicate the lab session.

1. The lectures contained information that was relevant to the lab.
2. This information (see Q1) was easy to understand.
3. The laboratory instructions were easy to comprehend.
4. The instructions gave enough information to complete the lab in a useful manner.
5. I considered myself well-prepared when I arrived to the lab.
6. The teaching assistants did their best to help me through the lab.
7. I found the lab too difficult.
8. I had problems with the lab equipment.

We also let the students comment, in free-text, on what they believed could be improved by the next laboratory session in *the course they were currently taking* as well as by the time *the same laboratory* is given next year.

4.1 Results

The 101 answers in our survey, are summarized in Fig. 3(a)-(h) where Fig. 2 explains how to interpret the pie charts. In short, darker colors indicate disagreement while lighter colors signify agreement. Parts of our analysis uses data and correlations that are available upon request.

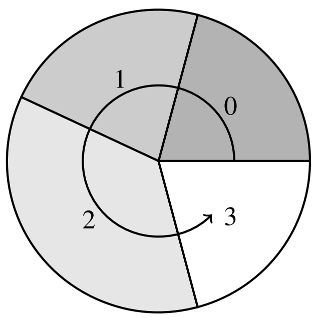
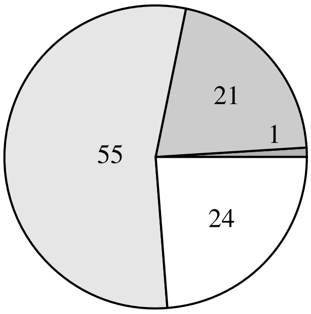
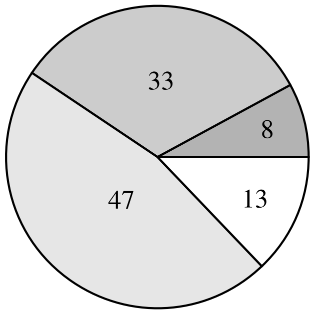


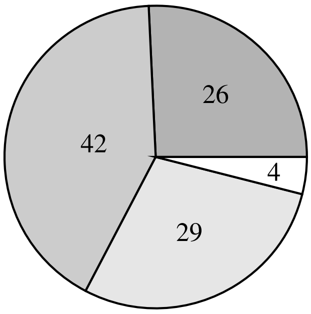
Figure 2: Legend for Fig. 3. Each chart begins at "three o' clock" and progresses anticlockwise in the manner illustrated here. The range 0-3 corresponds to the range in answers from "do not agree at all" to "fully agree".



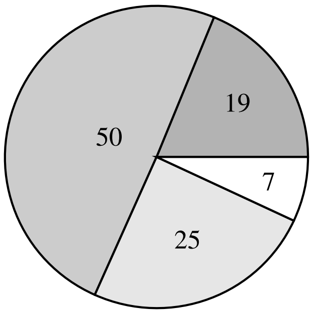
(a) Q1: The lectures contained information that was relevant to the lab.



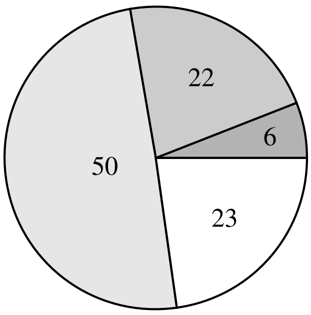
(b) Q2: This information (see Q1) was easy to understand.



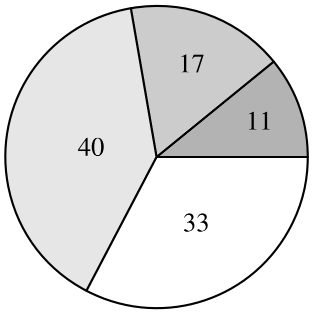
(c) Q3: The laboratory instructions were easy to comprehend.



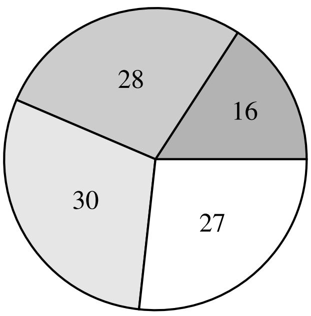
(d) Q4: The instructions gave enough information to complete the lab in a useful manner.



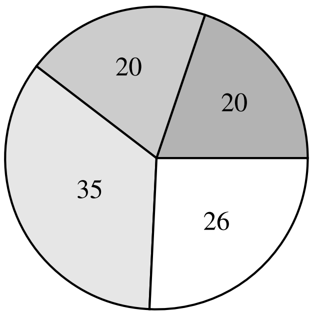
(e) Q5: I considered myself well-prepared when I arrived to the lab.



(f) Q6: The teaching assistants did their best to help me through the lab.



(g) Q7: I found the lab too difficult.



(h) Q8: I had problems with the lab equipment.

Figure 3: Answers to the questions asked. See Fig. 2 for a legend.

5 Survey Analysis

It is no coincidence that we chose to evaluate this particular laboratory. Some of the authors have first-hand experience of the difficulties in this electronics course. This lab, in particular, is known to be quite difficult. We have split our survey analysis into the four main links in the education chain leading up to this lab.

5.1 Lectures

The students feel that the lectures contain information relevant to the lab session. Furthermore, they find this information reasonably easy to understand, see Fig. 3(a) and Fig. 3(b). Students that find it easy to understand lab-relevant information in the lectures are often more at ease with interpreting the lab manual. However, even these students rank the manual as hard to understand. Our conclusion is that the lectures are not a major contributor to the lab problems.

5.2 Laboratory Manual

Our survey results clearly show that the laboratory manual is regarded as nearly incomprehensible. With four top scores and 26 bottom ones (out of 101), the distribution of the answers is shifted well below average, see Fig. 3(c). This gives the manual an exceptionally low score. The instructions are a major problem for the students, as further indicated by Fig. 3(d). This is also communicated through the free-text answers. Comments like "Improve the manual!" were abundant. Virtually all students that found the manual difficult, also found the laboratory session very hard. Hence, there is room for improvement.

5.3 Laboratory Preparations

The students generally regarded themselves as being quite well-prepared for their laboratory session, see Fig. 3(e). This is interesting in itself, but curiously, even the well-prepared students did not find the laboratory session easy. With no other indications on session difficulty, it is tempting to dismiss the poor laboratory results with the conclusion that freshmen are not used to lab preparations. However, our survey shows that there are other factors that need to be taken into account.

5.4 Laboratory Sessions

The three lab sessions were not given on the same day. The second one was given one day after the first, and the third session a full week later. According to the student answers, the laboratory sessions gradually got easier, with the first session being the most difficult. Our survey took place after a remedy lab session. It is noteworthy that the lab itself is not perceived as very difficult afterwards, as indicated by Fig. 3(g).

There are several reasons why the labs were seen as easier by the students at the later sessions. First, as with students, the level of preparation of the teaching assistants is important. As Fig. 3(f) shows, the students were in general satisfied with the TAs. However, the free-text answers from the students in the first lab session seem to clearly indicate discontent in this regard. Over time, the TAs get used to their job so that they can anticipate questions, and more readily solve problems with the equipment. This is indicated by the change in answers to the question in Fig. 3(h). Many students also commented on the low TA-to-student ratio, in particular during the first session. Some free-text comments stated, paraphrased, "The TAs did a very reasonable job, there were just too few of them!". This explains how to reconcile the many opposing comments, like "We need better TAs!" and "The TAs did a good job!".

Another reason why the students did better at the later sessions is time. Students have additional time to digest the information from the lectures if they attend a later session. Some students commented on this in the free text field.

Further, the students were given access to additional and simplified instructions in the last two lab sessions. These simpler instructions are used by the CS students. As described earlier, the labs are nearly identical. Apart from the fact that the laboratory sessions were given at different times, the additional aid that these instructions provided is the only other factor that seems relevant.

6 Conclusions

Our main conclusion is that the laboratory manual given to the electrical engineering students needs to be improved. The results of our survey clearly point to the lab instructions as the main concern. In fact, all other parts of the course fare reasonably well. Even the difficulty of the lab is considered acceptable by the students, despite the fact that hardly any of them passed without a remedial session.

In general, the students were quite happy with the difficulty and relevance of the lectures. The students felt that they had understood the lectures, and considered themselves prepared for the lab. Hence, it is strange that they did not pass this expository lab, further indicating that the laboratory manual is at fault. In particular, the preparations were clearly not sufficient.

The good thing about the manual is that it aims at a deep approach to learning. However, if the time constraints are too high, there is no time for understanding. Hence, the students are forced to take a surface approach to learning, which fails since the assignments are too difficult for this approach to learning.

6.1 Improvements

Our main recommendation lies in modifying the lab manual. Clearly, the students felt the laboratory was relevant to the lectures, and the difficulty acceptable. Hence, the lab itself is good, but the instructions are not. The lab manual given to computer science students were used as a last resort in order to help the students. Therefore, a good place to start is to change the instructions to resemble those of the CS students.

Another improvement is to change the lab itself. It would undeniably be interesting to see whether the EE students performed better if they had the same lab as the CS students, but using the electrical engineering manual. Since the EE lab takes place very early in the education, the students may simply have difficulties with constructed scenarios. Ideally, the students would be split into two groups: one that performed the CS lab using the EE manual, and one that performed the EE lab with the CS manual.

Both the computer science and electrical engineering labs are expository in nature, with the latter being slightly more aimed at deep understanding. A small modification to the lab manual would be to use step-by-step instructions in the first parts, then slowly move into more loose problem formulations. This would allow the students and TAs to become accustomed to the scenario and the equipment before getting to the difficult parts.

We suggest that the scope of the lab is reduced. This would allow the students more time to process the information, which stimulates a deep approach to learning. After all, it is better that the students learn half as much than that all of them learn very little. As it stands, the lab aims for the moon and hits nothing.

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