

Evaluating the Open Lab Format in Supporting Student Learning

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Abstract

This project investigates whether the open-lab workshop format used in the course FYSN35, Electronics for Physicists, supports student learning more effectively than traditional one-day laboratory sessions. Using constructive alignment and the SOLO taxonomy as analysis frameworks, we examine how students perceive their learning during workshops and which types of learning activities they associate with the two laboratory formats. Data were collected through a mid-course Mentimeter poll and a questionnaire performed during two workshop sessions. The results indicate that students rate the workshops substantially higher in supporting their learning and that they to a higher degree associate workshop activities with higher cognitive processes, such as reflecting, hypothesizing, and creating their own investigative strategies. These results suggest that the workshop format fosters greater independence and deeper learning, although our conclusions are limited by the small sample size and the self-selected nature of participation in the workshops.

1 Introduction and aim

Laboratory work is a central part of physics education, and is expected to play a significant role in the transformation of students into full-fledged physicists. It allows students to describe physical phenomena and critically apply physical theories onto them. Acquiring the expertise to do so successfully requires a cultivation of different ways of thinking, such as problem-solving, creativity, and analytical reasoning. For students to learn these skills, it is important that they actively engage in practice throughout coursework, e.g. during lab sessions. This is part of the principle known as constructive alignment [1, Chapter 4], in which it is argued that learning activities must be aligned with the intended learning outcomes and assessment method. Achieving this can be difficult with “traditional” lab sessions, where the students follow a list of instructions and where the labs take place during a specific period of time, which is set apart from the rest of the course, i.e., the lectures and exercise classes. An alternative approach is the so-called *open lab* format, in which students work actively and independently on partially open-ended laboratory projects. The aim of this project is to investigate the effectiveness of the open lab format by evaluating the learning activities which take place during such sessions, and compare this with more traditional laboratory sessions.

2 Background

2.1 Course description

The subject of study for this report is the course FYSN35, Electronics for Physicists, given at the Department of Physics at Lund University. It is an elective second-cycle course geared at 3rd- or 4th-year physics students at the Faculty of Science. It is given in its current form for the first time during the writing of this report, being reworked from the earlier course FYSN15, Experimental Tools. The latter followed a traditional format with 2-hour lectures on statistics and electronic components, assessed through smaller hand-in exercises. This was then followed by a 2-week open-lab session, where the students were given free access to all available electronic equipment

and tasked with building certain circuits. While supervisors were available by request during the building phase, the detailed planning of the work process was left to the students. The students were instructed to show the completed circuits to the lab supervisors and write reports analysing not only the resulting circuit behaviour but also the work process.

Following consistent student feedback that the open lab period was the most rewarding part of the course, a significant revision was made along with the new syllabus. The lectures were scrapped altogether and the statistics part of the course was removed. The electronics part of the lectures was significantly reworked into a new 3-hour lesson format. A typical lesson will start with a memory dump activity, where the class is divided into smaller groups (usually 4-5 students) to discuss some topic relating to previous lessons, which is followed by class-wide group presentations on the topics. This is followed by a combination of smaller presentations on electrical components, practical demonstrations and further group discussions.

A large portion of the lessons, typically 1-2 hours, is dedicated to so-called breadboard activities. These are practical exercises that students are expected to complete. Some contain direct instructions while the activities in the latter part of the course may only state an aim and the students have to decide how to reach them. The activities are assessed through small written reports which contain task descriptions, reflections on the task and work procedure, as well as answers to discussion questions. To allow students to complete their work independently, there are also scheduled weekly open-lab workshop sessions (hereafter referred to simply as workshops). In the workshops, students have access to all equipment used in the course and teaching assistants (doctoral students) are available for answering questions. The workshops have no set plan, but students are encouraged to determine for themselves which breadboard activities (or other voluntary extensions) they wish to perform. The students may work individually or in groups, as long as they document who they performed the work with.

2.2 Literature review

To evaluate student learning in this laboratory setting, the so-called SOLO taxonomy [1, p. 76-80] will be applied. As illustrated in Figure 1, the SOLO taxonomy identifies four different levels of learning and divides these into two phases. At the unistructural cognitive level, the student knows a single element of the subject matter, in the sense that they are able to name and identify it. At this level, the student is able to follow a simple procedure. At the multistructural level, the student's understanding encompasses several elements of the subject matter, and they are able to list these, describe them and follow algorithms consisting of several steps. Together, the uni- and multistructural levels are known as the quantitative phase. In this phase, disconnected elements of the subject matter have been learned, and an increase in the student's understanding corresponds to an increase in the number of grasped elements, or an increased level of detail in the students' descriptions of what they know.

A shift occurs when students move to a higher cognitive level and into the qualitative phase. Here, an increase in understanding entails a qualitative change, i.e. a change in how well students integrate, analyse and make use of their knowledge. In this phase, to increase understanding is to "deepen understanding" [1, p. 79]. At the relational level, the different elements of the subject matter can be related to one another. Causes can be explained, arguments can be formed, and different elements can be compared, contrasted and analysed in relation to one another. At the final cognitive level, the extended abstract, the student can use their understanding in other areas, and can generate new knowledge and new understanding from what they know. This level involves hypothesising, generalisations, reflections and creative thinking.

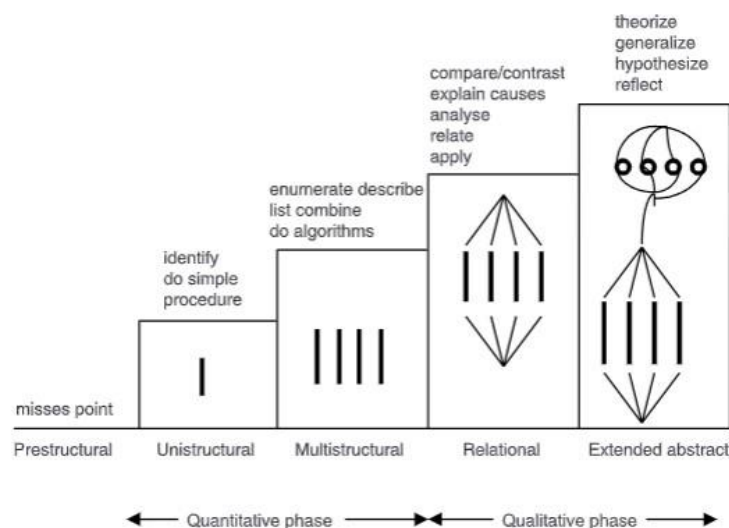


Figure 1: Schematic representation of the SOLO taxonomy, where the two phases, the different cognitive levels, and some associated verbs are shown. Reproduced from Ref. [1, p. 79].

In many cases, the intended learning outcomes of university courses refer to the higher cognitive levels in the qualitative phase. A goal of higher education is to develop creative and intuitive thinking within the subject matter, and to achieve this it is necessary that the students practise these ways of thinking in their learning process. An example of a learning activity designed to induce creative thinking is presented in Ref. [2], where an experiment is given as an example of “learning by doing”, involving a conceptual understanding of the equipment used combined with investigations performed independently by the students. The considerations mentioned in Ref. [2] are reminiscent of those used to describe “learning through inquiry” in Ref. [3, Chapter 6]. Here, it is argued that to facilitate the students’ learning of critical and creative thinking, which belongs at the qualitative SOLO levels, the appropriate learning activities involve responding to non-rhetorical, open-ended questions which require students to practise these ways of thinking. In Ref. [2], the students’ engagement with the learning activities demonstrated creative thinking manifested in them taking initiative, acting spontaneously, independently discovering and attempting to mitigate errors, and formulating problems themselves. These are abilities which belong to the two highest cognitive levels of the SOLO taxonomy. It is stressed in Ref. [2], that to facilitate these activities, the experiment must be motivated by being put into a greater context, must not contain “black boxes”, i.e. aspects or equipment which are not fully understood, and must be open-ended. This view of open-ended, student-driven experimentation as a vehicle for fostering higher-level reasoning is consistent with broader reviews highlighting the potential of inquiry-oriented laboratory work to support learning in science education [4].

Much of this can be said to also apply to the workshops in FYSN35, where the students are encouraged to do their own investigations, ask themselves questions and plan and structure their own work. This format is reminiscent of the studio-style setup described e.g. in Refs. [5, 6]. Although not investigated in these previous studies, one may expect that creative thinking, as well as other abilities belonging to the higher SOLO levels, will be cultivated during the workshops. This is in opposition to traditional labs, where students often carry out a list of instructions, and thus not necessarily reach higher than the multistructural level. The disjointedness of the labs and the lectures in the traditional course structure, might also mean that it is harder for the students to connect different elements of the course (the theoretical knowledge and the experiences in the lab) such as is required at the relational and the extended abstract cognitive levels. Similar concerns about highly structured, recipe-like laboratory formats leading mainly to algorithmic work rather

than deeper conceptual engagement have been raised in previous studies of laboratory instruction [7]. A closer integration of the different elements of a course might mean that connections are easier to form, and that theoretical knowledge is more readily put into practice in the lab. The pedagogical challenge under study in this report is to determine whether the workshops in FYSN35 actually support the kinds of higher-order learning and creative engagement described in the SOLO taxonomy, or whether student learning remains at primarily quantitative levels.

3 Design

In FYSN35, the shift from traditional one-day labs to the workshop format constitutes our proposed pedagogical solution to the challenge identified above: fostering more independent, higher-level learning. In this project, we do not propose an additional redesign of the course, but rather investigate how well this existing solution functions in practice. To this end, we performed two data collection efforts. The first was aimed primarily at establishing some baseline understanding of student perception of the workshop concept. As part of a check-in meeting (generally intended to gauge expectations and experiences of both students and teachers) three weeks into the course (2025-11-19), we asked students whether they were making use of the workshops and L211 (another open lab setting always available but without active supervision). For those who indicated that they participate in workshops, we asked how they utilised the sessions. For those who do not participate, we asked what prevented them from joining the sessions. The exact questions and the anonymised answers (published with permission) are given in Appendix A.

To study students' perception of their learning during workshops, a second questionnaire was handed out to the students who joined the workshops held on 2025-11-25 and 2025-12-02. This questionnaire had two main parts. In the first, students rate the perceived effectiveness of traditional lab sessions (defined as one-day labs separated from the lecture periods) and workshops on a scale from 1 to 10. The second part seeks to characterise student learning by letting students reflect on which activities they engage in during the respective laboratory setting. The activities (mostly in the form of single verbs) are taken from the SOLO taxonomy. The questionnaire in its entirety is shown in Appendix B.

It should be noted that both of these data collection efforts were performed with consent from the course responsible. Both surveys were carried out anonymously and voluntarily. The Mentimeter poll was performed digitally in class while the questionnaire was collected on paper at the end of the workshop session. It should be noted that one of the authors (Linus Persson) is a teaching assistant in the workshop and also participates in grading of student reports. To emphasise to students that this study has no relation to student assessment, all data collection and results compilation of the questionnaire was performed by the other author (Emilia My Kjærdsdam Tellés).

4 Assessment and evaluation

4.1 Results

The results from the Mentimeter poll are shown in Appendix A. Out of the 19 respondents, 12 attended the first workshop (63%) while 10 (53%) had begun making use of the open lab space in L211. Of the 7 who chose not to attend, 6 attribute it to being busy with commitments in other courses. Only 1 respondent reports skipping workshop due to having already finished the relevant tasks in class. Of the 12 who did attend, 8 used it to finish the (mandatory) main tasks from class,

3 used it to do voluntary extensions and 1 reports using it for some form of circuit troubleshooting. Note that one of the answers (the third to last) was an accidental duplicate.

The results of the questionnaire are summarised in Figures 2-4. The responses to the first two questions, where the students are asked to assess how well the workshops and the traditional labs support their learning, are shown in Figure 2, and from this it is clear that the students rate the workshops higher than the traditional labs, with the workshops having an average score of 8.6, while the traditional labs have an average score of 4.9. In the latter two questions, the students were to circle verbs that described learning activities in both the workshops and traditional labs. The frequency of the different verbs for both these cases is shown in Figure 3, where vertical lines are drawn to indicate which SOLO level the words belong to. Finally, Figure 4 shows the total number of circled verbs in each level, divided by the number of verbs from each level which was included in the questionnaire.

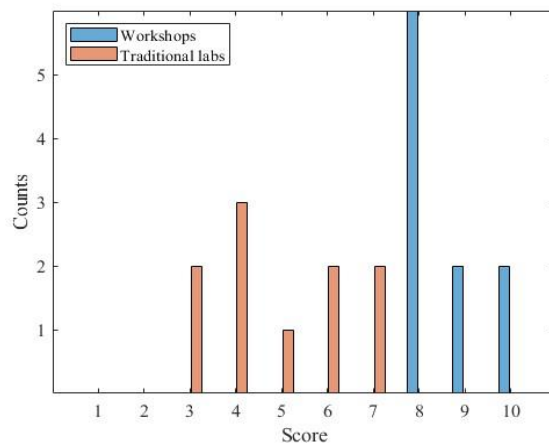


Figure 2: Histograms showing the responses to the first two questions of the questionnaire, namely how well the students think that the workshops and traditional labs, respectively, support their learning (1 - Not at all, 10 - To very high degree).

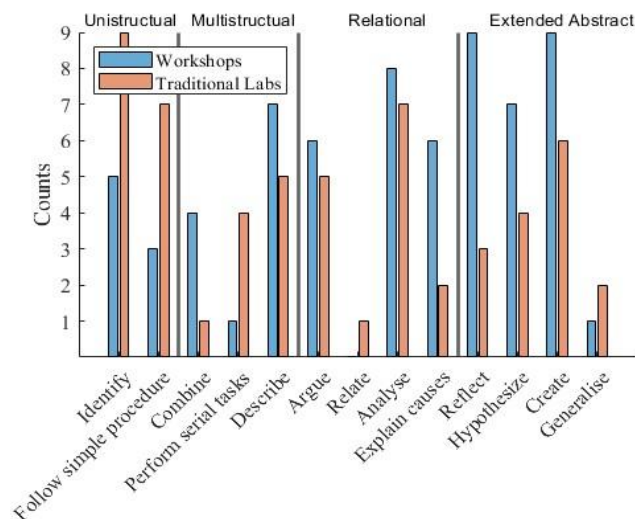


Figure 3: The frequency of the different verbs for both the workshops and the traditional labs. The verbs are organised according to the different SOLO levels to which they belong.

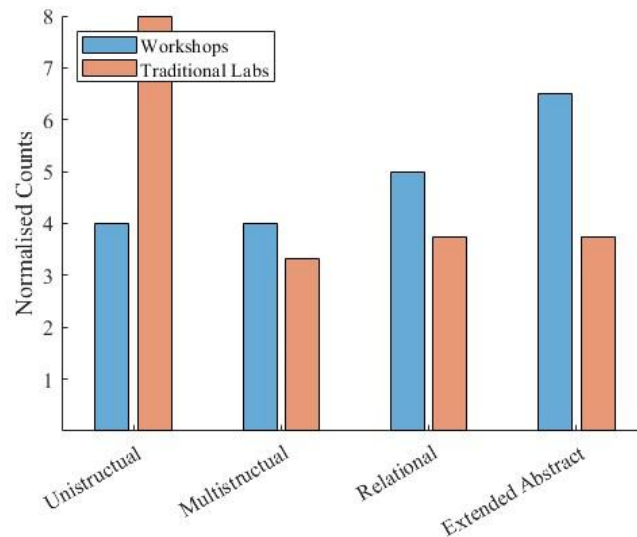


Figure 4: The frequency of verbs belonging to each SOLO level, normalised to the number of verbs for each level included in the questionnaire, for both the workshops and the traditional labs.

4.2 Discussion

Let us begin by briefly discussing the Mentimeter results. An attendance rate of 63% is not low by comparison with other non-mandatory components in physics courses. However, it is significantly lower than in the lessons where (>90%) attendance is regularly observed. While the large fraction of students not attending due to scheduling conflicts is unfortunate (and partly due to the varied background of the student population), it should be considered for coming iterations of the course. However, the fact stands that students do not seem to prioritise workshops as highly as lessons or traditional lectures, even though they are stated as important instructional time since the students are not expected to finish their circuit building during lesson time. In the presence of scheduling conflicts, the ability for students to also work in open lab settings such as L211 is critical. Unfortunately, these results do not tell us whether there is overlap in the student populations using L211 and workshops or whether they are complementary. In the experience of the teaching team, many students who do not attend workshop describe working in group formations not seen in the classroom, implicitly suggesting they must be making use of L211. The fact that students use the workshop for both catching up on tasks and for voluntary extensions suggests that the workshop fulfils its purpose in providing individualised education, not only giving a lifeline for students in need of extra support but also allowing more advanced students to perform further studies beyond the basic requirements.

Before analysing the results of the questionnaire, it is worth noting the small sample size. Only 10 different students participated in the workshops during the time of the data collection, and the number of responses is thus limited. Following from this, the statistical significance of the results is restricted, but nevertheless some tendencies can be extracted from the responses.

It is evident from Figure 2 that the students rate the workshops higher than traditional labs as it relates to their learning. This reflects their own, subjective experience, and as such it does not assess the depth of their learning in these two lab formats. It does, however, show that the students are happy with their learning in the workshops. However, in hindsight the word “traditional” might have been poorly chosen, as it is often deemed to have connotations of being old-fashioned and stale, which might bias the participants’ answers. The use of another, more neutral, word might affect the results, but it is difficult to find one which also conveys the meaning of “traditional labs”,

i.e. the labs that are common in other courses that the students have taken. Furthermore, a bias might have arisen from the fact that the participants in the questionnaire were found among the students who participated in the workshop. These students can be expected to be the ones who like this teaching format and might not be representative of the full student population.

Figures 3 and 4, on the other hand, are intended to give an indication of the depth of learning that the activities during the two lab formats are fostering. From Figure 3, it is apparent that almost all learning activities associated with the multistructural, relational and extended abstract SOLO levels are viewed as being present to a higher degree in the workshops than in the traditional labs. Exceptions are to *perform serial tasks* and *generalise*, which appear more frequently for the traditional labs than for the workshops, and *relate*, which is only mentioned in connection with the traditional labs. For the unistructural level, however, the workshops are less associated with both learning activities in this category. This is summarised in Figure 4, which shows the frequency of learning activities in each category (normalised to the total number of learning activities in that category) and makes it clear that the students experience learning activities associated with the three higher SOLO levels to be more present in the workshops compared to the traditional labs. The biggest difference between the two lab formats is found at the extended abstract level, where the workshops have a higher count, and at the unistructural level, where it is the traditional labs, which dominate.

By looking at the frequency of the different verbs in Figure 3, limitations of this survey method beyond the small sample size become apparent. It seems unlikely that so few participants should have related different subjects in either lab format. It could perhaps be explained by each lab session concerning different topics, but even within one topic, one might imagine that different things are related. It is plausible that it has not been clear to the participants how the different verbs are to be understood, and that different participants might have interpreted them differently. The responses showed more varied replies to questions 3 and 4 than one might expect from the very similar experiences of the students. This could also be explained by the students having different experiences in the lab, but with this study design, it is not something that can be distinguished from the students having different interpretations of the verbs. To mitigate this problem, the verbs could have been explained more, or there could have been short descriptions of model scenarios, that the students could more easily recognise as having experienced or not. Similarly, it is somewhat unexpected that the traditional labs are having lower counts in the unistructural level while having a higher count of the higher SOLO levels, since the unistructural understanding is a prerequisite for reaching higher levels of understanding. This might be taken to indicate that the focus of workshop is not directed towards learning activities at the unistructural level, but it might also be due to an unwillingness of the participants to circle too many words, or again to the lack of understanding of the meaning of the verbs. In either case, it demonstrates the limitations of this method for assessing the degree to which each level of learning is reached.

Despite these limitations, the results appear sufficiently consistent to indicate that the workshops are associated with learning activities characteristic of the qualitative phase of the SOLO taxonomy to a higher degree than the traditional labs. This tendency is consistent with findings that laboratory environments emphasising authentic experimental practice and student agency support the development of more expert-like views of experimental physics [8].

References

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Process report

Given that we were only two group members, most of the work has been done jointly, including conceptualization, design and data analysis. Because Linus was teaching this course, he took responsibility for communicating with the rest of the teaching team while Emilia was responsible for all data collection and anonymization. The writing of the report was divided such that Emilia had primary responsibility for Sections 1 and 2.2 while Linus had primary responsibility for Sections 2.1 and 3. Section 4 was written jointly and all sections were proof-read and discussed in group meetings.

The work proceeded quite smoothly with well-functioning communication and plenty of in-person interaction. The main thing we would have liked to improve is to commence the writing process earlier. While the data analysis necessarily had to occur late because of the data collection timeframe being restricted by the course schedule, the background and design sections certainly could have been written earlier to reduce the workload close to the deadline.

In terms of the study itself, we are quite happy with the study design and the results. The main thing we would have liked is a larger sample size. Since only 10-15 students regularly attend the workshop (and these are the people of primary interest for the study), we were inherently limited when studying a single course in this way. The fact that the students who show up vary slightly from time to time is the reason we decided to perform the questionnaire on two occasions, which at least increased the number of responses from 7 to 10. For a full pedagogical study, an even larger sample size would be desirable.

Feedback summary

Feedback was received on an earlier version of the report and small adjustments were made accordingly. Before, both “open labs” and “workshops” were used to refer to the student-led learning sessions under study, thus creating some confusion. This was addressed by writing “open lab workshops” when they were first mentioned in the abstract and background, and thereafter

referring to them as simply “workshops”. Another feedback we received was that the colour code differed between Figures 3 and 4 in the earlier version, and this was also rectified.

Several smaller changes were also made regarding the content. The description of the aim of the project in the introduction was expanded to include the comparison of the workshops with traditional labs, so as to better match the abstract and the discussion. Furthermore, a short discussion of the use of the word “traditional” in the questionnaire was added, as well as a remark about the inability to distinguish between variations in the experiences of the students and variations in their interpretation of the verbs in the questionnaire. Lastly, the summary of the qualitative phase of the SOLO taxonomy was expanded in order to be clearer about the disconnectedness of the learned elements in this phase.

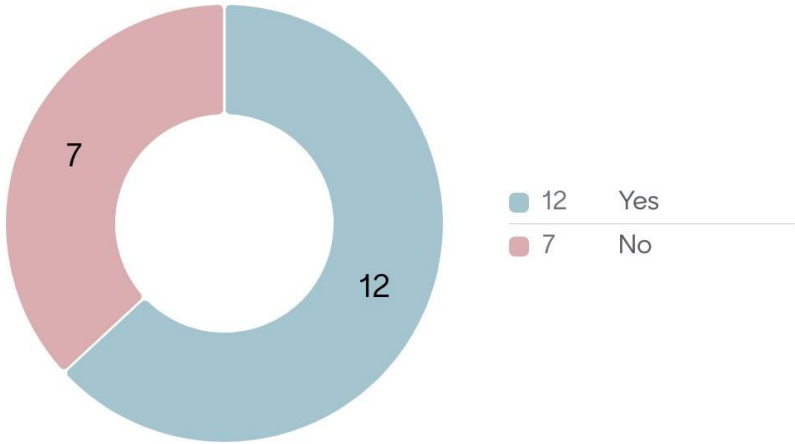
Two suggestions for changes in the Background and Design sections were made, but these were not included in the final report. One concerned the addition of a description of our expectations for the questionnaire in the Design section. As this is already addressed in the literature review, we felt it to be unnecessary to mention again. Another suggested change concerned an expansion of the description of the memory dump activity in the lesson. In this case, we felt the existing description is sufficient given it is not part of the study, but mainly included for context. To conclude, we wish to thank the other course participants for their feedback which was valuable in improving the report.

AMentimeter poll



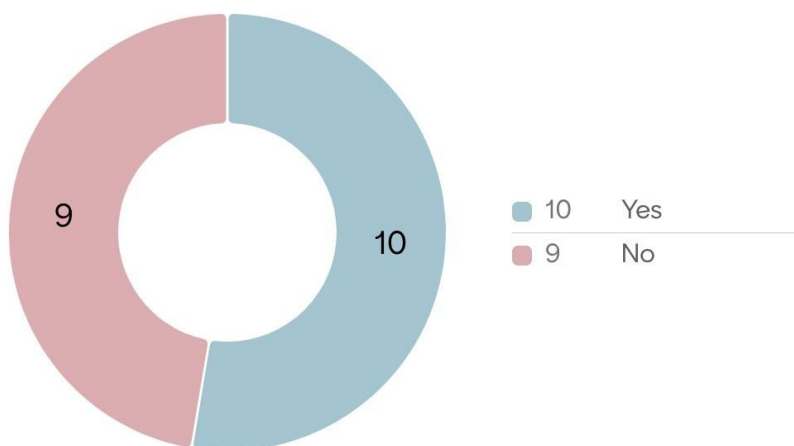
Workshop isn't required, yet it is budgeted instructional time

Did you go to workshop on Tuesday 11 November?



L211 is a room downstairs with some equipment available 24/7

Have you used L211?



Give a brief description of what you worked on during the workshop time

How did you use workshop time? If you didn't go to workshop, why not?

Had a lecture then

I've used it for extension tasks, but this week I need it to catch up :)

To finish what i missed in class.

Lectures in other course

Finishing an extension on one of the breadboard activities.

Had a lecture then

Trying to build breadboards... it still hard but ..

Had a lecture

Give a brief description of what you worked on during the workshop time

How did you use workshop time? If you didn't go to workshop, why not?

Complete task 2 of voltage dividers and redo task from RC circuits.

Busy with other course commitments

The workshop overlaps with another course I am taking

Do previous tasks we did not have time to do at class

I was sick, I did RC from the lecture before

To finish measurements of voltage divider activity and repeat the RC activity

work on the tasks from lectures, re-do or finish them

Didn't go, finished the task during class

Give a brief description of what you worked on during the workshop time

How did you use workshop time? If you didn't go to workshop, why not?

Extension tasks

I did task 2 of one of the weeks, but I probably won't attend the next workshop since I have a lecture from my other class during that time

Trying to build breadboards, its a bit hard but)

Other lecture

Troubleshoot circuit

B Questionnaire

Questionnaire

How well do you think the workshops (and L211) support your learning?

1 2 3 4 5 6 7 8 9 10

Not at all

To very high degree

How well do you think traditional course setups (with separate lecture periods and oneday labs) support your learning?

1 2 3 4 5 6 7 8 9 10

Not at all

To very high degree

Circle the words which you consider to describe something you have done *during the workshops?*

Argue	Reflect	Hypothesize	Identify	Create
Combine	Relate	Follow simple procedure	Generalise	Perform serial tasks
Describe	Analyse	Explain causes		

Circle the words which you consider to describe something you have done *during traditional one-day labs?*

Argue	Reflect	Hypothesize	Identify	Create
Combine	Relate	Follow simple procedure	Generalise	Perform serial tasks
Describe	Analyse	Explain causes		