Article:

Beck, S.B.M. orcid.org/0000-0001-5986-862X, Lazari, P. and Di Benedetti, M. orcid.org/0000-0001-7870-1323 (2025) Lab group size and laboratory duration. International Journal of Mechanical Engineering Education. ISSN 0306-4190

https://doi.org/10.1177/03064190251315693

Original article

IJMEE

Lab group size and laboratory duration

International Journal of Mechanical Engineering Education
1–14

DOI: 10.1177/03064190251315693
journals.sagepub.com/home/ijj
Sage

Stephen BM Beck[1], Panos Lazari[2], and Matteo Di Benedetti[2]

Abstract

Engineering courses all have an element of practical work. One category of this is the laboratory where students perform experiments to either look at physical phenomena or systems. There has been very little research into how students and staff would like these laboratories to be conducted to optimise their experience. A questionnaire was sent to staff and students in the Faculty of Engineering at Sheffield University to find out their opinions on laboratories. The response rates were lower than would be hoped, but the actual numbers of responses (40 staff and 181 students) were reasonable for this type of work. This paper reports on the results obtained on lab duration and group size and also whether students like or dislike laboratories. The results show that students like relatively short labs (a maximum of two hours). Students and staff would ideally like students to do experiments in pairs. Students who like labs tend to want smaller groups while those who dislike them desire larger groups. Surprisingly, both students who like and dislike labs would generally like more labs., This work shows that shorter labs in smaller groups take the same resources as longer labs with bigger groups while generally providing a better experience. It is hoped that this work will help make laboratories more efficient, effective and attractive to students.

Keywords

laboratory teaching, group size, laboratory duration, questionnaire

Introduction

In common with engineering courses throughout the world, all accredited UK engineering courses must have a practical element.[1] This varies from manufacture (make and test) to experiments that illuminate topics and get students to deal with data and uncertainty.

[1]The University of Sheffield, School of Mechanical Aerospace and Civil Engineering, Sheffield, UK
[2]The University of Sheffield, Multidisciplinary Engineering Education, Sheffield, UK

Corresponding author:
Stephen BM Beck, The University of Sheffield, School of Mechanical Aerospace and Civil Engineering, Sheffield, S1 3JD, UK.
Email: s.beck@sheffield.ac.uk

The faculty of engineering at the University of Sheffield has created a centralised provision for all their 6400 students across Batchelor of Engineering (BEng), Master of Engineering (MEng) and Master of Science (1 year taught MSc) courses. In a single building, five large laboratories and several smaller ones are shared between all the students in the faculty. The creation and delivery of all of the experiments are conducted by a team of 45 teaching academics and technicians supported by about 5 admin staff. There are several publications describing this setup in greater detail.[2–4] This interest in teaching practical engineering education by the team has led to them improving the student experience in terms of quality and quantity of labs which has led both to high approval and efficient delivery. It is interesting and valuable to find out what makes students want to attend the labs. Many of the labs are not compulsory, so we must make the experience worthwhile, otherwise, they will prioritise other activities.[5]

This work analyses the responses to a questionnaire and compares them to what the students experience to make some recommendations about lab group size and laboratory duration to allow curriculum planning and lab organisation to be more effective.

Literature review

In a previous publication[6] we describe student and staff impressions and drivers for attendance at labs. The questionnaire that this was based on is included as an appendix in that publication. In the questionnaire, in addition to the results previously published, we also asked students about their desired lab group size, number of labs and duration. We also circulated the questionnaire to staff and asked about their desired student lab group size. The authors have only discovered small amounts of literature on lab group size. In an early publication on practical education, Hammond[7] writes, without evidence, that

> '…in the laboratory, size is immensely critical. Each individual must be confronted by the facts. But in a group of 3, it is likely that one will learn nothing'.

Moody[8] states that 'There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups of two members and those with four members'. This is corroborated by the later work of Flora and Cooper[9] stating that outcomes are not affected by lab group size, but students put in large groups (seven) asked to be put in smaller groups for future experiments. A more recent publication by Cresswell and Laughlin[10] states, anecdotally, that students do not like working in larger groups (of four in this case) and that smaller groups were preferred as all students then had to participate.

There is of course a much larger body of literature on group sizes for other work. For example, Griffin, Griffin and Llewellyn[11] looked at the duration and group size for capstone projects and found that it did not make much difference for student outcomes, but in groups of more than six, students can freeload more easily. Hunkeler and Sharp[12] looked at groups containing three and four students in Chemical Engineering Senior (final year) classes and concluded that groups of four students performed better than groups of three, possibly because of there being more diverse learning styles in a larger group. Having an academically better student in a group raises the outcome. So they suggest that these students should be distributed evenly among the groups or can be put in to make up groups of three to even out this advantage.

Afify[13] looked at group size in discussion sessions. Although their work was for online interaction, they found a lot of literature on this subject. However, to examine lab group sizes, this work is not applicable as a 'small' group is designated as less than 10 students.

It is acknowledged that student concentration starts to drop off after about 20 min during lectures.[14] While there has not been the same research conducted in laboratory sessions, it is also well known that active learning will increase student engagement and concentration[15] and laboratory experiments should fall into this category. Subsequently, it is unclear what an optimum laboratory duration is, though a 'one size fits all' approach to this will be inappropriate as different labs will have different complexities and numbers of learning outcomes.

The rest of this paper addresses and attempts to answer the research question:

'What lab group size do students like and what lab duration suits their learning styles?'

Context

It is worth noting that lab groups are formed in a number of ways. Different labs or departments may use one or more of the following:

- Tutor groups, though these may often be of an unsuitable size for the equipment.
- Ad hoc groups. These are formed on the day as students arrive in the lab.
- Organised groups. Particularly for projects these may be formed with a view to inclusiveness.[16]
- Some other organised grouping, which may vary between labs, or be fixed for a period of time.

It is also worth noting that the assessment of labs can vary enormously. Due to the relatively large number of labs delivered to engineering students at Sheffield University, the lab report is not used universally. Other approaches to assessing the labs include:

- Group report and/or presentation. This is usually used for longer, multi-part labs
- Online quiz (this is quite common)
- Short report
- Submitted spreadsheet.

The organisation of the labs into the courses varies widely too. Some courses have a lab module, in others the labs are integrated into modules. Marks may be given for reports or completing quizzes. Alternatively, attendance may be monitored or a 'pass to progress' approach used. Some labs are thought to be more formative, though they will almost always still have a post-lab exercise to complete to ensure that students reflect on the experience.

Method

A questionnaire was prepared and circulated to the 6400 students in the faculty of Engineering at Sheffield University. A full description of this and a copy of the final student survey is shown in Appendix A of a previous publication.[6] That output concentrated on student perception of the value of laboratories and drivers for attendance. In the questionnaire, students were also asked questions about lab duration and their impression of the lab group sizes they had experienced. Students were also asked whether they enjoyed labs or not. Considerations of word count meant that the results from these aspects of the questionnaire were not included in that paper.

One hundred and eighty-one student questionnaires were returned. As these contained information on which course and year each reply came from, it was possible to use relevant student timetables to identify what baseline to compare their replies to. This is because different cohorts and years naturally had different group sizes and lab durations, based on the complexity of the labs and the amount of equipment available for the students to use.

A similar questionnaire was also circulated to all of the academic staff in the faculty, numbering about 450 of which we received 44 responses. The outcomes from this in terms of reasons for students to attend laboratories have been published, but they were also asked about their desired lab group size. Both staff and student questionnaires allowed free text results, which can help to contextualise the responses.

Results

Student perception of group size

To encourage student attendance, we are investigating whether group size, the number of labs, and lab durations influence engagement. Is laboratory attendance genuinely beneficial for students, and does it have a significant impact? With growing cohort sizes in higher education, laboratory resources face increasing demands. How can we optimise the student experience within these constraints?

Students were asked to reflect on their entire lab experience when responding to the survey question: "What group size do you prefer for labs?" The options were "same size," "smaller groups," or "larger groups." To accurately interpret these results, it's essential to compare them with the Typical Group Size (TGSs) students experienced in their labs. However, different labs operate with different group sizes. For example, the Electrical Lab is designed for pairs, the Structures Lab accommodates groups of four, and the industrial-scale Pilot Lab requires larger groups to manage complex, interconnected processes.

The TGS was determined through a two-step process:

- Identify the most common group size for each lab space.
- Determine each cohort's usage of the various lab spaces.

First, each lab's academic coordinator identified the group size they deemed most common based on their experience. Since labs cater to multiple student cohorts, a specific group size was then assigned to each cohort (defined by department and year of study)

Table 1. Typical Group Size calculated as median lab group size in each department for year 1 and 2 students.

Dept.	ACS	AER	BIO	CBE	CIV	EEE	GEE	MEC
Year 1	2	3	2	2.5	4	2	2	3.5
Year 2	2	3	2	2	4	2	3.5	4
Trend	**Same**	**Same**	**Same**	**Smaller**	**Same**	**Same**	**Larger**	**Larger**

NOTE: Full department names are provided in Appendix A.

according to the patterns of lab usage. This assignment was based on an analysis of timetables to estimate the proportion of lab time each cohort utilised. Using these lab usage proportions and lab-specific group sizes, the median group size was calculated for each cohort, as shown in Table 1. For instance, first-year Civil Engineering students attended the Materials, Fluids, and Structures Labs, working primarily in groups of four; the Thermodynamics Lab, in groups of three; and the Workshop, where they worked individually. This resulted in a median group size of four, which is referred to as the TGS throughout this paper.

The calculated TGS values provide benchmarks for interpreting students' survey responses on preferred group size.

The TGS marginally changes for CBE (decreases) and MEC (increases) and significantly increases only for GEE. It should be noted that it was only possible to define a TGS for first- and second-year students, as these students take the bulk of the formal student labs; therefore, only the survey results of these students were considered for studying the students' impressions of lab group size.

Students' impression of lab size is shown in Figure 1. This is divided by year. In year 1, students equally think that the group size should either stay the same (38%) or increase (40%).

By the end of year 2, the perception seems to change with almost half (47%) of the students showing a preference towards retaining the same group size, but almost 40% would like to work in smaller groups (Figure 1). Only a small percentage of second-year students (14.5%) wanted larger groups. These seem to be in line with the results of the survey filtered by cohort and year of study (Figure 2). For example, MEC students primarily wanted larger groups in year 1 (TGS 3.5) and to keep the same grouping in year 2 (TGS 4). However, while the TGS remains unchanged in years 1 and 2 for most departments, the students' perception varies. A good example is CIV (TGS of 4 in both years), where year 1 students primarily wanted the same group size, but year 2 preferred to work in smaller groups. This could be due to their increasing confidence and ability to work autonomously. The nature of the experiments could also be a factor. Also, by the second year, students may have found a suitable 'lab partner' with whom they work effectively.

What are staff impressions of an ideal group size?

There were 41 staff responses to this question out of 44 staff responses overall. This is shown in Figure 3.

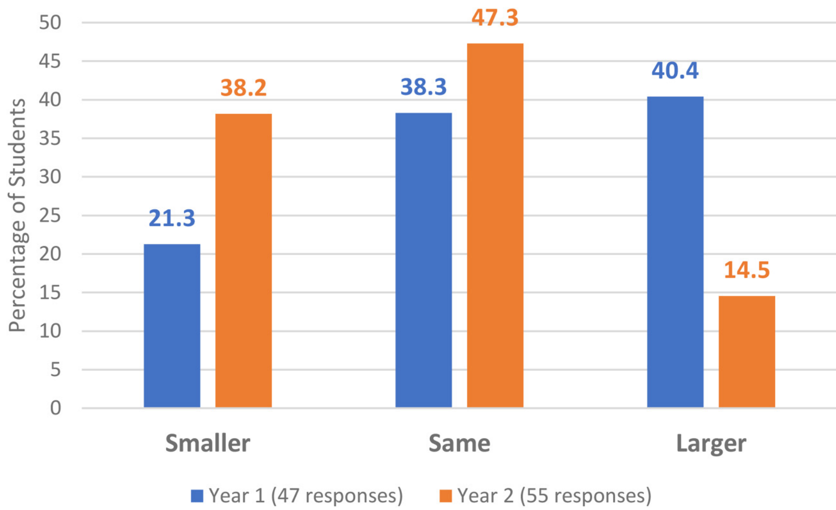

Figure 1. Group size preference normalised by the number of responses obtained from students in the first (left) and second (right) years.

The most popular desired group from staff size is working as pairs. Very few staff thought that students working on their own was a good choice. It is worth noting that during some of the periods of COVID-19, students needed to work with at least 2 metres of separation, so lone working was the de facto norm, though it is undesirable. In their reply to the questionnaire, one staff member commented that;

> 'Group size varies, as it depends on the nature of the practical work. In a conventional lab then no more than 4, but in a group project then it can be more, perhaps up to 6.'

This appears to be sensible and indeed the information gleaned from students shows that for them, the optimum lab group varies across subject and year of study. However, the large number of staff believing that three is a suitable number for a lab group is interesting as neither the students nor the (scant) literature point to this outcome.

Can we identify an ideal group size?

Figure 4 analyses students' preferred group size relative to the TGS for their cohort. For instance, a first-year Civil Engineering student (with a TGS of 4) is represented within the grey bar of the histogram according to their preferred group size (smaller, same, or larger). The results indicate that none of the students who typically worked in groups of three wanted the same group size and would prefer to work in larger groups. Conversely, students working in pairs or groups of four are predominantly happy to keep using the same group size. It is interesting to note that students do not like working in groups of three. This is probably because two of them work together and

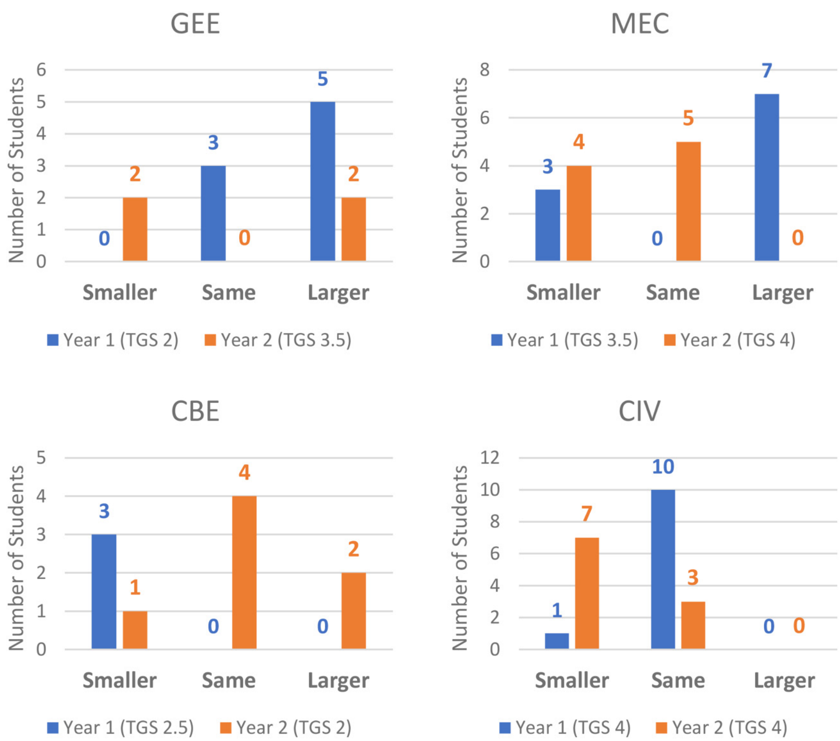

Figure 2. Desired group size (students for several departments and years). Note that the numbers in the figure are the number of responses, not the group size. The Typical Group Size (TGS) is provided in the legend as per Table 1 as a benchmark for the students' responses.

one is carried or excluded. This agrees with the anecdotes in the literature. Thus, groups of two or four are probably optimum, subject to the experimental requirements, typically the complexity or size of the equipment. In this case, received wisdom, the literature and the experience of educators agree with the students' impression.

Do students appreciate the number of laboratories they do?

Another interesting aspect is whether students like the number of labs they have timetabled or want a different amount. Student responses to the questionnaire are shown in Figure 5 where students preferred labs numbers are normalised by students who like and do not like labs. It is shown that students generally like the number of labs that they get. Due to how these are organised, Engineering students at Sheffield get a relatively large number of laboratories, particularly in their first two years. Very few students want fewer labs, though here it will be seen that most of those who want fewer labs are those who do not like them. Just over one-quarter of the students want more labs, but very few of those do not enjoy labs. Roughly 60% of the students like the number of labs they get irrespective of whether they enjoy them or not.

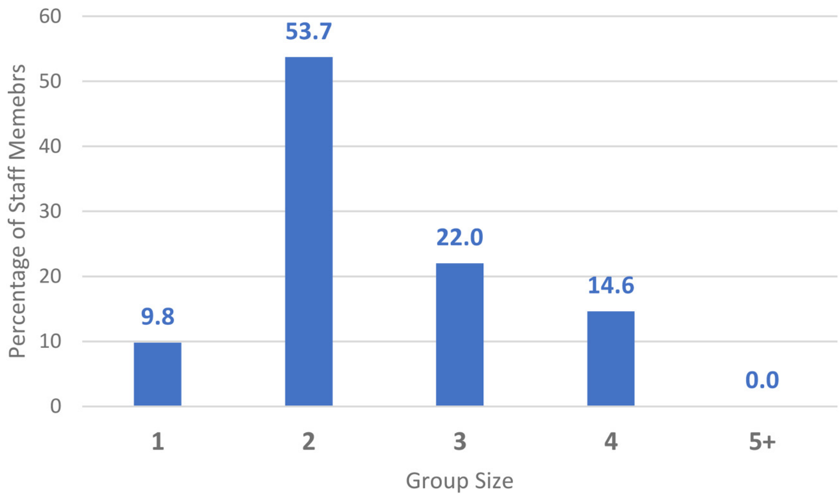

Figure 3. Staff responses on desired student group size.

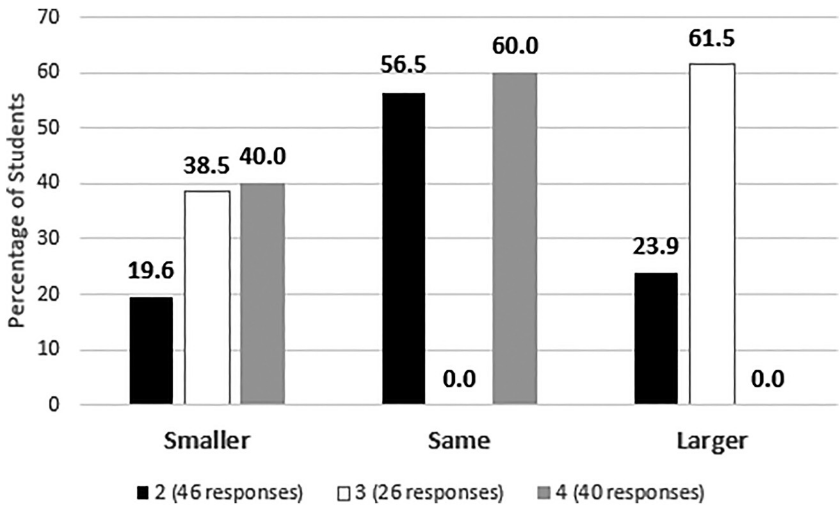

Figure 4. Group size preference normalised by the number of responses obtained from students typically working in pairs (black), as a three (white), and in a four (grey).

The real difference comes in whether students want more or fewer labs. Not surprisingly, students who enjoy labs want more, while those who don't like labs would like less. However, there is a small, but noticeable cohort who do not like labs but want more. This could be that they do not enjoy them but can see that they are an important

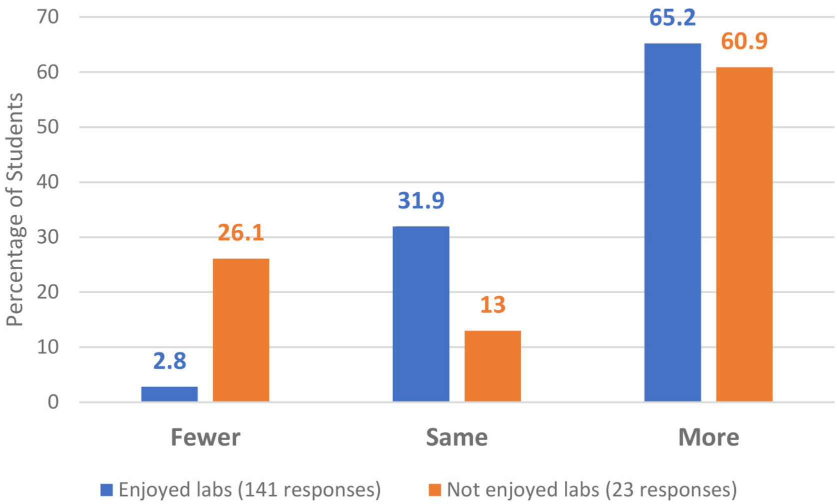

Figure 5. Lab quantity preference normalised by the number of responses obtained from students enjoying (left), and not enjoying (right) labs.

element of their engineering education. This reinforces the answers to the questions on 'what students think labs are for', reported in a previous publication[6] where the top two responses were 'Reinforcing lecture material' and 'To gain practical experience'. The responses to this question are therefore likely to be somewhat independent of whether a student likes labs or not.

Is lab duration a factor?

Students were asked to reflect on the duration of their labs and whether the length was sufficient to complete their tasks. Based on students' responses, the authors could determine if lab durations should be shorter, longer, or remain the same. Specifically, students' preferences regarding lab duration were analysed by filtering the data according to their enjoyment of lab activities. Figure 6 shows that all the students who responded, regardless of their appreciation of practical activities, do not want longer experiments. In addition, 77% of students who enjoy labs would like to retain the current duration, while 65% of students that did not enjoy labs prefer to have shorter sessions in the future.

It is important to note that the teaching teams at Sheffield University's Faculty of Engineering have made an effort to reduce the duration of laboratory sessions from their historical durations of two to four hours. This is based on both experience and the literature, which while having no particular reports on laboratory sessions and concentration times does report a drop off in student concentration in lectures[17] from about 15 min in and getting low after an hour. Laboratories are typically scheduled for around two hours, though some may be as short as one hour, with a few extending for longer. Where feasible, historically lengthier experiments are often divided into shorter sessions, each with fewer and more focused learning outcomes.

Despite these relatively short durations, compared to the sector, students still want to have labs of the same or shorter duration. This is particularly evident when the data is sliced by those who enjoy and do not enjoy laboratories. Here, those who like labs overwhelmingly want them to be of the same length as they currently are. Two-thirds of students who do not like labs want them to be of shorter duration, a not surprising result. Information on comparing the number of labs that students want to have, what they think the current number is appropriate and whether or not they enjoy them can be gleaned from some of the comments that students wrote on our questionnaires.

> ’Some labs were 3 h long and there was not really a learning outcome. Going or not going would have not made a difference as you did not really have to do something.’

> ‘Having to work 9-5 with no break due to 4-h long labs (1–5) on already busy days’

There were a small number of converse comments.

> ‘Labs are repetitive and too long’

> ’Some labs were just too short, I was put under much pressure in order to complete them (I have very good theoretical knowledge but my manual skills are not as good so I often get really stressed).’

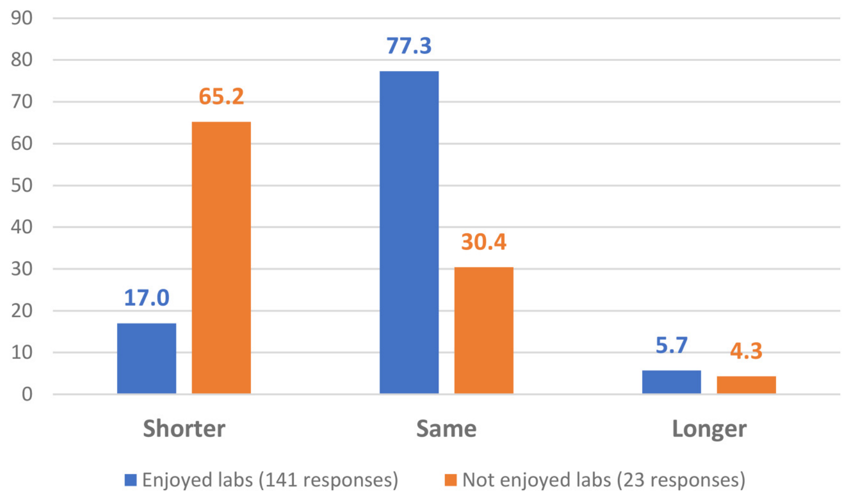

Figure 6. Lab duration preference normalised by the number of responses obtained from students enjoying (left), and not enjoying (right) labs.

It is clear from these that, in general, long labs are undesirable. However, as the last comment shows, artificially shortening labs either to reduce student burnout or for efficiency reasons can prevent students from completing labs or turn them into a sprint whereby little actual learning takes place. So care needs to be taken to ensure that the duration and the learning outcomes are appropriate.

A trade-off between group size, duration and number of labs

Beck[2] showed that there is a simple relationship that allows labs to be organised and planned to take place in a short period of time. This is shown in Equation 1.

$$N = \frac{S}{GWL} \tag{1}$$

Here W is the number of weeks it takes to get a cohort through a given experiment, L is the number of lab sessions per week, S is the number of students in the cohort, G is the number of students per experimental rig, with N being the number of sets of matching kit in the lab.

We can use this type of approach to state that H, the total number of hours the lab is used over a year is shown in Equation 2.

$$H = DEWL \tag{2}$$

Where D is the average lab duration in hours and E is the number of experiments each student has in a year. The variables L and W and their product, LW, is the number of sessions for a given lab. We can therefore equate them in Equations 1 and 2 to get,

$$\frac{S}{NG} = \frac{H}{DE} \tag{3}$$

Rearranging equation 3 will give the ratio of lab session duration, D, to group size, G, which is shown in Equation 4.

$$\frac{D}{G} = \frac{NH}{SE} \tag{4}$$

Generally, due to equipment, staffing and timetabling issues, all of the variables on the right-hand side of Equation 4 are fixed (N being the number of sets of matching kits in the lab, S, the number of students, E, the number of experiments each student has in a year and H, the total number of hours the lab is used over a year), It can be seen that all of these describe the demand, the resources and the number of students. We can say thus that,

$$\frac{D}{G} = Constant \tag{5}$$

In effect, Equations 4 and 5 tell us that within the same resource model, the ratio of lab duration, D, to students per group, G, is fixed. So, if smaller groups are desired, each lab session must be made proportionally shorter. Based on the student feedback from the questionnaire, this could make the laboratory sessions more attractive to (and thus probably more effective for) students. This approach should also entail a review of what is done in each of the actual lab sessions themselves.

Concluding remarks

It would have been useful to get a bigger response rate from the student questionnaires. The response rate was only about 3% which is low even if the number of responses (almost 200) was good. However, the responses were obtained from a wide range of courses and years of study. This may mean that there was a smaller range of responses than a larger sample would have produced. Therefore, the conclusions and recommendations which follow will need to be tempered by this. The sample may have been skewed towards those who like, appreciate and understand labs and also those who do not and wanted to point this out.

However, the response from staff was about 10%, so can be assumed to be a more typical sample of their thoughts.

It is clear from the available responses that the optimum approach to planning labs is for them to be of a short (though appropriate) duration and delivered to small groups (four maximum). Also, the replies from our students suggest that they are less keen on working in groups of three than in groups of two or four. It is also clear that having a single rule for the size of a group is an oversimplified approach. Group size needs to vary with the actual experiment and the level of the course.

It is hoped that this work will help those organising labs to optimise them for a superior student experience. Even if timetabled sessions are compulsory, students should see the experience as a worthwhile use of their time. Shorter labs and smaller groups can use the equipment as intensely as longer labs in small groups and (from our results) provide a better student experience, likely with equal or better outcomes in terms of student learning experience.

Once again care is needed if labs are to be shortened, but learning outcomes can be preserved (or even enhanced). For example, this approach might entail thinking about whether students need to do so many repeats of data. In some cases, it may be possible to pool a complete cohort's results to allow better analysis. So each group may only need to take a small number of readings. Also, is the valuable, yet expensive, time spent in the lab being used effectively? Effective pre-labs can mean that students can use the equipment as soon as they enter the laboratory. Writing up the experiment and analysing the data can be done in other spaces, allowing more groups access to the equipment at the same time?[18] Can they be moved to a different space to analyse the results and discuss them with staff while a new group uses the equipment in the laboratory?

In the Faculty of Engineering at Sheffield University, we have been doing these things over the past decade or so and student satisfaction has improved. We have not reduced group sizes manifestly, as we started off with relatively small ones. However, the efficiency gains from careful examination of what labs are for and their learning outcomes have allowed us to put on a larger quantity of experiments (in effect increasing E in Equation 4, while decreasing D), preserving the valuable lab time actually for students to actually do practical activities and interact with their group and the staff in the lab.

We propose that for the same equipment and timetabling slots, student experience, learning and satisfaction can be increased. The main costs of this change are in the intellectual and writing time needed to alter labs to be more effective learning experiences, and also to be attractive and engaging to students.

Acknowledgements

This work was conducted under Sheffield University Ethics Approval Reference Number 043273

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Stephen BM Beck https://orcid.org/0000-0001-5986-862X
Matteo Di Benedetti https://orcid.org/0000-0001-7870-1323

Data availability statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

References

1. Engineering Council. *Accreditation of Higher Education Programs (AHEP)*. 4th ed. UK, Engineering Council, 2020.
2. Beck S. On having the right size laboratories. *Int J Mech Eng Educ* 2023; 51: 111–122.
3. Di Benedetti M, Day H and Archibald S. Scaling up practical teaching. The one-thousand student week. In SEFI 50th annual conference proceedings: engaging engineering education, 2022, pp. 1911–1915. European Society for Engineering Education (SEFI).
4. Garrard AR and Beck SBM. Pedagogical and cost advantages of a multidisciplinary approach to delivering practical teaching. In: *Book, the interdisciplinary future of engineering education*. 2018, pp.33–48. London, UK: Routledge.
5. Wyatt G. Skipping class: An analysis of absenteeism among first-year college students. *Teach Sociol* 1992; 20: 201–207.
6. Beck S, Lazari P and Di Benedetti M. Why do engineering students attend labs? Staff and student reasons for lab attendance, desired group size and number of laboratories. *SEFI J Eng Educ Adv* 2024; 1: 26–37.
7. Hammond P. The case for the teaching laboratory. *Electron Power* 1971; 17: 77–79.
8. Moody JD. The effect of grouping by formal reasoning ability, formal reasoning ability levels, group size, and gender on achievement in laboratory chemistry. Mississippi State University, 1990.
9. Flora JR and Cooper AT. Incorporating inquiry-based laboratory experiment in undergraduate environmental engineering laboratory. *J Profl Issues Eng Educ Pract* 2005; 131: 19–25.
10. Cresswell SL and Loughlin WA. An interdisciplinary guided inquiry laboratory for first year undergraduate forensic science students. *J Chem Educ* 2015; 92: 1730–1735.

11. Griffin PM, Griffin SO and Llewellyn DC. The impact of group size and project duration on capstone design. *J Eng Educ* 2004; 93: 185–193.
12. Hunkeler D and Sharp JE. Assigning functional groups: The influence of group size, academic record, practical experience, and learning style. *J Eng Educ* 1997; 86: 321–332.
13. Afify MK. The influence of group size in the asynchronous online discussions on the development of critical thinking skills, and on improving students' performance in online discussion forum. *Int J Emerg Technol Learn* 2019; 14: 132.
14. Eze C and Misava E. Lecture duration: A risk factor for quality teaching and learning in Higher Education. *Integr J Educ Train* 2017; 1: 1–5.
15. Freeman S, Eddy SL, McDonough M, et al. Active learning increases student performance in science, engineering, and mathematics. *Proc Natl Acad Sci USA* 2014; 111: 8410–8415.
16. Diversity Confidence in Engineering (DiCE), https://sites.google.com/sheffield.ac.uk/dice/home (accessed 22 October 2024).
17. Stuart J and Rutherford RD. Medical student concentration during lectures. *Lancet* 1978; 312: 514–516.
18. Garrard A and Nichols A. A teaching sandwich approach to integrating classroom and practical teaching. In 5th Annual Symposium of the United Kingdom & Ireland Engineering Education Research Network, 2018, pp. 87–90. Aston University.

Appendix A. Abbreviations for departments and major courses in the Faculty of Engineering

ACS Automatic Control and System Engineering
AER Aerospace Engineering
BIO Bioengineering
CBE Chemical and Biological Engineering
CIV Civil Engineering
EEE Electrical and Electronic Engineering
GEE General Engineering
MEC Mechanical Engineering