Facilitating Laboratory and Practical Classes

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Introduction

“If you can’t explain to the charwoman who is scrubbing your laboratory floor what you are doing you don’t know what you are doing.”

Ernest Rutherford

Laboratories and practical classes have been a substantial part of the teaching repertoire in Science and Engineering for many years. The key learning objectives of laboratory and practical classes tend to be “learning how to do things” - such as procedures, methods and skills. However, this form of teaching has come under considerable pressure because laboratories are expensive to run and can be very time consuming.

This booklet has been written based upon my practical experience of designing and running laboratory and practical classes. This booklet will help you to:

1. Identify the key factors to take into account when designing an activity for a laboratory or practical class
2. Develop optimum teaching strategies and student learning activities to enhance student learning in laboratory sessions
3. Identify the aims and objectives of the laboratory learning experience
4. Increase your sensitivity to the teaching and learning environment in your laboratory or practical class.

Further reading is provided at the end of the booklet.

Section A: Design of a laboratory or practical class

To a certain extent the choice of activity within a laboratory or practical class is prescribed by the learning outcomes detailed in the paper outline. However, this does not mean that there is no room for innovation in the design of laboratory or practical class activities. The following section provides guidelines to allow you to develop/design an activity for your course.

1. Aims and objectives of the laboratory or practical class

While thinking of an activity to perform in a laboratory or practical class it is important to consider what skills/knowledge you wish the students to have at its conclusion. Do you want the laboratory or practical class to:-
underpin essential knowledge of the students’ particular discipline

develop essential skills that the students will require for graduate employment

a combination of both of the above.

Underpinning essential knowledge

Generally theoretical knowledge is usually delivered through the lecture while practical experience is developed through the laboratory or practical class. The link between the two can sometimes be tenuous. To ensure that core theoretical principles are built upon it is necessary to bridge the gap between the lecture and the laboratory or practical class. There are a number of ways that this can be achieved (Gibbs and Habeshaw, 1997):

- Outline and develop experimental designs during lectures, embedded in the relevant theory.
- Give short theoretical lectures at the start of lab sessions or during labs.
- Allow students to design their own experiments or to produce reasoned modifications to standard experiments.
- Use some labs as demonstrations of phenomena in order to highlight the need for explanations and theory, which will be provided in a subsequent lecture.
- Allow time during and at the end of a lab to discuss theoretical issues and implications.
Developing essential skills
Most academic staff will be able to identify some of the essential skills required in a particular discipline. Additionally, it is essential to identify the essential skills required by external agencies likely to employ students from particular disciplines. For example, work by Boud, Dunn, Kennedy and Thorley (1980) used surveys from Graduates and Practicing Scientists to determine which aims were most important from a list developed for an undergraduate paper. Table 1 shows that both the Graduates and Practicing Scientists were in agreement with the aims and objectives required, while the undergraduates who took the course identified that not all the aims of the laboratories met those requirements.

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<th>Students</th>
<th>Graduates</th>
<th>Practising Scientists</th>
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<tr>
<td>To train students in making deductions from measurements and interpretation of data</td>
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<tr>
<td>To familiarize students with important apparatus and measurement techniques</td>
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<td>To teach basic practical skills</td>
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<td>To train students in observation</td>
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<td>To foster critical awareness</td>
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<td>To illustrate material taught in lectures</td>
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<tr>
<td>To help bridge theory and practice</td>
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Table 1: The five top aims ranked highest by each response group (After Boud, Dunn, Kennedy and Thorley, 1980)
So while this laboratory deals with some of the essential knowledge it should also help to develop some of the essential skills. Ideally the laboratory learning experience should combine both of these objectives. While research of this nature is a bit excessive for running one laboratory, many professional institutions and external agencies provide information about what they regard as essential knowledge and skills for graduates.

2. Teaching strategies for laboratories and practical classes
The next step is to develop teaching strategies that enable students to achieve the aims and objectives that you have outlined for the laboratory or practical class. Three main teaching strategies are generally used:

Controlled sessions
These are activities devised by staff and completed by the students in one or two laboratory sessions. This strategy is well suited to the development of specified key skills where practice can lead to a high degree of competence. This strategy usually comprises:

☞ The teacher or demonstrator introducing the activity
☞ The students carrying out the experiment following a written procedure
☞ The students writing and submitting a report for assessment.

It is easy to find examples of controlled sessions in journals and other sources but using them can be problematic as the examples might not give a
complete solution to a set of aims and objectives. In addition, if the aims and objectives behind the example are not present then students can be left without a clear understanding of the principles underlying the laboratory or practical class. Therefore it is better to develop a new activity rather than try to cobble together pieces in an ad hoc approach.

*Experimental investigations*

These are longer activities where there is some element of choice in the experimental procedure or the method of analysis. This strategy is well suited to developing investigational skills. This approach can be inspiring and motivational for students but can be difficult to run when faced with time constraints. However, there is great scope here for including preparatory work outside the laboratory i.e. reading of literature and/or design of laboratory experiments and also for including the computer for comparative or analytical work.

It is necessary at this point to sound a note of caution. This type of task is not really suited to first year students who are just experiencing a laboratory or practical class for the first time. Also it is necessary to keep the problem/activity small and if the investigation is more open-ended, it is important that teachers and demonstrators provide ongoing monitoring and support for students to ensure that correct approaches are being used.
*Research projects*

These are problems that are studied over a longer period of time. Generally this form of teaching strategy incorporates elements of the previous two. The intention here is to simulate more closely real-life research and development activities that students might encounter in their professional life. This teaching strategy can take the form of a small project exercise over a semester, or a longer research project which might allow a student to become part of a research group. Whichever approach is used, the student has to take ownership of the research project, and along with a supervisor explore various scientific approaches and analyses. While this teaching strategy is extremely important especially for Postgraduate students, it is outside the scope of this booklet.

(Adopted from Boud, Dunn et al., 1986)

### 3. *The ingredients of the activity*

Once an appropriate teaching strategy has been chosen, a detailed activity needs to be designed. While the underlying principles to be demonstrated are dependent on the discipline, the general steps required to develop an activity to show these principles are consistent across disciplines. Rowntree (1981) developed a simple framework which can aid in the development of a task based activity:

1. What is the task?
2. When should the task be carried out?
3. What tools, equipment, and materials are needed?
4. What are the objects on which the task is carried out?
5. How is the task to be carried out? What order is followed? How long does each step take? What safety precautions have to be observed? What are the most likely errors?
6. What are the criteria of successful performance? (How can the performer tell when he or she has carried out the task?)
7. What is the use or application of the task?
8. How much practice must be built into the training?

(Adopted from Rowntree, D., 1981)

What is evident from the organization of the activity in this way is that there are a large number of steps that the students will not see. These are all the planning steps. Therefore it is important that the students understand why they are doing the activity, why they are doing it in a particular way, and what they should achieve from it. What follows is a look at how to design the activity to achieve the greatest learning experience for the student, while achieving the aims and objectives of the activity.

*Organising the activity for student learning*
Step 5 above shows that most of the activities that people use in laboratory or practical classes tend to be made up of discrete steps or parts.
When these steps are completed, either concurrently or successively, they make up the activity ‘as a whole’. Deciding what parts make up the activity can be difficult, mainly because what would appear logical to the teacher may not be so to the student.

Sensitive teachers try to stand in the shoes of their students and envisage how they perceive and experience their learning environment. They try and identify the new ideas/words/actions that will be required to complete the activity. What decisions are they likely to make when faced with an activity? This is quite difficult for someone who is already competent (Expert) to regress to the role of someone who has no previous experience of the activity (Novice).

One of the reasons why experts may have great difficulty in teaching students is that it is very difficult to tell others about their expertise. There is also a tendency for experts to overwhelm students with masses of detailed information that will not make sense, or be useful to the student, until a later stage in the development of their own skills and expertise. Therefore it is necessary for teachers to plan learning experiences for students that take account of the perceptions and concerns that they characteristically experience. Therefore it is a good idea that once you have decided on an activity, to run through it yourself and analyze what steps are required to complete the activity into a number of sub-steps. However, there are few issues that you should consider as you do this:
A. INFORMATION HANDLING CAPACITIES

While human minds are very powerful, they do have some limitations that need to be taken into account when planning an activity.

☞ Capacity of short term memory
  Too much information, presented too quickly means we tend to stop paying attention. This has direct implications for the design of a laboratory or practical activity, which will require students to process information in a prescribed timeframe.

☞ One activity at a time
  Only one type of mental activity is possible at the same time (e.g. looking, taking notes). While it appears that we do this all at once, we rapidly alternate between them. When in a laboratory teachers tend to combine the performing of an activity with a description. Therefore should the student look or listen? It is a good idea to keep the performing and the talking separate so that the students can handle the information they are provided with.

B. TIMING OF THE ACTIVITY

In terms of timing, the laboratory or practical classes generally have to fit into a prescribed time frame. It is very difficult to estimate just how much time is required to complete the activity; especially if this is the first time that this particular activity has been taught. What has to be decided is whether there will be enough time for a description and demonstration of the activity as a whole, and
the students copy it, or would it be more prudent to describe the whole activity but to demonstrate just one part of it and direct the students to try just that one part. If you choose this second course of action then you will need to find a way of pulling the entire activity together at a later stage.

Another ‘timing’ issue to consider is the pace of a demonstration. The pace could be that of a competent performance to show the students what they should aim for. Alternatively the pace could be slowed to provide more opportunities for students to identify the significant features of the activity. Another related issue is the degree of existing knowledge and skills possessed by the students. If the skills range is large it might be worthwhile bringing in demonstrators to work with groups of students.

► Pre-laboratory activities
To make sure that the students are ready for the laboratory or practical class it might be a good idea to plan some pre-laboratory activities to explore certain aspects of the laboratory. Activities include a written exercise
before the laboratory takes place, or the use of media, such as a video, dvd, audio tapes or even Computer Aided Learning packages which set out the main themes and underlying principles of a particular task. If you have identified new ideas/words etc, now would be a good time to introduce them to the students.

► *Post-laboratory activities*
This is mainly confined to the written report that is handed in after the lab has been completed. While this gives a permanent record of what has been done, and can be completed in a very mechanical way by students, the report does not necessarily give an indication of a student’s practical skill in a laboratory. An alternative is to use small group discussions/presentations or interviews to identify what learning has taken place during the laboratory or practical class. However, interviewing large numbers of students can be time consuming, but this could be undertaken by demonstrators rather than the teacher/convener.

**Section B. Teaching in a laboratory or practical class**

Once the activity has been determined and broken down, and you are sure that it can easily be completed within the prescribed timeframe, the next thing to consider is how the laboratory/practical class will be staffed?
1. **So who facilitates what in the laboratory or practical class?**

With the ever expanding pressures on academic time is it prudent for the teacher, to spend a great deal of time in the laboratory or practical class?

**The Teacher**

There are a number of different staffing strategies that can be used, depending on the time that the teacher has to spend in the class.

► *Teacher as demonstrator*

If the teacher has the luxury of being able to spend three hours in the laboratory with a small class then there will probably be little requirement for further staffing. Here the teacher will be able to demonstrate the activity centrally and continually move amongst the students ensuring that a sufficient level of knowledge/skill has been gained. Additionally, if the teacher had also given the relevant lectures, he/she can make regular links to theory. In this scenario the student/teacher contact is at a maximum.

► *Teacher and demonstrators*

However, in most cases the inevitable increase in student numbers and the concurrent decrease in expensive laboratory space generally lead to large classes in cramped conditions. Here, although the teacher can still demonstrate or explain the activity centrally, there will not be enough time to see all students. It is therefore necessary to ensure that there are sufficient demonstrators who are competent in this particular field, who can mingle...
with the students and answer any questions that arise. In this case the teacher does not have to stay for the entirety of the laboratory or practical session. In this scenario the maximum contact tends to be between the students and the demonstrators rather than the teacher.

DEMONSTRATORS

Demonstrators are generally postgraduate students in the area or discipline of the laboratory or practical class activity. They will normally have very little teaching experience and will require guidance and training especially when confronted with a new laboratory activity. They will however, have been through similar laboratory experiences during their undergraduate studies. The best ways of preparing demonstrators and the teacher for the first laboratory exercise will be discussed in Section C.

TECHNICIANS

One of the most underrated members of staff in terms of the design and resourcing laboratories and practical classes is the laboratory technician. He/she has a wealth of practical knowledge and a high level of competence. This can be very useful from the very conception of the activity design right through to resourcing and managing the laboratory. It is a good idea to include the technician in any decision-making which could impinge on the smooth running of the laboratory or practical class. Indeed, it is a good idea to have a technician available throughout the running of the class in case of emergencies, breakdown of equipment etc.
2. What teaching skills will be required?
Both teachers and demonstrators will be asked to call on a large range of teaching skills during the running of a laboratory or practical class. Some of these are briefly outlined below:

**PERFORMING**

The performing of an activity for students to observe is the defining feature of this way of teaching. In some cases it may be the teacher doing the ‘performance’ or a demonstrator. Generally the performance is live with alternating descriptions. The flexibility of this approach means that questions can be asked and answered immediately. However if the class is very large or is part of a distance learning course then performances can be shown on video or DVD.

**DESCRIBING**

The teacher generally describes the important aspects of the activity. It is important to determine how much description you require. This should be based on the current level of the knowledge/skills base of your audience, and the skills that you want the students to be capable of when they finish the activity. It is a good idea to script some aspects of the description so that you can remember all the salient facts at specific points in your performance. Generally breaking up descriptions into small chunks helps to make the learning more accessible for students.

**EXPLAINING**

Explanations are essential if students are going to understand how the activity fits within the
curriculum of the course. By giving an explanation the students will have a realistic goal to achieve by completing the activity. However, the student’s interest in the explanation will be dependent on the learning characteristic of that particular student. Also it is relevant to note that explanations can be provided from a number of sources, such as textbooks, work notes etc, but giving an explanation in class does allow for questions and answers.

**QUESTIONING**

Questions are very important in this teaching environment. They can be used for a variety of purposes such as: determining the level of knowledge or skills that a student has; checking what they observed; seeking feedback etc. They way that you ask questions is important e.g. “Do you want to ask any questions?” may not get much response. Better options include:

- Where have you got up to?
- How would you explain your steps to someone else?

**DIRECTING**

During a laboratory session the teacher will direct the students to observe and perform actions. The directions should be very clear and unambiguous. Directions should also be realistic and at a level suitable for the knowledge/skills base of the students. It is a good idea to provide a worksheet which might include explanations, a glossary and a full set of clear directions which the students can use as an aide memoire. This can be provided before the class.
EVALUATING – GIVING FEEDBACK

Do not be afraid to give general feedback to students on their learning. This will allow them to improve and fine tune their performance. Remember to praise with explanations and that criticism is not bad when coupled with constructive corrections.

The sequence that these teaching skills are used in is totally dependent on the teaching-learning session and cannot be prescribed, but it would make sense to be ready to use all of them.

As well as the teaching skills mentioned, a good teacher/demonstrator will also have a number of other skills, such as:

- Establishing and maintaining good relationships with students
- Encouraging students to learn and to think about what they do
- Handling problem students
- Managing their allocation of time to students

These further skills and how they affect the running of the laboratory and practical class will be highlighted in Section C.
Section C: Running the laboratory or practical class

Laboratory and practical classes are generally run by a team of people: A teacher, demonstrators and sometimes a technician. As well as the design of the activity some thought must be given to the members of your teaching team. Special thought must go to those demonstrators who are postgraduate students with little or no academic teaching experience. Typical questions to think about include: What you will require the demonstrator to do within the laboratory class? How much support/direction are you willing to give your demonstrators prior to starting the laboratory? And how familiar are your demonstrators with the activity and the tasks that the students will encounter? In this section we will look at some activities that the teacher could ask demonstrators to do to produce an encouraging learning environment.

Generally there are four main phases to laboratories that the demonstrator will be involved in. Each phase is differentiated by its objectives and requires different skills and sensitivities. These are:

▪ Preparation
▪ Getting underway
▪ Doing the rounds
▪ Finishing

Let’s look at each of the phases and see what can be done to increase the chances for student learning. Please note that following strategies apply equally to teachers as well as demonstrators.
1. Preparation
How can you and your demonstrators ensure that you are well prepared?

✍ Review the assigned activity and tasks and try and envisage how the class may unfold.

✍ Consider if your knowledge and skills are at an appropriate level. If in doubt you and your demonstrators should run through the activity and complete the tasks set. This will ensure a competent and confident performance.

✍ Try working through the tasks as this will also highlight where problems might occur. Try and mitigate as many of them as possible prior to the start of the laboratory. If you will need conversion factors or equations to complete the tasks then keep them to hand. It is always good to be prepared.

✍ Get the demonstrators to set up the equipment and make sure it works. Ask the technician for help if there is a problem. Try to identify any issues that might arise as a consequence of faulty equipment.

✍ If there is a complex part of an activity then script what you want to say and do. This way all the pertinent facts will be presented.

✍ Be flexible and be ready to modify your plans. React to student responses.

Generally being prepared will ensure a more competent performance than trying to work ‘off the cuff’.
2. Getting underway

☞ Arrive at the class early. This will allow you to make contact with, and build up a relationship with the students in the class. Students are more likely to ask for help from someone who is genuinely interested in them.

☞ It also helps if you take the time to learn the students’ names. It shows that you are interested. Take time at the beginning of the session to introduce yourself, but also remember to introduce the other members of your teaching team.

☞ Always provide a calm exterior even if inside you are experiencing impatience.

☞ Generally try and be yourself and avoid putting on an act.

If you are providing the introduction to the laboratory or practical class, make sure you have done enough preparation to allow you to get underway confidently and competently.

3. Doing the rounds

Once the laboratory or practical class is underway, the demonstrators can start to move amongst the groups of students. This part of the laboratory process is where the main trouble-shooting and development of students’ critical thinking occurs.
TROUBLE SHOOTING
The first thing that the demonstrators will have to do is identify those students that might be experiencing problems. What is the best way of doing this? There are a number of options listed below:

i. Waiting in the wings to be called upon
The demonstrators wait in the wings scanning the class for students who clearly need help. This approach may seem most time effective, but not all students will publicly declare their need for help from you.

ii. Waiting in the wings and spotting the ‘in trouble’ student
As above, however this time the teacher and demonstrator use ‘cues’ to identify ‘in trouble’ students. But this approach does not take into account that some of the normal ‘cues’ might not be observable from a distance. Also this strategy assumes a certain level of teaching knowledge on the part of the demonstrator.

iii. Systematically calling on all students
The demonstrators move through the class calling on all students or group of students systematically, to assess whether help is required. This allows a close monitoring of the students work. Some students might find this intrusive.
iv. Hanging around

The demonstrator moves round the class in a random manner anticipating that students will request assistance as he/she moves by. This strategy will make it easier for students to signal you quietly. However the randomness of the route means that there is a chance that some students will be overlooked, or that the demonstrator will be locked in one place.

There is no perfect strategy for doing this, but a combination of the above approaches will allow demonstrators to become sensitive to the particular environment of the laboratory or practical class.

Once the demonstrator has identified an ‘in trouble student’, he or she needs to find an appropriate response. How do the demonstrators give help to a student without doing the work for them especially if the student is to be assessed formally? Also how can demonstrators get the students to help themselves in understanding their problem? It will always be a challenge to balance the need to provide students with support and enable them to take responsibility for their own learning.

HOW TO GIVE HELP AND PROMPT THINKING

The first part is to diagnose the student’s problem. The student can be asked to:
- Offer explanations of the difficulties they have
- Recount what they have done
- Attempt the activity again, and report what they notice, think or perceive is happening
Once the diagnosis has been made help can be given in a number of forms:
▪ Demonstrate the activity again so that student can spot essential features that might have been missed originally.
▪ Prompt the student’s attention to something they might have overlooked.
▪ Present options for what they could do and ask them to chose the appropriate on giving reasons for their choice.
Incorporate hints or clues in a question.

To prompt thinking the demonstrators should try to engage students in discussions/reviews of the activity, or even ask questions that make students think more deeply, clearly and critically about the activities they are engaged in. Ask them to provide further and more detailed ideas or information, or perhaps to clarify comments or answers.

HANDLING PROBLEM STUDENTS

It is a good idea to provide demonstrators with a list of problem students they are likely to encounter during the course of a laboratory or practical class. These will include students who:
• Call on you at the first hint of difficulty and expect you to lead them through the entire activity.
• Make it look as though they are doing well but are in fact experiencing difficulty.
• Doubt the accuracy of the information you have provided and make the same request of another demonstrator.

Here are some strategies that might help:
• Explain to students what your role is. Some students will not be aware of what a demonstrator is and what you can or can’t do.
• Provide private opportunities for students to make contact with you and talk about their concerns.
• Talk to your fellow demonstrators and share experiences so that a consistency in approach is established. However be aware that some students will relate better to some demonstrators than others.

DEALING WITH YOUR OWN ‘DON’T KNOWS’

There will come a time when a student will ask a question to which you will not know the answer. How will you respond?

You could try covering up that you don’t know. This is not a sensible option because it can lead to misunderstanding. However a lot of teachers do it to avoid embarrassment.
Acknowledge that you don’t know, and then try one of the following:

▪ Undertake to find an answer and report back to the student. However this method means that the student does not have to help answering the question.

▪ Prompt the student to find the answer to the question.

▪ Invite other class/group members to try.

▪ Suggest that you work together to find the answer.

The last three suggestions will also prompt critical thinking.

4. Finishing up
Identify with the demonstrators what the students need to have achieved to finish the laboratory or practical class. Will the students be free to leave once they have achieved these goals?
References


