PROMOTING INDEPENDENT LEARNING IN UNDERGRADUATE LABORATORY PROGRAMMES: RUNNING SESSIONS WITHOUT GTA DEMONSTRATORS

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Abstract: The Covid-19 pandemic has forced engineering departments to think carefully about practical/laboratory programmes, which are required for accreditation with professional bodies. Such programmes are normally run with PhD demonstrators (or GTAs) to guide groups through their experiments. At the University of Strathclyde (CPE), we have taken a contrary approach by running programmes with *just* one academic member of staff (MJH) and two technicians. In addition, a video and standard operating procedure (SOP) are supplied beforehand to allow adequate preparation. We also provide extensive post-experiment support in the form of VLE (Moodle) experimental forums (where results can be shared) and Zoom sessions – this gives the opportunity to ask questions. Our philosophy is that practical programmes are very much a partnership in learning between students, academic and technical staff - we all learn from each other. Certainly, one of the outcomes has been that experiments take longer to complete – an indication that groups are working more slowly and (perhaps) deliberately? In addition, the saving in demonstration costs has been significant. Survey comments would suggest that being able to work through the experiments independently is appreciated, but with support on hand should they run into difficulties – another type of 'safe space'. Importantly, it is helpful to see processed results on the forums, and the questions would suggest an impressive understanding of their experiments. We feel this programme functionality gives an improved learning experience over the traditional 'carry out the experiment then submit report' format - a silver lining to the Covid-19 cloud.

Keywords; practical education, laboratory education, independent learning

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1. INTRODUCTION

Practical (or laboratory) education is an important mode of delivery in all chemical engineering curricula regardless of location (Feisel and Rosa, 2005), and is an essential (based on a minimum credit weighting) in degrees accredited by professional bodies such as the IET, ICE, IMechE and the IChemE (IChemE, 2019). Furthermore, the Covid-19 pandemic has resulted in an increased spotlight on practical education because this is the one mode of delivery that does not lend itself to online or distance-learning (DL) delivery. The outcome at many institutions has been that practical education has been curtailed or has not taken place at all. In this context, there has been an increased focus on the two alternatives to hands-on (or traditional) laboratory experiments: virtual or simulated (where the behaviour of an experiment is modelled by software, similar to a flight simulator in pilot training) and remote (where there is an actual experiment that can be controlled and monitored by students from remote locations). The potential of these alternatives was recognized by Ma and Nickerson (2006), who reviewed and compared these alternatives against hands-on laboratory experiments. Bhute et al (2021) have recently reviewed the three delivery modes, by considering a range of science and engineering disciplines, and have proposed a broad categorisation of all experiments into three types. Even when we return to “normal”, it is likely that these virtual alternatives will still be evident in engineering curricula (Glassey, 2020). In the author’s department, it has not been possible to run laboratory experiments in 2020/21 because of local restrictions, and the alternative has been to supply actual data and a video of the experiment (describing the actual equipment and showing the experiment being carried out) and ask students to process the data for the results and use this as the basis of the report. Innovation often comes out of adversity, and a quite original approach has been the design and construction of experiments that can be conducted at home. For example, Larriba et al., 2021 have proposed utilising 3D printing for low-cost experiments to study a range of subjects including heat transfer and separation processes. Continuing with this domestic theme, the kitchen can be a useful location to demonstrate various engineering principles (Schultz et al., 2020). As the author discovered recently when coming across a *Merit* chemistry set in the family home, home experimentation is not a new concept although safety concerns are of course a major issue (Andrews et al., 2020). If this trend continues, and vice chancellors are aware of this development, the author could be soon out of a job!

At institutions such as the University of Strathclyde, there has been a longstanding focus on DL engineering degrees, even before the advent of Covid-19. Indeed, it is at the UoS that the UK’s first and only DL BEng (and now MEng) in Chemical Engineering was established, over 25 years ago. The issue of how to reconcile accreditation with DL delivery has been dealt with so far by the inclusion of a summer school, where students spend a week each year at Strathclyde and carry out various experiments. However, the future challenge in DL delivery is to enable the learning outcomes of practical education to be achieved from afar without attendance at a summer school.

The importance of laboratory experiments to aid understanding is not just limited to students. This summer, one of the tasks for the corresponding author has been to rewrite an experiment based on the principles of centrifugal pumps. This is not an area familiar to the author, and despite access to various textbooks, understanding of the experiment has certainly been facilitated by switching on, running the equipment, changing operating conditions, taking measurements and processing the data to obtain results.

2. BACKGROUND

The corresponding author commenced employment at Strathclyde in the summer of 2019. Each of the Year 2 and Year 3 laboratory programmes consists of 10 experiments. Previous to 2019, the staffing of each of the programmes involved five GTAs (each covering two experiments). The remit of the GTA was to guide each group through their experiment, making sure that the experiment was completed safely and answering any questions. There were also two technicians present to help with any technical issues, and ensure adherence to safe working. Marking was also carried out by the GTAs. Based on survey feedback, observations and the views of senior staff, there were various concerns about such a ‘GTA-led’ approach:

2.1 Costs. Based on five GTAs, three-hour sessions and a 20-week laboratory programme, the demonstration costs mount up. The total demonstration cost for the Year 2 and Year 3 programmes sums to five figures, based on 15 hours per week for each programme. The budget is limited, and money should be spent to maximise the UG learning experience and also provide effective training for the GTAs. This poses the following question: what is the best use of the limited financial resources? This might be supervising experiments or possibly GTAs should be deployed in other modes of delivery such as tutorials.

2.2 Variable student learning experience. Despite a training programme, there was an inevitable range of teaching styles from the GTAs. Indeed, some of the experiments completed in quite a short time (despite being quite complex) and others took much longer (despite being straightforward). This was the first warning sign. Also, some GTAs would simply run the experiment (with the students being mere observers) whilst other GTAs would be happy to take more of a back seat. The former is definitely the wrong approach and defeats the main object of practical teaching – understanding and confidence derive from student groups actually operating the equipment. This was the second warning sign. The third warning sign was from how GTAs dealt with any questions from the groups – some would simply give the answer whilst others would direct students to the instruction sheets. Reflection on these different pedagogies will be considered in more detail in Section 7.

2.3 Defining and expanding the technician role. The conventional approach in UG programmes is that the academic is *mainly* concerned with the principles and theory of the experiment, whereas the technician is *entirely* concerned with making sure that the equipment is working and maintained. One of the problems with such a tightly-defined role is that it does not make use of the technician's full capabilities and, while the equipment may be apparently 'working', some knowledge of the principles and theory of the experiment can be instructive in the whole demonstration process. In short, it would be beneficial to try and break down the barrier between the technical and academic roles.

3. OBJECTIVES

The driver for this work is that over the years, practical education has been based mainly on the same approach and typical activities, whereas the Covid-19 pandemic has given practitioners the opportunity to critically analyse all aspects of delivery.

1. To ensure a consistent and high-quality learning experience for all groups and all experiments. The reason why this objective includes both 'consistent' and 'all' is that some programmes involve each group carrying out a different set of experiments.

2. To design laboratory programmes that promote independent learning for all groups and all experiments. Following on from the previous objective, many UG engineering laboratories just have one experimental arrangement for each experiment, so that timetabling restrictions do not allow all groups to carry out the same set of experiments. At Strathclyde, in each programme each group carries out any six of the 10 available experiments.

3. To try and break down the traditional academic/technical barrier – by encouraging academics to gain more knowledge about the technical role and vice versa

4. To make better use of the financial resources (capital, running and space costs) available for laboratory programmes. Proprietary teaching equipment is expensive, and space costs are a concern because much space is required for the experiments, and such space is only used once per week based on typical timetabling.

5. For the GTAs to gain experience in a range of teaching modes. If any changes are to be made to laboratory programmes, we should consider ALL the stakeholders.

4. METHODOLOGY TO DETERMINE NEW ARRANGEMENTS

Table 1: Changes made to the delivery

No	Academic year change introduced	Change made to arrangements/staffing	Possible positive effects on objectives	Possible negative effects on objectives
1	19/20	Redeployment of GTAs to other teaching duties, for example tutorials	Objective 4 Objective 1	Objective 5
2	19/20	Provision of SOPs for each experiment to enable groups to carry out experiments independently	Objective 2	
3	19/20	Staffing in practical sessions reduced to academic and two technicians only	Objective 1 Objective 3	
4	20/21	Inclusion of VLE (Myplace) forums for groups to ask any questions before submission	Objective 1	
5	20/21	Inclusion of Zoom sessions for groups to ask any questions before submission	Objective 1	

The methodology is based on making changes to the programmes in order to try and satisfy the five objectives listed previously. The changes are listed against the corresponding objectives listed in Section 3 in Table 1. The completion of this table is based on our expectations before the changes were made for 2019/20 and 2020/21. The reason that not all the changes were made at the same time was that the corresponding author only started employment in the summer of 2019, and it would have not been sensible to make too many changes in delivery. This is because when taking over as module leader, it is important to establish which changes are considered positive (and should be continued) and which negative (and so should be reconsidered). If too many changes are made in one year, it can difficult to classify changes based on survey scores and text comments. The last two changes were dictated by the Covid-19 pandemic and the pausing of all laboratory experiments for that academic year, in an effort to provide extra support in lieu of actually carrying out the experiments.

5. RESULTS AND DISCUSSION

Table 1: Information from University surveys and informal evaluations which have been based on verbal feedback from the Class Reps. The surveys carried out were University end-of-year, and a basic analysis involved comparing quantitative information and trying to crystallise any common themes from the text comments.

Survey factor	Findings
Response rate	There is no real change in the response rate, these being around 20%. Normally, if any changes have caused concerns to students, the response rate would increase. The fact that the response rates are roughly unchanged could be taken as a positive indicator.
Scoring	Across the Year 2 and Year 3 programmes, there are both upward and downward changes, but no significant changes from the previous years.
Typical comments	Much of the focus is on the documentation, particularly where this is not clear. This also includes any inconsistencies between the instructions sheets and the SOPs.

6. CONCLUSIONS

The five objectives from Section 3 are now considered in turn.

6.1 Because there are less staff involved (eight in 2018/19 to three in 2020/21), there certainly must be more consistency. However, without the GTAs in attendance, the spotlight naturally falls on the various documentation and the survey comments suggest that there is variation in the documentation between the experiments.

6.2 Groups are certainly spending longer in the laboratory, and written and verbal questions would suggest that independent learning has improved. However, it is quite possible that some groups will learn less without the GTA in close attendance.

6.3 This has certainly been achieved based on the fact that in Year 3, the technicians have taken on marking duties as well based on their increased learning.

6.4 Certainly, there has been a significant reduction in the operating costs. However, an additional benefit has been that the technical team has been proposing designs for new experiments, based on their increased technical knowledge combined with their knowledge and experience of construction.

6.5 There has certainly been a diminution of the GTAs' teaching experience based on their non-presence during the laboratory sessions. However, it is hoped that the increase in independent learning of the student groups will make up for the reduction in the GTA teaching experience.

7. FUTURE WORK

7.1 The major difference from the student perspective is that despite the presence of an academic and two technicians, there will be no GTA in attendance. In general, it was observed that groups worked independently and sought minimal assistance from the staff – meaning that the documentation took on paramount importance. In typical instruction sheets (written by the academic), there is a section for the experimental procedure, but of course this is also covered by definition in the SOP (written by the technical team). It is perhaps not surprising that there is confusion. We could manage expectations by explaining that there are likely to be inconsistencies, and that they should allocate say 30 minutes to access the documentation (instruction sheet and SOP) and watch the video before the experiment. A more fundamental question is: what are the ideal characteristics of this documentation to avoid confusion and enhance the learning experience, considering that we are trying to promote independent learning. It may be preferable for the instruction sheet to detail the order of the tasks, and the SOP to explain in detail how each task might be carried out. As an example, Task 1 might describe switching on the equipment, Task 2 setting a control, Task 3 taking a measurement and Task 4 shutting down the equipment. The SOP would show detailed information for each task (ideally with photographs) and then the instruction sheet (Experimental Procedure) would simply list the order in which the tasks were carried out including any repetition. This would require to-and-fro reading between the two documents. The current SOPs include numbered lists, which should probably be avoided because groups are likely to focus on the SOP at the exclusion of the instruction sheet, as became obvious from discussions with students.

7.2 This work should not be viewed as a 'Trojan Horse' to carry out cost cutting. Although cost saving is one of the objectives, this is very much secondary to the main objective of promoting independent learning. The GTA budget is generally fixed, and any saving in GTA time would simply allow more GTA activity in non-practical modules, rather than the money being diverted to support non-teaching activities. The real cost benefit is that the technical team feel able to suggest modifications to current equipment, and designs for new experiments based on their expanded roles. Indeed, it also conveys a positive impression to visitors and students when there are a number of in-house experiments to complement the proprietary equipment.

7.3 It is appropriate to reflect on the teaching styles and pedagogies demonstrated by the GTAs. It is easy to be critical, but it should be remembered that it was only when observing GTAs in action that it became possible to determine ways of improvement. The corresponding author, whilst at Sheffield, was involved in the recruitment, training and monitoring of GTAs for laboratory classes. Based on student feedback in Sheffield, the essential characteristic of a GTA is a deep level of knowledge that can facilitate answering the typically wide range of questions that might be posed by students. Probably the only way that such knowledge can be gained is by running the equipment, collecting data and processing the data to generate the results. Possibly, more than once. This can take some time given the complexity of the experiments. The underlying personal requirement is a real interest in the actual experiment, which then leads to following the experimental path taken by the students. However, this should be acknowledged in a workload model where adequate preparation time is included. This would only be a small part of the GTA costs, but this would certainly be money well spent. Preparation time is often not included in GTA workload models (not just for practical classes), but it should be because it can pay dividends regarding an improved student (and GTA) learning experience.

8. REFERENCES

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