Teaching Chemistry in Higher Education

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Edited by

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Teaching and assessing technical competency in the chemistry laboratory

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Teaching chemical technique has a long history going back to Michael Faraday, but assessment of chemical technique is comparatively rare in the modern teaching laboratory. In this work we aim to share our approach on teaching and assessing laboratory techniques. This is grounded in an exemplar-based approach incorporating the principles of formative assessment; whereby students have a known standard, are able to compare their efforts to the known standard, and are able to make appropriate adjustments to their work based on the standard in advance of submission for final summative assessment.

We describe the implementation of our approach based on the three components — providing an exemplar, facilitating peer review during activities, and assessment and formal feedback — for laboratory competency sessions in Year 1 and Year 2 of our undergraduate programmes. Techniques explored include glassware techniques such as titrations, setting up distillations, preparing standard solutions, as well as instrumental techniques such as UV/vis spectroscopy and gas chromatography.

We found that students tended to be highly prepared — likely prompted by the necessity to record their demonstration — and that their levels of knowledge, confidence, and experience improved as a result of the activities. We offer some guidance for others wishing to implement a similar approach in their practice.

Influence of Professor Tina Overton (Michael Seery)
I first met Tina at a Summer School for new lecturers in Malta and our relationship has remained sunny ever since. Her pragmatic and no-nonsense approach were exemplary and student interests were always at the heart of everything she advocated. She brought new and fresh perspectives to my thinking on graduate attributes, problem solving, and in more recent years her extensive work on laboratory education has been enormously influential to my practice. But it is Tina’s example of a professional in the discipline of chemistry education that has shaped much of my own career, and continues to do so.
Introduction

Learning technical skills in the laboratory
Laboratory work is recognized as a core component of the chemistry curriculum. Professional and Learned Societies require that students must have hands-on experience of laboratory equipment and instruments in order to learn chemistry and be prepared for future coursework and employment (ACS, 2015; RSC, 2015). Laboratory skills are not unidimensional. They encompass a range of skills and techniques related to experimental work in the laboratory, such as analytical skills, manipulative practical skills, and instrumental skills (Kirton et al., 2014), as well as soft skills, such as critical thinking skills, teamwork skills, and written communication skills (Bruck et al., 2010).

While there is sustained interest in the teaching of experimental technique (DeMeo, 2001), assessment of laboratory work is typically conducted by means of laboratory reports. This conventional approach to assessment of learning in laboratory often results in low quality reports, due to lack of guidance and clear expectations (Gragson & Hagen, 2010) and learner fatigue caused by the requirement to produce a large number of laboratory reports (Carnduff and Reid, 2003, p. 23). More importantly, laboratory reports do not directly assess students’ hands-on laboratory skills, which they actually have to perform for most of their time in the laboratory. This necessitates an approach that directly assesses students’ laboratory skills with the purpose of improving their performance in the laboratory as well as their understanding of the corresponding chemical concepts.

Literature on direct assessment of laboratory skills tends to describe approaches such as post-hoc assessment stations (Kirton et al., 2014), where students demonstrate a particular skill under formalized testing conditions, or by proxy, where the purity or yield of a product is used as an assessment of laboratory technique (Graham et al., 2008). Examples of assessment by observation have been reported in organic chemistry (Chen et al., 2013). More recently, work describing the assessment of techniques using video was reported (Hensiek et al., 2017; Hensiek et al., 2016; Towns et al., 2015). We have previously described a modified use of these video assessment methods that incorporates preparation techniques and peer-review, with the intention of emphasizing formative assessment and incorporating preparative activities (Seery et al., 2017).

As well as considering assessment of laboratory techniques, there is also a need to consider the learning environment in the laboratory, and how students can master techniques. Laboratory environments have long been known to impose a high cognitive load (Johnstone & Al-Shuaili, 2001; Johnstone et al., 1994; Johnstone & Wham, 1982). It can be difficult for students to learn how to master skills and techniques while simultaneously needing to complete their practical work on time, consider theoretical concepts, and learn about processing data from the laboratory. As well as the number of considerations students need to process in the laboratory, we argue that the relationship between these considerations also imposes a difficulty, and describe the laboratory as a complex learning environment (Agustian & Seery, 2017). Learning in a complex environment requires students to be able to master the individual components so that they can draw them together for the additional challenge a complex scenario brings. Therefore explicit consideration is needed with regards to teaching chemical techniques. Supporting learning in complex environments can be achieved by provision of preparatory activities (Agustian & Seery, 2017).

Formative assessment
We use the model of formative assessment described by Sadler to consider how to help students learn chemical technique (Sadler, 1989). Formative assessment is a means to provide students with the capacity
to close the gap between their current understanding and skills with the desired level or outcome. According to Sadler, the formative aspects of formative assessment are:

1. that students have a clear concept in advance of pursuing a task of the standard required;
2. that they are able to monitor the quality of their own work by comparing it to this standard;
3. that they have the means to modify their work to adjust it to the standard prior to final summative assessment.

While discussing formative assessment, Hendry proposes the use of exemplars to represent required standards, arguing against the “loading up” of feedback until after the task is completed by students, and instead providing feedback on an ongoing basis as they complete the task (Hendry, 2013).

**An exemplar-based approach**

From the literature on laboratory education over the last four decades, it is concluded that pre-laboratory activity tends to increase the efficiency of students’ laboratory work and reduce the time spent on experimental tasks, resulting in improved understanding of laboratory tasks and fewer experimental errors. Aligning these observations with the concept of exemplars, our approach to teaching chemical technique relies heavily on providing exemplar information in advance of the laboratory session. This is done to provide students with the intended standard that they will need to achieve. When in the laboratory, students complete their work while comparing it to this standard with the help of peer review, and can make improvements to their final piece of work submitted for assessment. Our exemplar-peer review-assessment approach therefore aims to draw together guiding principles regarding learning in the laboratory, pre-laboratory work, and the role of exemplars, and align them in a framework mapping on to the guidance from Sadler regarding formative assessment. The framework is shown in Figure 1.

In this chapter, we describe the implementation of the exemplar-peer review-assessment approach for technical and instrumental techniques needed in the laboratory based on our experience. We elaborate on our understanding of the nature of preparative resources that students prefer, as well as consider some affective aspects students consider when completing the activity. We illustrate this with some insight from our own implementation and offer suggestions for those wishing to consider the assessment of practical skills in their practice.

**Design and Implementation**

The context of our implementation is with students in their first and second year of a research intensive university in the United Kingdom. All students involved are on a chemistry majors programme, with class sizes of about 150. The activities we describe fit into one three-hour laboratory session. We ran the
activity for the Year 1 students in their second week of laboratories after arriving at university. The Year 2 students completed their “experimental techniques laboratory” as one of the rotations of six in their physical chemistry laboratory session. We describe the implementation of these below, and subsequently illustrate how they ran, and some outcomes from evaluation.

**Laboratory skills in Year 1 — titrations, distillations, and preparing standard solutions**

Students in the first year of our chemistry programme complete one three-hour chemistry laboratory a week for 11 weeks. A decision for those who wish to implement in their own practice will be whether to have a dedicated session for a practical competency exercise, or whether to use spare time in the laboratory, as was described in another similar approach (Hensiek *et al.*, 2016; Towns *et al.*, 2015). We opted for a dedicated session, as it was felt that some students might struggle to find sufficient spare time in their practical schedule to complete these competency tasks. In the case of Year 1 students, having a dedicated session early in the semester meant that students had the opportunity to learn and receive feedback on some core experimental techniques prior to their use in actual experiments in the subsequent weeks of semester.

Our model is based on providing exemplar materials to students in advance, and for the techniques in our case (titrations, distillations, and preparing standard solutions) we prepared four videos that students were required to watch in advance. To give an indication of content, these videos are available to view at the weblinks shown:

- A video describing pipetting highlighting the use of volumetric pipettes which was an ancillary component of the preparation for titrations (http://bit.ly/skillsvolpipette)
- A video describing the set-up and completion of distillation (http://bit.ly/skillssstandardsoln)
- A video describing the preparation of a standard solution, including the correct approach to weighing a solid (http://bit.ly/skillsdistillation)

These videos were prepared by an undergraduate student who had previous experience with the Chemistry Olympiad, and some postgraduate students with significant experience of laboratory teaching (funded by a small university grant). Videos typically lasted from 4–7 minutes in length.

Students’ laboratory manuals included details about how the laboratory would run, along with a prompt about watching videos in advance. In addition, laboratory teaching assistants were told to remind students in the first week to prepare for the second week. Students also received an email reminding them to watch the videos in advance of the practical session.

When students came into the laboratory, they worked in their pre-assigned pairs through the laboratory activity. This was described in the laboratory manual, and structured around three peer-review sheets (Supplementary Information), outlining what students should do in the laboratory for each technique, as well as providing prompts for their peer to feedback on (see Figure 2 for an example). The main task was to video the competent demonstration of each task. To do this, students would give their mobile phone to their partner and then while their partner recorded them, they would demonstrate the technique. The use of the student’s own phone to record the video emphasises the sense that they retain ownership of the video.

An important point was that students narrate their technique as they completed it, explaining each step of the process. This was a useful way of giving students practice at explaining chemistry techniques verbally, and also made assessment much easier. Students could record their videos as often as they liked. After
Lab Skills: Peer Observation Checklist

Part B: Setting up Quickfit® distillation

<table>
<thead>
<tr>
<th>Protocol Step</th>
<th>Lab Partner Comments / Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assemble the necessary glassware and ensure it is clean. To check: presence of round bottom flask (25 ml), still head, thermometer with adaptor, condenser, receiver adaptor and beaker, clamp.</td>
<td></td>
</tr>
<tr>
<td>2. Connect rubber tubing to water supply and condenser. To check: sequence of connection to tap, water in (bottom of condenser), water out (top), tubing goes over the widest part of the connector.</td>
<td></td>
</tr>
<tr>
<td>3. Assemble apparatus. To check: flask with the connected still head in the heating mantle, condenser clamping securely but without strain, collection beaker in place, wiring to the heating mantle is in a sensible position. DO NOT PLUG IN HEATING MANTLE.</td>
<td></td>
</tr>
<tr>
<td>4. Introduce yourself and apparatus. To check: explaining overall arrangement, noting position of thermometer, cables and tubing away from heat source. Turning on water and showing steady water flow. State that you would add 2 – 3 bumping granules.</td>
<td></td>
</tr>
<tr>
<td>5. Explain the distillation process. To check: liquid would be added via funnel (remove stillhead), heated until boiling, temperature rise noted until steady, collect fraction until temperature rises again, replace flask until temperature steadies again, replace flask. Clear statement of what each flask would contain.</td>
<td></td>
</tr>
<tr>
<td>6. When to finish and cooling down the apparatus. To check: statement regarding leaving some liquid in the flask to avoid explosion, waiting until liquid cools, shutting down water.</td>
<td></td>
</tr>
</tbody>
</table>

Begin videoing the demonstration at this point

End videoing the demonstration at this point

Figure 2: Example of a peer review sheet for performing distillations
a recording, the peer could offer feedback using the sheets, but in practice we found that such feedback tended to be verbal.

After the laboratory, students uploaded both videos to a video hosting platform, typically YouTube or the University’s own platform, and submitted the links to specified assignment areas on the virtual learning environment (in our case, Blackboard). This was reviewed by the teaching assistant using a rubric, and once competency was demonstrated, a pass grade was awarded. The mark from the rubric was used to generate the laboratory mark for students in that week, and in terms of workflow, once the rubric was used, the mark automatically entered the gradebook for students which hosted all of their laboratory marks for their course (module). Figure 3 shows an example rubric for the titration technique. It is important to keep the rubrics simple and short so that they can be used for correcting large numbers of submissions. The choice of asking students to submit a link to an elsewhere hosted video was a conscious one; it meant that students had ownership of the video themselves and could use it elsewhere as they wished (to show to friends, or to use in internship applications).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Levels of Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 – 3 drops only of indicator added to titrant</td>
<td>Not Completed: 0 Points</td>
</tr>
<tr>
<td>NaOH added to burette via funnel, level of liquid brought down to below zero</td>
<td>Not Completed: 0 Points</td>
</tr>
<tr>
<td>Initial burette reading given clearly (with associated camera shot) and read to two decimal places</td>
<td>Not Completed: 0 Points</td>
</tr>
<tr>
<td>Tip of burette and sides of flask washed down with water regularly before endpoint</td>
<td>Not Completed: 0 Points</td>
</tr>
<tr>
<td>Final burette reading given clearly (with associated camera shot) and read to two decimal places</td>
<td>Not Completed: 0 Points</td>
</tr>
</tbody>
</table>

**Figure 3: Example of an assessment rubric for titrations**

**Laboratory skills in Year 2 — using the UV/vis spectrometer and the gas chromatograph**

A similar approach was used in our second year. This was implemented one year after the first implementation in first year, meaning that most students in the class had completed the first year version described above. As part of their second year, students complete laboratory classes, including six 3-hour laboratory classes over six weeks in physical chemistry. These experiments are completed on rotation, and to incorporate our laboratory competency activity, one of the rotation experiments was an experimental techniques class. This class covered use of the UV/vis spectrometer and gas chromatography (GC). Following the approach taken in first year, students were told to view preparation materials in advance of their scheduled laboratory class which included a video describing the basis and competent use of the technique, along with some additional reading materials about the technique. These videos were also prepared by undergraduate students working on summer placements.

In laboratory time, students had an opportunity to discuss the technique with a teaching assistant to
clarify any queries, and then proceeded to demonstrate the use of the technique to their peer, while the peer recorded the student on the demonstrating student’s mobile phone as described above. The demonstrating student had the chance to review the video, undergo a peer review with a provided checklist, and once satisfied, proceeded onto the second experiment. Time permitting and not included in this process, students also received an in-laboratory demonstration of the Karl Fisher titration apparatus from the teaching assistant. The organization of the class meant that in any one three-hour session, there were approximately 6–8 students allocated to this activity, which had a dedicated teaching assistant. Students were required to complete this activity, but in this case there were no contributing marks from the activity to their laboratory course grade.

Evaluation approaches
Ethical approval for all evaluations was granted in accordance with our university's requirements. Students were informed that completion of surveys or discussions about the technique had no bearing on their assessment, and that they could opt not to engage with evaluation, or choose to withdraw afterwards without penalty. No individual student is identifiable in our work. Where example videos of students are shared, these are done after receiving written permission from the students to do so.

Detailed evaluation of the implementation with Year 1 students including access and use of materials, students perception of their knowledge, confidence, and experience was carried out and has been previously published (Seery et al., 2017); pertinent outcomes are shared here. A subsequent evaluation of the implementation with Year 2 students was conducted, and aimed to explore some affective aspects regarding the completion of this task. In this case, students were issued with a survey after completing their laboratory work. As an incentive, students were told that three names from the submitted responses would be selected and awarded a £20 retailer voucher. 52 students (40%) responded to the survey.

Presentation and Discussion of Findings

Access and use of videos
For Year 1, we studied closely the use of videos. As they are hosted on YouTube, some detailed analytics are available, and are described in detail elsewhere (Seery et al., 2017). A key finding from that study is that students in the main watch the videos in advance of the practical class, and once they had clicked on the video tended to watch it almost to completion. Some drop off in watching occurred at the end of videos, where the video demonstration ends and some slides appear regarding subsequent calculations or other non-practical related considerations.

In Year 2, we surveyed students regarding their preparation. Students were provided with pre-laboratory resources for both experiments, consisting of briefing documents and explanation videos. In general, the majority of students stated that they used all of the resources available to them (85% for UV/visible spectroscopy and 81% for GC). When asked which type of resource they preferred most, 71% prefer the videos to information sheets whilst preparing for laboratory work. In addition, in Year 2, we asked students about their perception of preparedness. Students were asked to which extent they felt prepared for both experiments, on a scale of 1 (not at all) to 5 (very prepared). More than three quarters of the students felt well prepared (4 or 5 on Likert scale) for the UV/visible spectroscopy experiment (Figure 4). A small number of students felt unprepared (2 on Likert scale) or not prepared at all (scale 1). The profile for the GC experiment is slightly different from that of UV/visible spectroscopy (Figure 4). While more than one third of the students felt well prepared (4 or Likert scale, 36%), only 2% actually scored very high (scale 5), as opposed to the previous experiment (35%). This is unsurprising, as students will have already had
some familiarity with the operation of UV/visible spectroscopy, whereas this will be the first time they are exposed to GC. In general, however, it can be said that students reported that they felt well-prepared for both experiments.

Our findings indicate that students welcomed the opportunity to prepare for the experiment, echoing the sense of preparedness we observed in our previous studies for students in earlier years. This extent of preparation may reflect a desire by students to feel organized. In their work on exploring student experiences and perceptions of control, Bretz describes how a student in their study had an increased perception of control by feeling organized after the students were required to write procedural information in their laboratory book (Galloway et al., 2016). While the task in the laboratory is different in our case — just focusing on technique — the awareness of students in knowing they will need to demonstrate the task may emphasize their desire to feel organized. The teaching assistant noted that the students were generally well prepared and tended to progress well during the activity.

**Improvements in knowledge, confidence, and experience**

In the evaluation of our implementation with Year 1 students, we followed a protocol proposed by Towns in analysing pre- and post-survey questions exploring students’ knowledge, confidence and experience of the various aspects of each experimental technique (Hensiek et al., 2016; Towns et al., 2015). For each of the three techniques, we saw statistically significant shifts in the pre- to post-survey responses, showing demonstrable increase in students’ knowledge, confidence, and experience of titrations, distillations, and standard solutions (Seery et al., 2017). For distillations, this effect was most pronounced (most decrease in choice of Likert scale 1 combined with most increased choice of Likert scale 5). In discussions with students we found that while it was common for students to learn about distillations at school, they often did not complete the technique in practice because schools did not have the appropriate glassware. For titrations (biggest decrease in scale 3 and increase in scale 5) and standard solutions (biggest decrease in scale 4 and increase in scale 5), shifts were less pronounced, but still significant, as students would have been more likely to complete these techniques at school.

**Affective aspects**

After our survey of knowledge, confidence, and experience in Year 1, we subsequently moved to considering some affective aspects of this work. This was in part in reaction to the growing interest in affect in laboratory education research (Galloway et al., 2016) but also because that it was clear from our implementations with both Year 1 and Year 2 students that students took the task of completing a video demonstration very seriously. As mentioned, we found near universal preparation among all students (even though there was no direct mark for assessment in the case of the Year 2 work) and students in
the laboratory tended to show themselves to be very well prepared and wanting to do a very thorough demonstration – so much so that it was unusual for a student not to complete the activity successfully.

Students were asked whether they enjoyed the laboratory in general, and three quarters of them said that they did. However, we were interested in particular about how students felt about demonstrating the technique on video. Students were asked to select a word from a given list that best matched their feelings about giving a video presentation. The responses showed that about 2/3 were associated with some kind of negative feeling (such as being worried, nervous, uncertain, and bored), whereas one third of them felt positive about the experiments (confident, relaxed, excited, and carefree). Suggested ways of managing this in future include asking 1 or 2 students from the year ahead to come in and speak about how they felt recording the video, prompting reflection on how this activity impacted on their lab competency, and emphasising how these communication skills are required in the workplace when training others or in interviews.

We wished to further explore confidence in techniques by asking whether they would feel confident in explaining the technique to others. We categorized the audience in terms of peers (other students), academic staff, and in a job interview. As with the perception of preparedness, students were less confident about explaining the GC technique; only 1 in 5 students felt that they would be confident to explain this technique in a job interview (Table 1). However, despite some apprehension in GC laboratory, 92% of students feel they are confident in applying these techniques to another experiment. Comparable to other parameters for GC, students’ confidence in explaining techniques are lower. Only 19% are confident in explaining to all three audiences (other students, academic staff, and in a job interview), as opposed to 56% for UV/visible spectroscopy. This is likely due the fact that this technique would have been very unfamiliar to them, and points to an important note for implementation, especially for advanced techniques, in taking some more time with the preparatory materials to ensure students got some opportunity to familiarize with the processes involved. We are working to improve the preparatory materials to help improve confidence regarding GC. It should also be noted that at the time of this survey, GC was not on our second year lecture course curriculum. Some further student perceptions and a video example of a student completing UV/vis spectroscopy demonstration are available (Lykkeberg et al., 2017).

During our observations, students who expressed anxiety at the start of the session noticeably relaxed as the session progressed and seemed to focus more on learning the actual techniques. When asked, students felt that without the constant feeling they were being assessed during the learning of the techniques, they could spend more time focused on understanding how each technique worked. Students also appeared to find having a practice prior to the video being recorded allowed them to better organize and structure everything they had been told/read during the preparation phase of the experiment. Group enthusiasm

<table>
<thead>
<tr>
<th>Table 1: Student responses to question “Do you feel confident that you could explain these techniques to…”</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV/vis spectroscopy</td>
</tr>
<tr>
<td>Not confident in explaining technique</td>
</tr>
<tr>
<td>Other students</td>
</tr>
<tr>
<td>Other students and academic staff</td>
</tr>
<tr>
<td>Other students, academic staff, and in a job interview</td>
</tr>
<tr>
<td>Other combinations</td>
</tr>
</tbody>
</table>
was also very high during the course of the experiment and videoing one another seemed to encourage teamwork and critical self-assessment of the group's performance.

**Assessment**

Assessment of laboratory competency in our case is only feasible by viewing students' videos after the laboratory. In all cases we prepared a rubric to create a simple assessment protocol, meaning that assessment of large numbers of videos is feasible. Laboratory teaching assistants (demonstrators) corrected the video submissions for approximately 12–15 first years in each semester and six second years (weekly for six weeks). As well as rubric score that is used to generate the laboratory mark for the activity (in the case of our Year 1 students), assessment by this method meant that feedback could be very individual regarding technique, highlighting to students specific instances where they had completed a task incorrectly. In general the assessment process went well, with one exception: several students (up to 10%) set their video to private on their sharing platform, which meant that they couldn't be viewed. This required correspondence to tell them how to make it unlisted or public. We added further details to the documentation in later years to ameliorate this problem, although it still persists, albeit to a lesser extent.

**Digital badges**

As students have provided digital evidence for their technical competency in the form of a video, we opted to trial the issuance of digital badges. Digital badges are an emerging assessment method in laboratory education. Previous work by Towns (Hensiek et al., 2017; Hensiek et al., 2016; Towns et al., 2015) as well as our own work (Hennah & Seery, 2017; Seery et al., 2017), have reported the use of digital badges to accredit individual experimental skills. Once students achieved a pass grade (3/5 in the rubric) for a technique, they were issued with a digital badge in each of the relevant techniques (Figure 4). In our VLE (Blackboard), these are called achievements, and the system can be automatically set up so that achievements are released once a core score has been obtained (in our case 3/5). Students in the early years of implementation had the option to push these badges from the VLE to an external environment for hosting badges (such as the Open Badges backpack, backpack.openbadges.org). The purpose of such websites is to allow learners accumulate badges from a variety of educational scenarios in one place. However, changes to the architecture underpinning this badge transfer as a result of the Mozilla Foundation divesting from Open Badges has meant that the link from Blackboard to external sites was not operational in the last two years. However, students still receive their badges within the VLE.

**Implications and Adaptability**

We have implemented laboratory competency activities at large scale to groups of ~150 students in Year 1 and ~120 students in Year 2 undergraduate chemistry courses. After several years of implementation, some core considerations for others wishing to adopt this approach in their own practice have been compiled:

- **Preparatory materials**: at the heart of our approach is the provision of preparatory materials to students, and in our case we relied on videos. These take some time to develop, but given the extent of their usage, it is worth while taking the time to prepare them to a high standard. In our case we secured some small grants for university teaching and learning activities to fund summer interns, but there is also the opportunity to find interested postgraduate students, etc., who may be keen to work on activities that help them with their Associate Fellowship of Higher Education application or similar. In our work, students preferred videos over reading materials, and videos recorded in the laboratory that they will be working in maximised the opportunity for advance preparation.
• Working with stakeholders: running undergraduate laboratories involve a lot of stakeholders, and it is important to work with course organisers in advance of implementation so that laboratory manuals can be developed, as well as laboratory technicians to help prepare documentation for technical development and confirm any breaks in the rules regarding mobile phones in the laboratory. The approach described in this chapter is outside the norm for typical university departments, and will need to be actively championed by whoever wishes to implement it.

• Training: if the laboratory runs with the assistance of postgraduate demonstrators, training will need to be included in their initial briefings to help them help with the implementation of this approach. This involves explaining how the process works, managing students in the laboratory as they complete the task, and explaining how the assessment process works. These demonstrators will understandably be concerned with workload, especially of assessment, and in our case rubrics were useful to help assuage those concerns. Correctly implemented, demonstrators will likely be the biggest advocates, as they know more than most about the need to develop students’ experimental skills!

• Troubleshooting: Common queries and issues arise in our implementation. The first is the situation where a student does not want to be recorded. As part of our training, demonstrators are told to be encouraging of students in their ability to do the demonstration, but that if there is any indication that the student does not want to complete the activity for any personal reason, they do not have to do so, and instead the activity becomes one of demonstrating competency to the demonstrator rather than by recording. In our case, after implementing with several hundred students, only one known case of this has arisen. A second issue is unfortunately more common – students submit videos which are have been set to private status and therefore cannot be viewed. It is important that however you encourage students to submit videos, you give clear guidance on making sure that the video is visible for the purposes of assessment, and that they can change the settings or remove the video after assessment. We have been proactively prepared with phone chargers, etc. for troubleshooting technical issues in laboratory classes, but in our experience, students tend to sort out any of these issues on their own.

Limitations
The approach described has worked relatively smoothly in our institution for the last three years. It does require the dedication of one laboratory session where students complete the competency activity in place of a traditional laboratory exercise. Demonstrator training and the alternative approach for assessment do need some consideration, as this is outside the normal practice of teaching and assessment that demonstrators will be used to. It also requires resource to develop the preparatory materials, but some appropriate generic resources may be available through other sources, such as the RSC practical section on Learn Chemistry (RSC, no date).

Conclusions
The assessment of laboratory skills by video, utilizing exemplar videos to prepare students in advance of their activity worked well in our application for both simple glassware techniques and instrumental techniques. We found evidence that our approach led to improvements in experimental competency, and in students’ perceptions of their knowledge, confidence, and experience of experimental techniques. Students felt confident about their levels of preparation, but as the technique being demonstrated becomes more complicated for them, careful thought is needed on how best to ensure they feel
prepared about the task. However, even in that scenario, the central goal of enabling students to develop competency that they feel they can draw on in future tasks was achieved.

**Supplementary Information**

Supplementary information referred to in this chapter is available at: overtonfestschrift.wordpress.com.

**Acknowledgements**

We acknowledge Prof Marcy Towns and her colleagues for their workshop on digital badging and experimental assessment at Biennial Conference in Chemical Education (BCCE) in 2016 as well as her publications cited here — these were invaluable in encouraging us to make the leap to using this kind of assessment. We acknowledge the University of Edinburgh’s Principal’s Teaching Award Scheme and the Principal’s Career Development Scholarships scheme which supported this work.

**References**


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