Lessons learned from implementing blended and online undergraduate chemistry laboratory teaching during the Covid-19 pandemic

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In March 2020, the Covid-19 pandemic led to unprecedented circumstances which impacted significantly on Higher Education. Since that time, requirements for social distancing and reduced access to in-lab teaching facilities have meant a dramatic redesign of many Chemistry undergraduate laboratory courses. This chapter presents the lessons learned from the redevelopment of the 2020-2021 first-year chemistry undergraduate laboratory course at Durham University. The two pre-existing laboratory modules were converted from their traditional in-lab delivery (supported by online pre- and post-lab activities) to a blended delivery module and a fully online module. The blended module focused on the key manipulative skills students need to gain competence in to progress successfully to second year laboratory work. The fully online module focused on scientific enquiry skills. This chapter presents practical and theoretical considerations for the development of blended or online laboratory courses before discussing lessons learned from the evaluation of the process of implementing the course and the impact for students.

Introduction

In March 2020, the Covid-19 pandemic forced a change to the way that undergraduate laboratory courses were taught. Although this was not a strategically planned change, it nevertheless presented an opportunity for rethinking and redeveloping laboratory teaching using different modes of delivery (Table 1), which otherwise may have not been possible.

However, the situation presented by Covid-19 also produced several challenges: 1) that students had not applied for their degree courses expecting to undertake laboratory work remotely 2) that the time for planning and redeveloping materials by course instructors was limited and 3) that the learning objectives for the course could not be changed as these are agreed significantly in advance of the timeframe which was available for redevelopment.

The approach taken for the first year Chemistry undergraduate laboratory course at Durham University was to rethink which key aspects of the course required in-person "hands-on" laboratory time and which could be effectively taught online. The changes were subsequently evaluated to understand the impact for students and staff.

In this chapter we present an overview of evidence in the literature to support the decision-making for the course redevelopment, followed by a detailed description of the design of the new course, evidence from the evaluation, concluding with lessons learned and challenges for the future of laboratory teaching.

Table 1: Definitions for the modes of laboratory delivery

Mode of delivery	*Definition for this chapter*
Distance/remote Learning (DL)	An approach to teaching and learning in which there is a physical, and often psychological, separation between students and instructors. [1]
Online learning (OL)	Learning experiences in synchronous or asynchronous environments using different devices (e.g., mobile phones, laptops, etc.) with internet access. [2]
Blended learning (BL)	The combination of in-person and online learning activities. [3]

Considerations for the design of laboratory courses

The following section summarises factors for consideration in course design, split into three areas:

1) Identifying learning objectives
2) Creating an environment for meaningful learning
3) Understanding student progress

1) Identifying learning objectives

The focus of in-person laboratory work has traditionally been on the development of psychomotor skills (i.e. hands-on manipulation of equipment, instruments and chemicals). [4] In the UK, the Quality Assurance Agency (QAA) and Royal Society of Chemistry (RSC) have outlined benchmark standards which detail the levels of competence expected for holders of chemistry degrees. [5] Pre-Covid-19, the RSC accreditation guidance required that "Students must develop a range of practical skills" and included reference to a typical time requirement of 400 hours of in-lab time for an integrated Masters degree, with 300 hours for a BSc[6], with little specific detail about the exact types of skills which must be covered by the course. The guidance was then interpreted by course designers to identify the key areas and competences that were to be addressed within modules. Table 2 shows the subdivision of chemistry practical work competences into three skill groups to support implementation within laboratory courses.

Due to the unprecedented situation created by Covid-19, the RSC issued updated guidance in September 2020 related to the requirements for laboratory work during the pandemic, stating that online resources could be used to ensure that students are still exposed to a wide range of practical techniques, where in-lab work is not possible. [7] The existing guidance on number of hours of in-lab time was also no longer considered a feasible requirement and flexibility would be used by accreditation panels, with a focus on the skills students obtained and not solely the lab hours. The specific skills were not described.

Table 2. Subdivision of chemistry practical work competences

Skill type	*Definition*	*Further division*
Hard	Skills related to the technical aspects to undertake tasks, often taking into account the acquisition of knowledge. [8] Usually highly specific, hands-on skills (e.g. using apparatus).	Psychomotor skills (manipulative) Procedural skills (having the knowledge to successfully use certain techniques and implement them) General laboratory skills (e.g. knowing how to act safely in a laboratory)
Soft	Relate to the "behaviours that promote the formation of skills applied to acquire knowledge and then disseminate what is obtained". [9] Subject knowledge is required for these skills but they are often more subjective than hard skills in the way they are assessed and are usually developed rather than taught.	Data-use skills Enquiry-based skills Communicating science skills.
Transferrable	Skills which go beyond the laboratory and can be utilised in a range of different fields. Often defined as "the interpersonal, human, people, or behavioural skills needed to apply technical skills and knowledge"[10] (e.g. organisational, communication and self-motivation skills). [11]	

2) Creating an environment for meaningful learning

For meaningful learning to occur in the undergraduate chemistry laboratory, psychomotor experiences should be assimilated with the cognitive and affective domains, i.e. manipulative skills should be combined with the "thinking behind" and "feeling of" doing science. [12] An example of a task that could promote the "thinking behind the doing" could be asking students to deduce and explain why reagents must be added in a specific order to prevent the formation of unwanted byproducts during a synthesis. This task accompanies the in-lab activity, where the synthesis is carried out.

Opportunities should be provided for students to relate new knowledge to relevant concepts and propositions. [13]

Consideration of several factors have been shown to facilitate a meaningful learning environment.

- *Interactions* (Figure 1) - Key to learning being achieved through interactions is the bidirectional flow of information. Online social interactions may be synchronous, when communication takes place instantaneously (e.g. live chat and videoconferencing) or asynchronous via delayed communication (e.g. discussion boards and email). [14]
- *Attitude* - Attitude is comprised of three components: behavioural, cognitive and affective components. [15] Recent research has indicated that students consider online learning to be the least effective and least enjoyable method of learning, and can lead to lower affective student attitudes. [16]
- *Self-efficacy* – This is a student's judgement of their own capability[17], developed by four main sources of influence: mastery experiences, vicarious experiences, social persuasion and emotional states. [18-19]
- *Confidence* – A student's feeling of assuredness and lack of anxiety when completing laboratory activities. [20] Pre-laboratory activities (including the use of videos, quizzes, simulations and exercises) have been reported to increase students' confidence in completing practical activities. [21-24]

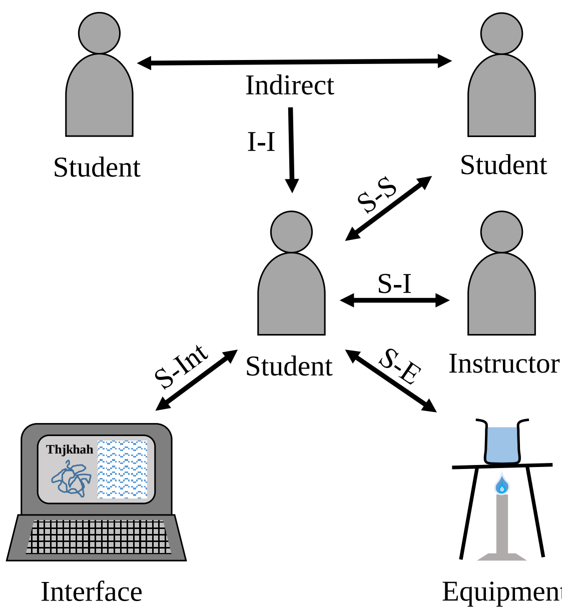

Figure 1. Summary of student interactions in a chemistry laboratory including students engaging with other people (student-student, S-S or student-instructor, S-I), with equipment (student–equipment, S-E) and indirect interactions (I-I) e.g. overhearing conversations of others. [25] Student-interface interactions (S-Int) are distinctive to distance learning[26] and use technology to mediate interactions between students, instructors and content.

3) Understanding student progress

Effective laboratory work requires links between:

1. the laboratory task (i.e. what students are intended to do) and laboratory actions (i.e. what students actually do)
2. the laboratory objectives (i.e. what students are intended to learn) and the laboratory learning (i.e. what students actually learn).

These can be evidenced through whether a student both finishes the task *and* whether they fulfil the stated key learning outcomes. [27]

The redeveloped first-year undergraduate chemistry laboratory course at Durham University

Pre-Covid, the Practical Chemistry 1A (P1A) and Practical Chemistry 1B (P1B) first year modules at Durham University were run as in-lab practical chemistry courses with online support (via the Virtual Learning Environment, VLE) both before and after each laboratory session. In some institutions the VLE may be referred to as the Learning Management System (LME). VLE will be used to refer to both in this chapter. The modules ran over two 10-week terms.

Due to social distancing requirements in the 2020/21 academic year reducing the number of students able to be in the lab at the same time from 60 to 18, the course was redesigned so that the two modules focused on different skills and were delivered via different methods. The aim of the redeveloped lab course was to achieve the same learning outcomes as the pre-Covid course, using implementation methods which were compliant with Covid-19 restrictions.

P1A was redeveloped as a blended laboratory module with alternating complementary in-lab sessions and online activities. The redesigned module focused on covering the key manipulative 'hard' skills students would need to gain competence to progress successfully to second year laboratory work, with the online component complementing this by delivering the related key procedural 'hard' and 'soft' skills (Figure 2). Students were scheduled to attend an in-lab session every fortnight (reduced one session per week prior to Covid-19) and online exercises and activities in the week in-between. Due to further Covid-19 restrictions, students were only able to undertake a maximum of three out of the planned nine P1A in-lab sessions and the remainder moved to online activities.

P1B was redeveloped to be delivered entirely online and focused on procedural 'hard' skills, 'soft' skills (including scientific enquiry skills using data sets for analysis, theoretical situations and experimental planning activities), and 'transferable' skills.

By the end of the course in March 2021, P1A students were expected to have completed three in-lab and 12 online activities and P1B students to have completed 16 online activities.

The aim and design of the redeveloped lab course

Given the lack of access to the lab, the development of hands-on, manipulative 'hard' skills was restricted. The goal of the online activities was to enable students to focus on the 'thinking behind the doing' (i.e. how, when and why different skills are used) until they could be in the lab to practice them along with analysing data and completing the usual 'out-of-lab' aspects of the course. The aim was to reduce the cognitive load on students when they were able to undertake work in the laboratory. The limited in-lab sessions aimed to allow students to experience as many of the manipulative skills covered in the course as possible. Figure 2 shows the structure and timeline of the P1A and P1B modules.

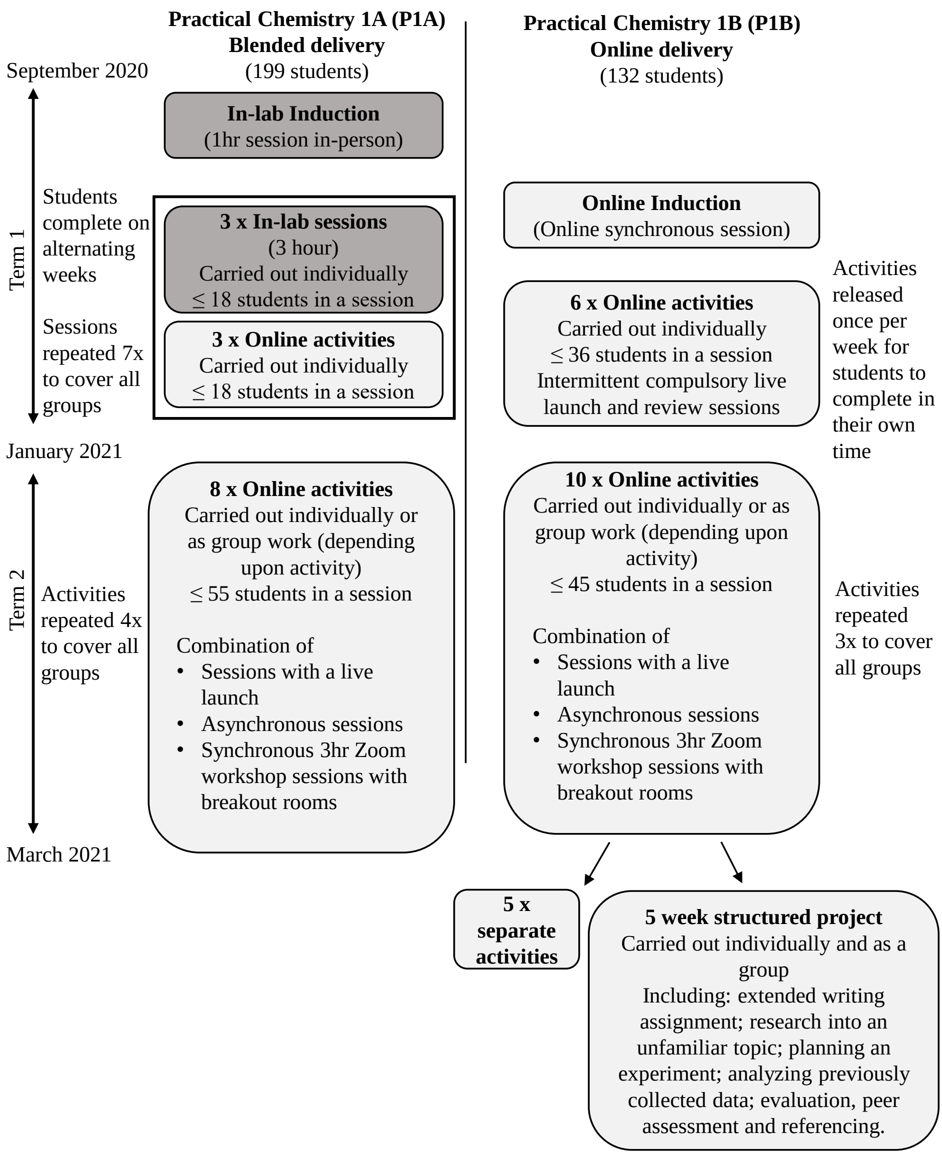

Figure 2. Structure of the P1A and P1B modules, including in-lab sessions in dark grey and online activities in light grey.

When working online, P1A students were encouraged to undertake their work during their timetabled session for the module, however, they could choose to complete the work flexibly at a time which best suited them during the two-week timeframe for the activity. Zoom breakout room workshops were introduced to both P1A and P1B in term 2 to facilitate interaction between students, as well as synchronous interaction with teaching staff. The workshop sessions were designed to provide students with the opportunity to form social work groups as well as academic support. Breakout room groups were randomly allocated so students met new peers each time. Figure 3 shows the materials, resources and support arrangements for the in-lab and online activities.

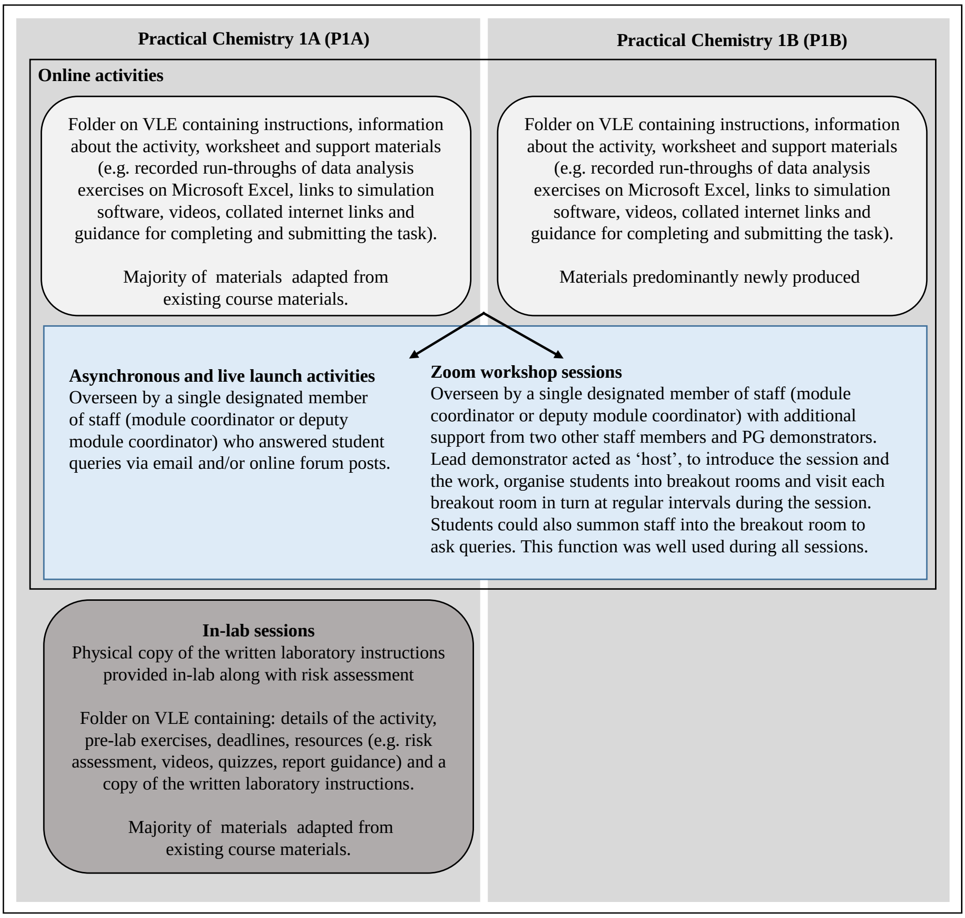

Figure 3. Materials, resources and support arrangements for the P1A in-lab and online activities and P1B online activities.

Where possible, feedback was collected over the duration of the course from students and staff (including the course coordinator, demonstrators and advisors) and was used to update and adapt course materials and delivery. Adaptions included the introduction of the Zoom workshops to tackle student complaints of feeling isolated or not knowing anyone on their course. Adaptions also had to be made to ensure compliance with changing restrictions due to Covid-19.

Method

Data were collected across three research studies (Table 3) to understand both the context of the incoming first year chemistry undergraduate cohort in October 2020 and to evaluate the skills development and experiences of students in their laboratory modules at the end of term 1. One Zoom workshop had been held at the point of data collection for study 2 and 3.

Table 3. Research studies with the 2020/21 first year undergraduate chemistry cohort

Study	*Method*	*Cohort*	*No. of participants taking part in the study*
Study 1	Survey 1 (Sept 2020)	210 students	103 (49%)
Study 2	Survey 2 (Jan/Feb 2021)	199 students (45.2% female, 54.8% male)	122 students (61% response rate) (49.5% female, 48.5% male, 1.8% prefer not to say)
	Semi-structured interviews (Feb 2021)	Volunteers through the survey	9 students (5 male, 4 female)
	Semi-structured interview (Feb 2021)	Course coordinator	1 member of staff
Study 3	Survey 3 – students and demonstrators (Jan/Feb 2021)	199 students (45.2% female, 54.8% male)	86 students (43% response rate) (52% female, 44% male, 3% prefer not to say)
		16 demonstrators	8 demonstrators (50% response rate) (63% female, 25% male, 13% prefer not to say)

Results

Successful completion of work and meeting learning outcomes

Of the 86 (43%) students responding to survey 3 relating to the P1A module, 45% strongly agreed that they had successfully completed their in-lab work, with 36% somewhat agreeing. The figure was less for P1A online activities, with 21% strongly agreeing and 55% somewhat agreeing that they had successfully completed their work. Module marks were not available at the time of data collection due to covid-related assessment timeline changes.

Interactions

Students were asked to report on the frequency with which they participated in a specified set of interactions in the in-lab and online activities (Table 4). A distinct difference was seen between communication with the demonstrator between the in-lab sessions and online activities (survey 3). When asked about materials for supporting their learning (survey 2), 34% of students found the videos for both the in-lab and online activities very useful.

The students predominantly worked individually for the in-lab and online activities in term 1. Twenty-three percent of respondents (survey 3) reported they had not completed any online activities with another student or group of students (data were collected prior to students attending the Zoom workshop sessions).

Table 4. Interactions which the greatest percentage of students carried out more than three times per in-lab or online session.

Interaction	*% respondents reporting carrying out interaction more than 3 times per session*
In-lab sessions	
Reading the written instructions	64%
Talking to a demonstrator about lab equipment	31%
Talking to a demonstrator about lab procedures	31%
Online activities	
Observing or listening to a video from a demonstrator providing guidance on the lab task	45%
Observing or listening to a video demonstration of how to do a lab technique	43%
Using the internet to look up information about the lab task	43%
Online activity lowest %: Communicating with a demonstrator about the task instructions, general guidance on the task, scientific concepts, equipment or techniques or data analysis	≤2%

All the demonstrators that responded to survey 3 reported that they were more likely to initiate interactions with students first in an in-lab context than the students initiating the contact. However, the result was split 50:50 in the online context, with half saying that they would wait for students to initiate the interaction. The four respondents who said that they would wait for the student to initiate the interaction first in the online context had all been demonstrating for more than three years.

Attitudes

Respondents to survey 2 rated on a scale of 1 to 5 how they felt about in-lab and online activities (Figure 4). A significant difference was observed between students' perceptions as to how worthwhile in-lab and online activities were. Eighty percent 80% of respondents gave a score of 5 (worthwhile) for in-lab sessions compared to only 17% for online activities. No respondents rated online activities as being at the top of the scale for excitement, compared to 37% for in-lab.

Respondents in study 2 expressed that they felt they were missing out on developing 'practical' skills due to undertaking fewer in-lab sessions than they had been expecting when they applied for their degree course. Participants also indicated that they were worried that they would be unprepared for future years of study due to the loss of in-lab time. The respondents did not consider that online activities replaced their expectations of the skills they would have developed within an in-lab session.

> *"I just don't think that a practical course can be replaced with something that's not practical... Actually putting acid in the flask and watching something happening and doing something, it's just you can't compare."*

Respondents enjoyed in-lab activities as they considered that it gave them the opportunity to gain hands-on practical experience. This met with their expectations for a chemistry degree.

At the start of the second term, online simulations were introduced to the course. Students' attitudes were mixed towards the introduction of the simulations with some enjoying these and others not seeing how they helped to develop lab skills.

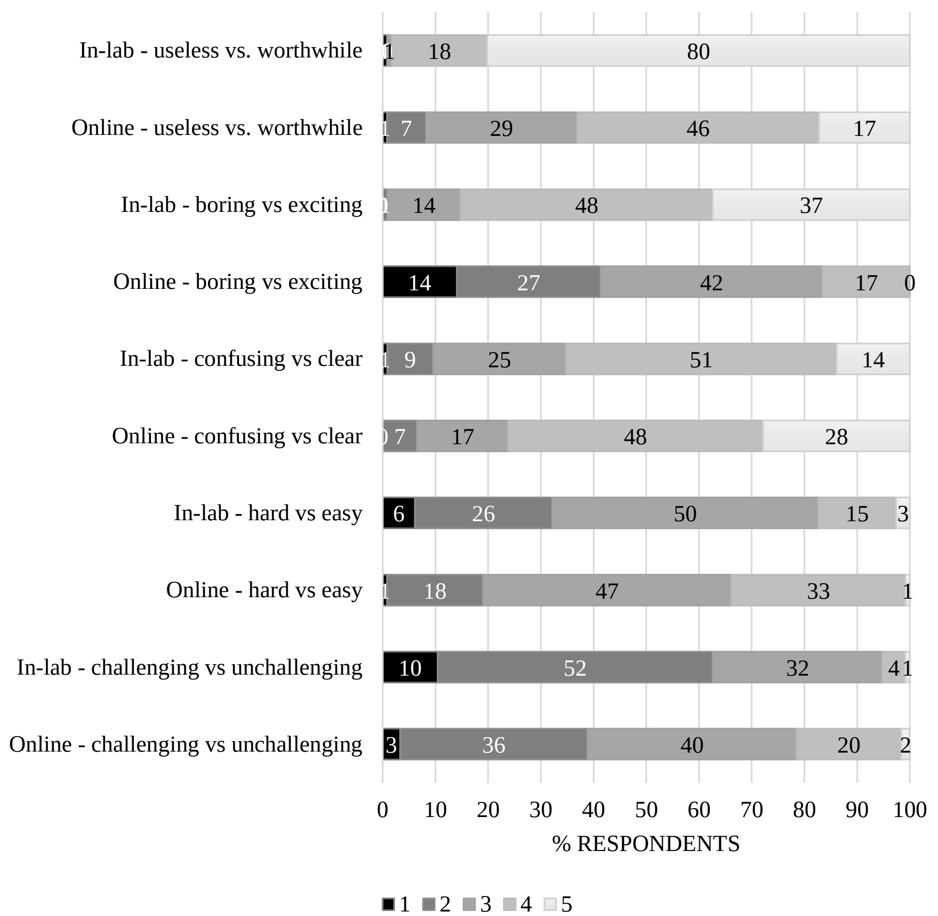

Figure 4. Percentage of respondents choosing ratings from 1 to 5 for their perceptions about in-lab and online activities (1 = leftmost description to 5 = rightmost description e.g. 1 – useless, 5 – worthwhile, n = 115 – 122)

Self-efficacy and confidence

Respondents to survey 2 reported that the online activities typically took longer to complete (Table 5), however, it should be noted that pre- and post-lab activities were not included in the time for in-lab sessions. Only 8% of respondents completed all the online activities in the time-tabled slot, with 28% reporting that they had never completed them in this time slot.

Table 5. Time taken to complete in-lab and online sessions. (n = 112 in-lab, n = 114 online)

Mode	*Time to complete session*	*% respondents*
In-lab	1 – 2 hours 2 – 3 hours	15 85
Online	1 – 2 hours 2 – 3 hours 3 – 5 hours	26 54 19

Feedback from the course coordinator indicated that in order for the students to effectively engage with the online lab course, the students had to understand how to use the VLE, had to ensure that they checked the weekly schedule at the start of each week and read emails and announcements. These time management and organisation skills were essential for effective engagement with the course.

Table 6 shows the skills (from a specified list of 32 skills) which more than 60% of respondents to survey 2 indicated that they could carry out well and which they were confident in undertaking after the first term of teaching (indicated by selecting the highest rating of 5). A strong correlation was observed ($r = 0.973$, $p<0.001$) between how well students considered they could carry out the 32 skills and how confident they were.

Table 6. The skills which more than 60% of respondents to survey 2 gave the highest score of 5 for ability or confidence. The survey contained a list of 32 specified skills for students to provide a rating of 1 (lowest) to 5 (highest) for their self-assessed ability and confidence. (n = 101 – 104)

Skill	*Type of skill*	*How well (%)*	*How confident (%)*
Using a top-pan balance	Manipulative	83	80
Washing glassware	Manipulative	69	67
Using Microsoft Excel to calculate the mean of a dataset	Soft	68	62
Using appropriately sized measuring cylinders to measure volumes	Procedural	65	55
Using cell references in Microsoft Excel	Soft	63	62
Using Microsoft Excel to calculate the standard deviation of a dataset	Soft	60	50
Using formula in Microsoft Excel	Soft	56	64

Zoom workshops

At the time of the interviews in study 2, when participants had completed one online Zoom workshop, they considered the group work that had been introduced through this method had overcome some of the challenges faced by completing online activities independently. The students particularly liked the opportunity to get to know others on their course, and that they were able to discuss thoughts and ideas with other students. It also reduced their sense of being alone.

However, some students commented that not all students participated equally in the workshop sessions and that conversation could be dominated by a small number of individuals. They suggested that the lack of social cues relating to when other students were going to speak and taking time to become comfortable sharing ideas may have impacted. Having the same group of students in a breakout room group in each session, rather than changing groups each time, was suggested as a way to overcome this. Feedback from staff indicated that some students were extremely anxious about attending the Zoom workshops. Accommodations were therefore made so that students could attend only the introduction to the session with camera and microphone off and then leave to complete the session individually, rather than in a group with other students.

The course coordinator commented that when they “dropped into” the breakout rooms in the Zoom workshops, the students asked more questions than they typically did in pre-Covid in-lab sessions. They postulated that this may have been due to the online interface feeling less intimidating than asking questions in person in the lab.

What worked well?

The flexibility of being able to work at their own pace, in their own time, so long as they submitted within the deadlines, was considered to be a particular benefit of the online activities by students. The clarity of instructions was also commented as having been particularly good. Respondents considered that they had been taught a range of different skills in the online laboratory activities and that these skills that were not always developed as well in the in-lab environment.

Challenges and barriers

Technological Difficulties

Twenty-five percent of respondents to survey 2 reported experiencing technical difficulties, with issues with internet connection affecting their ability to complete online activities. The course coordinator reported that managing the Zoom workshops was made more difficult by students having connectivity issues. This was disruptive to discussions between the staff ‘host’ and the other student groups in the breakout rooms as the member of staff had to leave to re-admit the students with the lost connection to the Zoom session and then re-allocate them to their breakout rooms. There had also been connectivity issues for the course coordinator which disrupted one synchronous session.

Impacts of the Covid-19 pandemic

Participants in study 2 reported feeling ‘isolated’ when completing both in-lab and online activities due to social distancing requirements, including the requirement to wear face masks in the in-lab sessions. The requirement for social distancing since the beginning of their time at university meant that students felt that they knew few peers on their course and felt like it was harder to interact with other students both in-lab and online. This also impacted on how confident they felt being able to ask for help. The course coordinator had noted that they had not received much informal feedback from students during the activities and that the online environment had made gauging how students were feeling, by observing their body language and via informal chat, very difficult. They reflected that they had not realised until this year that this was something they relied upon so heavily for feedback.

In addition to restricting social interaction, Covid-19 also led to a lower frequency of revisiting skills; in many cases it had only been possible to cover material once during the course.

Support

A consequence of the sense of isolation and not getting to know staff or other students was that some respondents in study 2 found it difficult to ask peers and staff for help. Thirty-seven percent of respondents did not ask anyone for help when completing online activities. Of that group, 43% stated that they didn’t ask anyone for help because they did not feel comfortable asking for help and 21% stated that they didn’t ask because they did not know how to get in contact with someone.

> *‘So it's just … where to go for like help if you need it? …[Y]ou can ask on the discussion board which is good because it's anonymous but then it’s waiting for the reply and then you may have to ask another question and the follow up to that. And it's just difficult if you don't really understand what's going on.’*

From a staff perspective, the online activities required significantly more input than in-lab sessions, which were predominantly supported within the scheduled session time with support from a technician. For online activities, each weekly cycle required the course coordinator to undertake: the design and writing of the activity and assessment guidance instructions, producing videos/quizzes/assignments, proofreading, collating resourcing, uploading to the VLE, monitoring engagement, training PGs to mark the assignments, returning marks to students and providing feedback. Support for students undertaking the online activities was provided via emails, discussion board posts (outside scheduled session times) along with some synchronous sessions repeated four times per week (P1A) and three times per week (P1B). The number of students commenting on the anonymous discussion board had been less than expected by the course coordinator.

Discussion and conclusion

The data collected evaluating the implementation of the blended (P1A) and online (P1B) laboratory modules have provided several useful insights for future development of online or blended teaching.

Student attitudes towards online laboratory teaching

The redeveloped course was carefully designed to retain the learning objectives of the traditional laboratory course whilst separating out the elements that required hands-on experience and those that could be taught effectively outside the laboratory. However, what is clear from the student responses, is that students' did not perceive this to be providing them with an 'authentic' practical chemistry experience. Students' perceptions of what was required in practical work highlighted that they did not consider 'soft' skills (e.g. data use, enquiry based skills) and procedural 'hard' skills to be worthwhile unless they were carried out at the same time as the manipulative and general laboratory 'hard' skills within the laboratory environment. Attempts to manage students' expectations and understanding of the design of the course in the induction session did not stop the students considering the online activities to be less worthwhile than the in-lab sessions. It was, however, interesting to observe that the skills which students reported feeling most able and most confident in by the end of term 1 were predominantly soft and procedural skills, despite these having been taught in the online activities, which they considered to be less worthwhile than the in-lab sessions. The students did note that the range of skills which the online activities had covered had been broad and that the in-lab sessions were not always able to cover the skills which had been targeted in the online activities.

Successful completion of work (as perceived by the students) was reported to be higher for in-lab than online activities. Further evaluation is required to identify whether their perceived completion of tasks matches their assessment scores for the learning objectives for the course.

Flexibility offered by online activities

Students found the flexibility in scheduling their work for the online activities to be beneficial. However this introduced challenges in ensuring all students attended the correct live sessions and required a significant investment of time using multiple modes of communication by the course coordinator to ensure attendance at the correct sessions. Attendance in live online sessions improved through the course, but it was clear some students were confused about the requirements due to the variety in structure each week.

Interactions

A key challenge presented by Covid-19 was the social distancing requirement for students both within and outside the laboratory. Within the lab, it significantly impacted on students' communication with demonstrators due to maintaining 2-metre separation and

PPE requirements. Online, students were impacted as they did not feel they knew their peers or staff well enough to feel comfortable asking for help. In the online activities, communication with the demonstrator was significantly less than in the laboratory sessions, with only 2% of students reporting that they communicated with a demonstrator more than three times per activity. Staff were also less likely to initiate contact in the online activities compared to in the lab. Online videos from the demonstrator providing guidance or demonstrating techniques were much more widely engaged with, as was use of the internet for information gathering. The interaction which the highest proportion of students undertook most frequently in both the in-lab and online sessions was reading the written instructions.

Although social distancing is potentially unique to the Covid-19 pandemic for in-lab sessions, there are still important lessons to draw for future online or blended learning courses. Providing opportunities for students to get to know one another and staff at the start of the course (e.g. through ice-breaker activities within induction sessions), facilitating interactions between students (e.g. through group work and Zoom workshops) and staff initiating interactions with students (rather than waiting for students to ask for help) can aid in creating a more effective learning environment, helping students feel less isolated, more connected with their peers and supported by staff. In turn, this may help to improve students' satisfaction with the course, as providing more social support may help students to engage in help-seeking behaviours, which may improve their perceptions of self-efficacy.

There are still some challenges to address for implementation of the Zoom workshops. Firstly, how to encourage participation from all students and to prevent domination of conversation by a small number of individuals. Secondly, how to ensure that students that lack social confidence or that find interaction with strangers challenging do not feel excluded or anxious in facilitated group work sessions. One solution may be to offer an option of a 'quiet' room within the Zoom workshop where people can work alone, with camera and microphone off, but still be able to seek help if needed. It is also important to ensure that the student and staff induction sessions introduce the concept of diversity of personalities and supports how they should aim to be understanding and inclusive in their own actions and behaviors within sessions.

Elements to retain in future courses

Emerging from the pandemic, much of the new approach will be kept. The explicit separation of training in manipulative skills (in the lab) and procedural and soft skills (online) will continue, integrated into coherent activities. Pre- and post-lab will be focused on the soft and procedural skills directly, with related manipulative skills covered in the lab. This could include online independent or group work activities probing the 'thinking behind the doing' related to the manipulative skills. Future laboratory course timetabling might consider including online-only sessions alongside the in-laboratory sessions, to give students structure in their online study and to allow for synchronous teaching sessions to support the online study. These could continue to use the successful Zoom breakout room model.

Adaptions for future implementation

Anticipated adaptations to the course content are expected to include more detailed instructions in the induction on the use of the VLE and the skills that the course aims to develop. The perception of the value of the online activities may be clearer to students if the distinction between, and value of, the manipulative, procedural and soft skills is made more explicit in the induction. Expanded training for demonstrators will also emphasise the aims of the course and include the importance and relevance of the online activities as well as the in-lab work.

Integrating ongoing evaluation activities into the course structure will also be carefully considered. Planning in time to periodically collect information from staff and students and to reflect during the course on what is working well, the challenges in implementation, how different groups of students are responding to the course and where adaptions can be made has been extremely beneficial and should not be lost.

Consideration will also be given to the collection of informal feedback about student attitudes and experiences throughout the course. The online activities reduced the opportunity to gauge students' facial expressions and body language. This social interaction between student and teacher is key to developing effective teaching and learning as well as ensuring student wellbeing, therefore it is essential to find a mechanism through which this can be re-established for the online environment.

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