# The impact of COVID-19 on practical work for incoming first year undergraduate Chemistry students at Durham University


## Chapman Hau



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Supervisor: Dr Helen Cramman

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# INTRODUCTION

## Background

Schools and higher education (HE) are facing unprecedented challenges from the continued disruption to teaching and learning during the COVID-19 pandemic. 'Normal' resumption of teaching will not occur before October 2020, and the following academic year will be affected by social distancing measures and previous missed teaching time (Savage, 2020). The transition to remote learning has presented particular challenges for practical work in schools (Fox et al., 2020). Practical work is defined as "a learning activity in which students observe, investigate and develop an understanding of the world around them, through direct, hands-on, experience of phenomena or manipulating real objects and materials" (SCORE, 2013). This means that demonstrations, simulations and online experiments will not be considered as practical work in this research project. Drawing from a survey sent to incoming first year undergraduate chemistry students at Durham University, this project will report on the impact of COVID-19 on practical work in schools. When considering impact we are concerned with the impact on the provision of practical work in schools and students' preparedness for Chemistry laboratory courses on entry to university. Preliminary findings from this project will be the first step in a larger project to understand the changes to school practice for practical work and the impact of the school closures on the quantity and type of practical work occurring. Findings will also be used to inform HE staff responsible for laboratory courses on the impact of COVID-19 on practical work for incoming first year chemistry students.

Advanced levels (A level) are Post-16 subject-based qualifications that are common prerequisites for entry to university. A levels are generally worked towards over two years. As part of the reformed A level Science qualifications, students obtain a practical endorsement if they have completed a minimum of 12 required practical activities and meet the Common Practical Assessment Criteria (CPAC) (Table 1 and 2). The CPAC consists of key practical skills that students must consistently and routinely meet in order to obtain the practical endorsement. Students who demonstrate the required standard across all the requirements of the CPAC receive a 'pass' grade (i.e. practical endorsement). Students are also expected to use their knowledge of practical work in written examinations, which accounts for at least 15% of the marks (Table 3). The UK government issued guidance on 20th March 2020 that schools were to be closed for all students except those with a guardian classed as a key worker or for vulnerable children (Department for Education, 2020). Those students remaining in school were not expected to follow normal classroom teaching.  School closures has had a particular impact on science due to the requirement of practical work. For example, teachers were unable to set standard secondary school science activities due to the absence of specialist equipment/chemicals and health and safety issues (CLEAPSS, 2020).

According to a cross-board statement from UK examination boards, most Year 13 students will have completed the minimum of 12 practical activities before school closures occurred, and so will have been assessed on all of the CPAC statements. As such, the impact of COVID-19 on practical work of these students should be minimal and obtaining the practical endorsement is still possible. However, some students will have incomplete practical work. Whilst practical endorsement can still be obtained by considering evidence of the CPAC on all previous practical work, we are more concerned about the impact on students missing out on practical work they would have otherwise completed. Moreover, some schools complete intensive practical courses in April or May to meet practical requirements, and so some students would not have completed any practical work due to school closures. In this case, students cannot obtain a practical endorsement. For these students who have very limited practical work, the impact of school closures on practical work will be substantial. This issue of disparity between students with varying levels of practical work experience has not yet be quantified, and so it is highly desirable to determine the impact that COVID-19 has had on the provision of practical work. This is important because the student's experience of practical work will affect their preparedness on entry to a science undergraduate degree. A recent study found that HE staff held the view that undergraduates are not well prepared with regards to practical skills on entry to university (Cramman et al., 2019). It is likely that COVID-19 will exacerbate this perception, resulting in potential impact in undergraduate laboratory courses. Findings from this research can therefore inform HE staff responsible for practical courses on possible mitigations if students are entering university with a wide range of practical work experience. For example, students with little practical work experience may require more support.

One recent study found that almost half of examination-year students in Year 13 were not provided with work by their school (NFER, 2020). The cancellation of A level examinations due to COVID-19 will have likely resulted in the lack of set work for Year 13 students (Ofqual, 2020). As such, many students will have missed opportunities to consolidate their knowledge through revision that would otherwise take place during the April and May. At least 15% of the overall assessment of A level Chemistry assesses knowledge, skills and understanding in relation to practical work. These examinations often assess procedural skills (e.g. solving problems set in practical contexts) that refer to 'the thinking behind the doing', differing from skills necessary for undertaking a non-written task (e.g. using a microscope) (Abraham and Reiss, 2015). These examinations therefore assess practical skills that are fundamental in laboratory work. Missing opportunities to learn and review these important skills could therefore be detrimental in the development of vital practical skills. On progression to laboratory courses at university, students may therefore find it challenging to carry out practical work. Moreover, some students will have disengaged from practical work for up to six months. On entry to university, students may find it challenging to adapt to practical work, especially in a new setting. This research project will therefore determine students' prior experience of practical work and practical skills.

**Table 1:** A level Chemistry required practical activities.

| Required practical activity |
|---|
| Make up a volumetric solution and carry out a simple acid-base titration |
| Measurement of an enthalpy change |
| Investigation of how the rate of a reaction changes with temperature |
| Carry out simple test-tube reactions to identify cations and anions |
| Distillation of a product from a reaction |
| Tests for alcohol, aldehyde, alkene and carboxylic acid |
| Measuring the rate of reaction by an initial rate method and continuous monitoring method |
| Measuring the EMF of an electrochemical cell |
| Investigate how pH changes when a strong/weak acid reacts with a strong/weak base |
| Preparation of a pure organic solid/liquid |
| Carry out simple test-tube reactions to identify transition metal ions |
| Separation of species by thin-layer chromatography. |

**Table 2:** A level Chemistry Common Practical Assessment Criteria (CPAC).

| CPAC | Requirements |
|---|---|
| Follows written instructions | Follow a set of written instructions, carry out steps in the correct order, generate an expected set of data, work independently, and feel confident to seek clarification. |
| Applies investigative approaches and methods when using instruments and equipment | Select the most appropriate apparatus, use ICT, work methodically, demonstrate 'multi-tasking', and consider apparatus that will support the collection of accurate data. |
| Safely uses a range of practical equipment and materials | Identify hazards/risks, demonstrate confidence in handling equipment/materials, deal with incidents effectively, be aware of personal work space, amend method steps to improve safety and wear safety goggles/clothing. |
| Makes and records observations | Design a data table, choose appropriate ranges for data collection, collect data at specific points to enable a pattern to be identified, present data to the correct number of significant figures and take an appropriate number of repeats. |
| Researches, references and reports | Write a short and concise report, give enough detail that work is repeatable, process data using software/tools and present calculations logically, research ideas linked to the scientific knowledge and use an appropriate referencing style. |

**Table 3:** Assessed practical skills in written A level Chemistry examination papers (accounting for at least 15% of A level Chemistry).

| Key competence | Requirements |
|---|---|
| Independent thinking | Solve problems set in practical contexts and apply scientific knowledge to practical contexts. |
| Use and application of scientific methods and practices | Comment on experimental design and evaluate scientific methods, present data in appropriate ways, evaluate results and draw conclusions with reference to measurement uncertainties and errors, and identify variables including those that must be controlled. |
| Application of mathematical concepts in a practical context | Plot and interpret graphs, process and analyse data using appropriate mathematical skills and consider margins of error, accuracy and precision of data. |
| Instruments and equipment | Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques. |

## Research Questions

**What has been the impact of COVID-19 on practical work for incoming first year undergraduate Chemistry students at Durham University?**

This separates into two research questions:

Research question 1: What has been the impact of COVID-19 on the provision of practical work for incoming first year undergraduate Chemistry students at Durham University?

Research question 2: What has been the impact of COVID-19 on students' preparedness for laboratory courses for incoming first year undergraduate Chemistry students at Durham University?

Practical work will be defined as "a learning activity in which students observe, investigate and develop an understanding of the world around them, through direct, hands-on, experience of phenomena or manipulating real objects and materials" (SCORE, 2013). This means that we are only concerned with hands-on practical work, i.e. not including demonstrations, online simulations or online experiments.

# RESEARCH METHODS

## Data collection techniques

The instrument used to investigate the research questions was an online survey with a selection of incoming first year undergraduate Chemistry students (academic year 2020/21) at Durham University. The study was conducted under Durham University's guidelines for empirical research involving human subjects. These guidelines adhere to those of the British Educational Research Association (2011). The project was approved by Durham University School of Education Ethics Committee. Data are password-protected and held securely. No individuals participating in the study are identified. Participation in the study was voluntary and respondents were free to withdraw at any time.

The study assesses the impact of COVID-19 on practical work on incoming first year Chemistry undergraduate students at Durham University via an online survey. The survey also acts as a practical skills audit and participants were encouraged to download a summary of their answers so that, if they wished, they could discuss it with their laboratory supervisor on arrival to university. The survey was sent to all incoming first year Chemistry students at Durham University during September 2020. The timing of the survey was set so as not to leave it too long that key insights were missed whilst they were still at the forefront of the mind, and allow students to reflect on their practical skills via the survey before they started their laboratory courses at university in October 2020.

Survey questions were designed to answer the research questions. Questions included those to elicit information on students' completion of various practical activities, preparedness of various practical skills and amount of revision of chemistry content completed during and after school closures. These questions were used to ascertain the impact of COVID-19 on practical work for incoming first year Chemistry undergraduate students at Durham University.

## Data analysis techniques

Survey data was transferred from Jisc Online Surveys into the Jamovi statistical package for analysis. Data analysis began at the stated deadline on the information sheet presented to respondents (although survey was kept live for a further week so that respondents could still complete a practical skills audit for their benefit). At the time of data analysis, there was 103 respondents (approximately 50% of all incoming first year Chemistry students) Each question was related to the research questions and used to answer these questions. Following analysis on Jamovi, the data file was interrogated to Excel to generate the reported data.

There were only four response from students that were not from the United Kingdom. However, all these students still completed A level Chemistry, so these responses were not excluded during data analysis. Due to the small sample size for these students it was not possible to determine if there were any differences in findings compared to students from the United Kingdom. There were also only four responses that did not complete A level Chemistry. These responses were excluded from data analysis, and so findings only reflect the impact of COVID-19 on practical work for students who have completed A level Chemistry (i.e. findings may differ for students completing other Post-16 qualifications).

# FINDINGS AND DISCUSSION

## What has been the impact of COVID-19 on the provision of practical work for incoming first year undergraduate Chemistry students at Durham University?

Figure 1 shows that 57% of participants had finished all Chemistry practical work planned by their school before school closures due to COVID-19. This suggests that the majority of incoming first year Chemistry students are starting their undergraduate laboratory courses having completed the A level Chemistry practical work requirements (i.e. at least completing a minimum of 12 required practical activities). However, 28% of participants had not finished their Chemistry practical work as planned by their school, indicating that a significant proportion of participants will enter university with missed practical experience. These findings quantify the cross-board statement released by the examination boards regarding the practical endorsement, which claimed that "most Year 13 students will have completed the minimum of 12 practical activities" (Cross-board Statement, 2020). It is not possible to determine from the responses how much practical work was omitted due to COVID-19 by those that answered that they did not finish all practical work planned by their school. Moreover, there is the potential issue that students will be entering university with varying amounts of practical experience, a pre-existing issue that is likely exacerbated by the school closures. Therefore, undergraduate laboratory courses will need to mitigate this problem by aiming to get every student to the same level of practical competence.

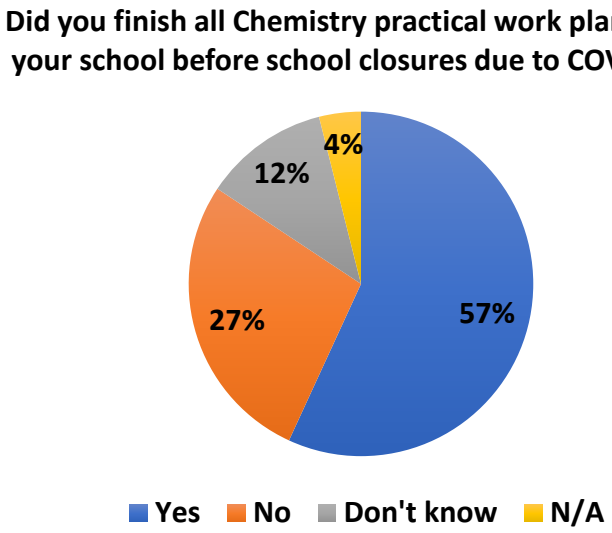


**Figure 1:** Pie chart showing how many respondents had finished all Chemistry practical work as planned by their school before school closures due to COVID-19. Respondents that answered "N/A" were those that did not attend school for the academic year 2019/20 (e.g. those that completed a gap year).

Participants were also asked when was the last hands-on practical activity that they carried out (i.e. not including demonstrations, computer simulations or online experiments), as shown in Figure 2. For most participants, the last hands-on practical activity was completed in March 2020. This means that, come October 2020 when students begin their undergraduate laboratory courses, many students will not have engaged with practical work for possibly more than six months. Starting laboratory work at university may therefore prove challenging for many students, especially as it is in a new educational setting. Hence, university laboratory courses may need to provide additional support for students. More concerning, 14% of respondents last completed hands-on practical activity before 2020, making it more than a year since these students have completed any hands-on practical work at all. It is important to note that the question asked did not consider demonstrations, computer simulations or online experiments, which some students might have completed.

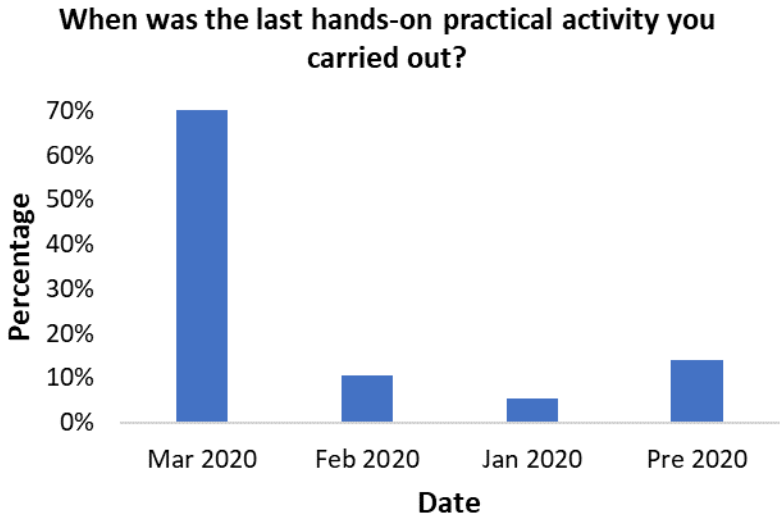


**Figure 2:** Bar chart showing when was the last hands-on practical activity (not including demonstrations computer simulations or online experiments) that participants last carried out.

Figure 3 shows how much school-guided and self-guided revision of Chemistry content participants completed. The majority of participants completed no school-guided revision of Chemistry content during April 2020 – July 2020 (i.e. from school closures to the end of the academic year). This is consistent with a recent study that showed that almost half the parents of Year 13s reported that the school was not providing school work to do at home (UKHLS, 2020). The cancellation of examinations will have played a major part in the absence of school-guided revision of Chemistry content for these students. Students did not need to complete further work to obtain their Post-16 qualifications as these were awarded based on teacher assessment and other inputs instead. Typically, students would have spent April – July revising for their examinations, which would seem pointless in the absence of examinations. This could have potential implications on students' preparedness for a Chemistry degree, as students would have missed opportunities to learn some content and consolidate their Chemistry knowledge through revision.

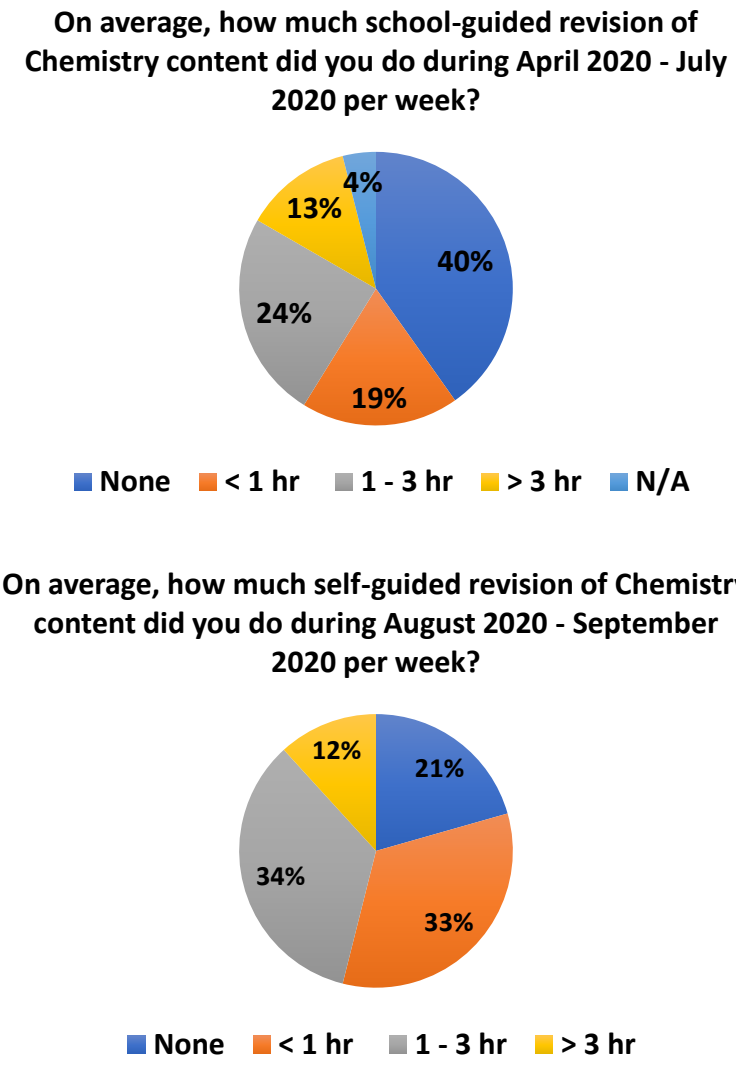


**Figure 3:** Pie charts showing how much school-guided and self-guided revision of Chemistry content participants completed during April 2020 – July 2020 (from school closures to end of academic year) and August 2020 – September 2020 (summer vacation), respectively.

Furthermore, at least 15% of the overall assessment of A level Chemistry assesses knowledge, skills and understanding in relation to practical work. These examinations often assess procedural skills (e.g. solving problems set in practical contexts) that refer to 'the thinking behind the doing', differing from skills necessary for undertaking a non-written task (e.g. using a microscope) (Abraham and Reiss, 2015). These examinations therefore assess practical skills that are fundamental in laboratory work. Missing opportunities to learn and review these important skills could therefore be detrimental in the development of vital practical skills. It is concerning that 21% of participants completed no self-guided revision of Chemistry content during August 2020 – September 2020, indicating that these students have not reviewed any practical skills during the summer vacation period. However, 79% of participants did complete at revision of Chemistry content, but it is not possible to determine if this revision involved reviewing practical skills.

Figure 4 shows a list of practical activities that participants either undertook in a laboratory, observed in a demonstration, undertook using an online experiment or have not encountered at all. These practical activities were selected based on the required practical activities that students are to complete as part of their A level Chemistry course. The majority of participants had completed the practical activities in a laboratory. If students had not completed the practical activity in a laboratory, then they have at least seen it in a demonstration or online experiment. Practical activities that had relatively high participants answering "never undertaken or seen practical activity at all" were usually those that required specialised laboratory equipment, for example, weighing mass of solids using an analytical balance.

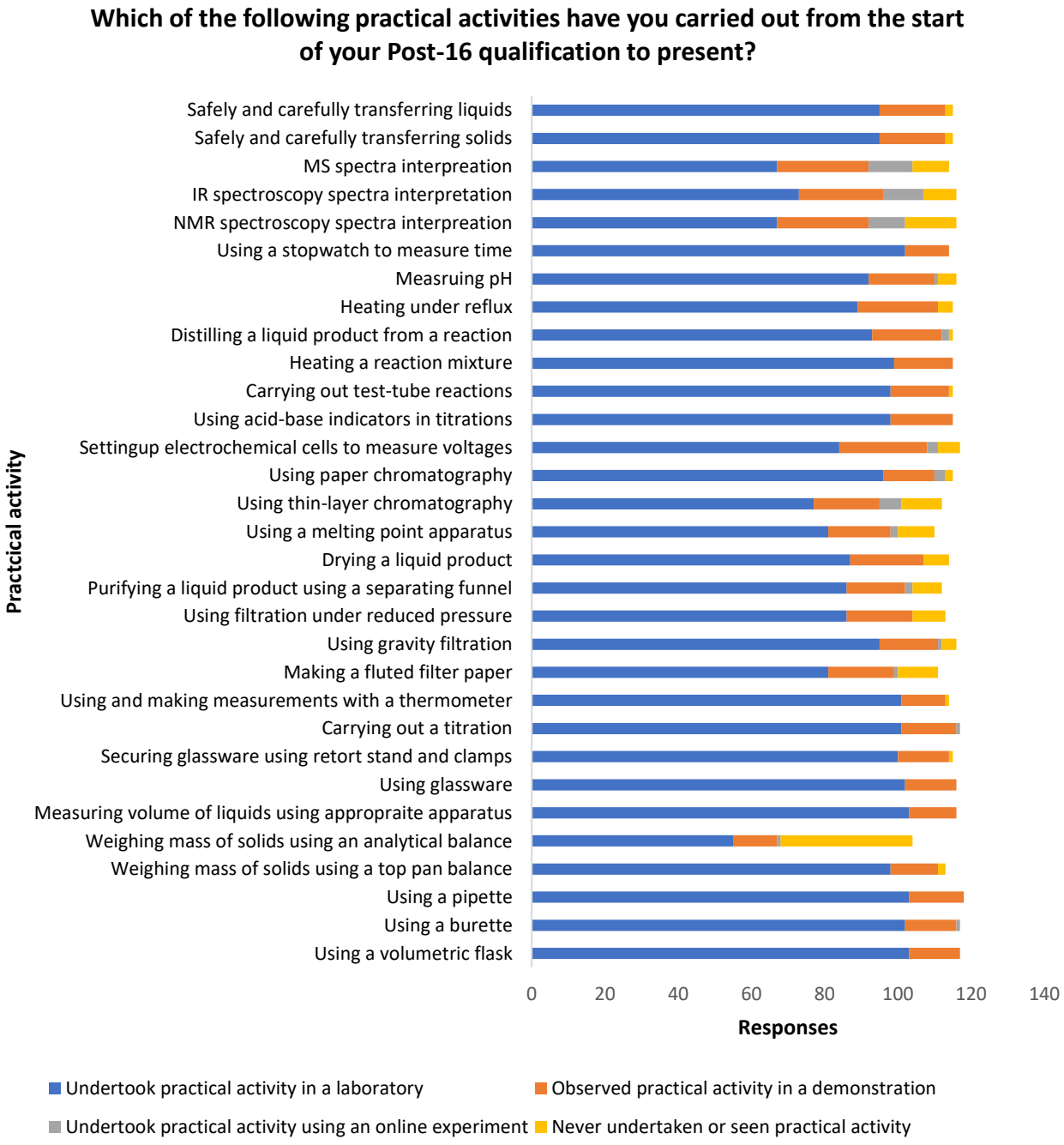


**Figure 4:** Stacked bar chart showing practical activities that participants undertook in a laboratory, observed in a demonstration, undertook using an online experiment or never undertaken or seen at all.

## What has been the impact of COVID-19 on students' preparedness for laboratory courses for incoming first year undergraduate Chemistry students at Durham University?

Participants were provided with a set of practical skills and asked how well prepared they felt for using these practical skills when they start university. Practical skills were divided into three sets. Figure 5 shows the practical skills that are featured in the A level Chemistry required practical activities. For example, one of the required practical activities is to make up a volumetric solution, within which students would encounter practical skills such as using a pipette or burette. Hence, these practical skills focus on an individual's competency in the manipulation of a particular piece of apparatus/equipment (i.e. hands-on practical skills). Figure 6 lists the practical skills that are assessed in the A level CPAC requirements, which students are meant to consistently and routinely meet over the course of their A level Chemistry course in order to obtain a practical endorsement. Finally, Figure 7 shows practical skills that are assessed in A level Chemistry written examination papers. These practical skills assess conceptual and procedural understanding, meaning a "knowledge base of substantive concepts" and "the thinking behind the doing of science", respectively (Abraham and Reiss, 2015). For example, consider the practical activity of carrying out a titration. The procedural understanding might entail knowing how to evaluate how accurate the measured titre are. The conceptual understanding might be to understand how the titre can be used to calculate the concentration of a solution. Procedural and conceptual practical skills differ from hands-on practical skills, such as the act of performing a titration itself.

Figure 5 highlights that for all practical skills listed the majority of participants were very well prepared or somewhat prepared for using these practical skills when they start university. There is also a direct correlation between the amount of preparation and if students had completed the practicals hand-on in a laboratory (Figure 4). For practical activities that had more respondents completing hands-on in a laboratory, the more respondents that were either very well prepared or somewhat prepared for using these practical skills when they start university. This is expected as students are more likely to develop confidence and competence in practical skills that they have undertaken themselves in a laboratory. For example, fewer participants answered that they were either very well prepared or somewhat prepared for weighing mass of solids using an analytical balance, which also parallels the relatively low amount of participants that carried out the practical hands-on in a laboratory. As a result, this practical activity had the largest proportion of participants answering that they were not at all prepared for using this skill when they start university. Therefore, more attention may be needed on these practical skills when students start their undergraduate laboratory courses that have higher responses answering somewhat prepared or not at all prepared.

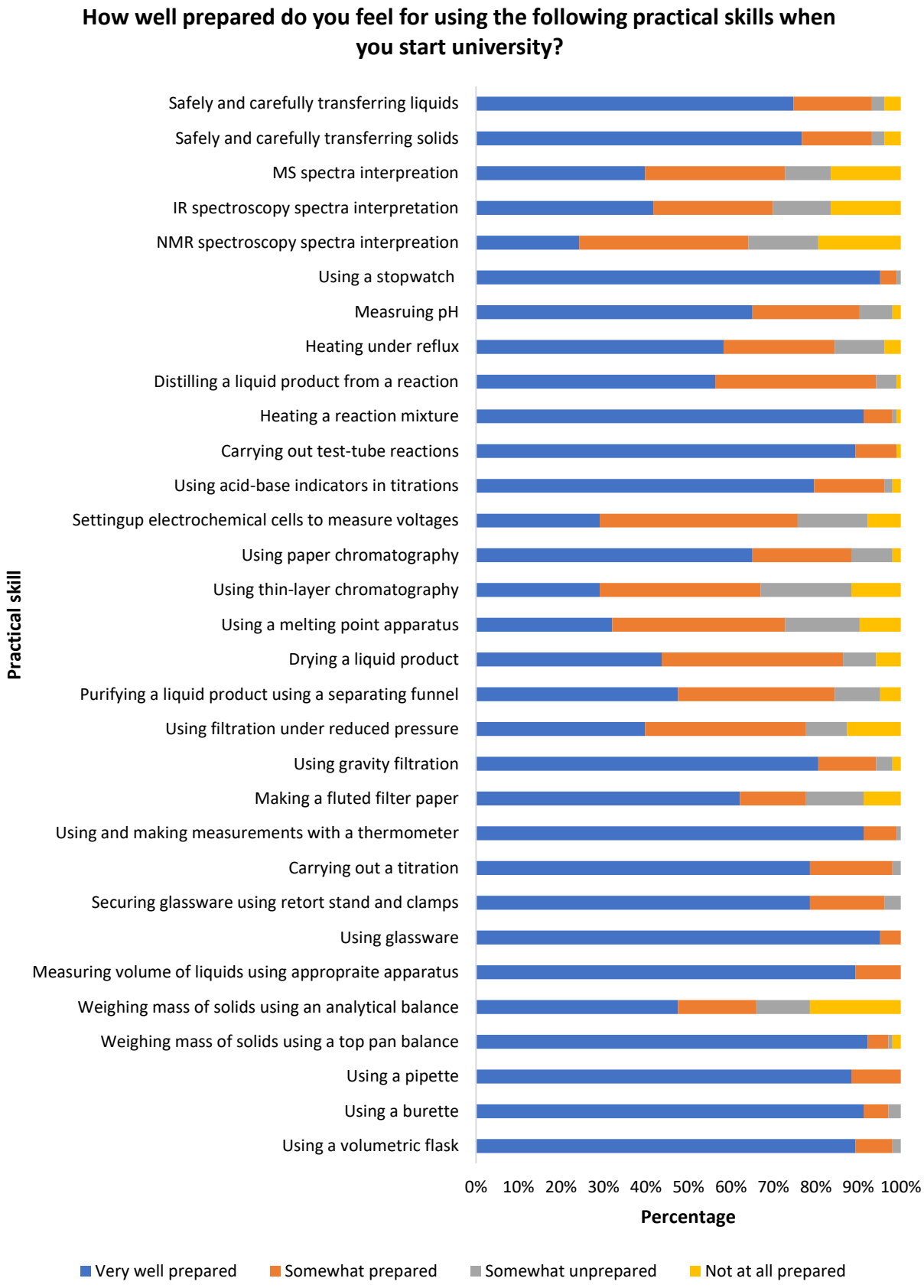


**Figure 5:** Stacked bar chart showing responses to how well prepared students felt for using a set of practical skills when they start university. These practical skills form the A level Chemistry required practical activities.

Figure 6 shows the practical skills that are featured in the A level Chemistry CPAC requirements that students are expected to consistently and routinely demonstrate in order to obtain the practical endorsement. Students were most prepared for following a set of instructions with 94% of respondents answering that they were very well prepared. This is expected as most laboratory work conducted at A level consists of students following written instructions with few opportunities for open-ended and extended investigations (Cramman et al., 2019). The majority of students also felt either very well prepared or somewhat prepared in working safely in a laboratory, making and recording observations and using laboratory equipment. However, using IT tools to analyse data and writing science reports had a higher proportion of respondents that felt that they were either somewhat unprepared or not at all prepared. Hence, more support may need to be provided in these areas when students begin their undergraduate laboratory courses. There are significant differences between preparedness between the CPAC practical skills, which might suggest that schools do not provide equal weighting to the CPAC requirements. For example, students might be expected to follow a set of instructions in every practical activity they complete, but may only write science reports for a few selected practical activities. It is important to note that it is not possible to know if students have obtain the practical endorsement by consistently and routinely meeting the CPAC requirements, since this was not probed in the survey.

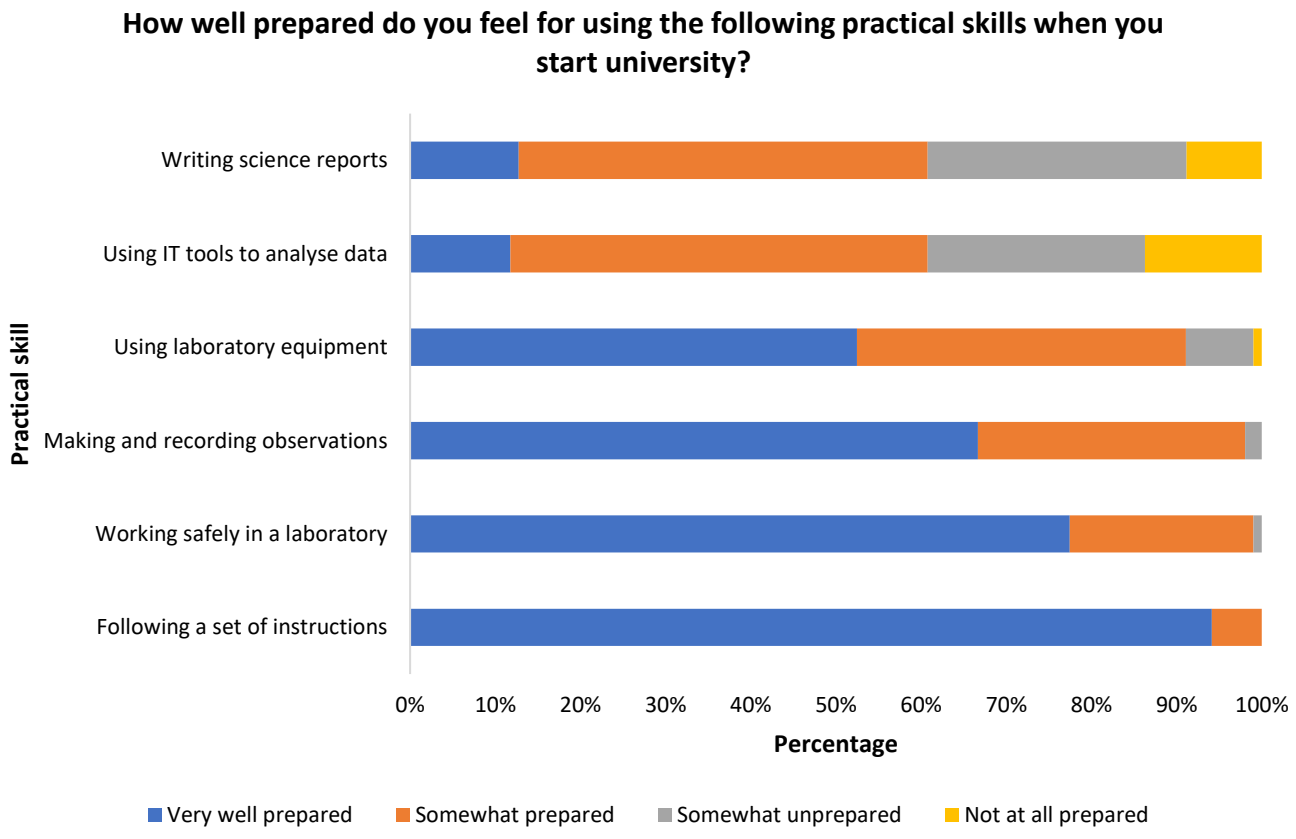


**Figure 6:** Stacked bar chart showing responses to how well prepared students felt for using a set of practical skills when they start university. These practical skills form the A level Chemistry CPAC requirements.

The final set of practical skills feature in written examination papers, assessing procedural and conceptual understandings of practical work, as shown in Figure 7. The majority of students answered that they were either very well prepared or somewhat prepared for using these practical skills when they start university. Students were most prepared at applying scientific knowledge to practical contexts. Practical skills are tested throughout each examination paper that A level Chemistry students take (accounting for at least 15% of the marks), so students will be well equipped at applying scientific knowledge to practical contexts. Students were also well prepared in identifying variables, plotting and interpreting graphs in practical contexts, and solving problems independently in practical contexts. However, a higher proportion of students were not prepared at considering margins of error, accuracy and precision of data and commenting on experimental design and scientific methods. These two practical skills may be considered more demanding as students are evaluating data and scientific methods. This can be explained using Dale's learning pyramid, which represents a continuum of cognitive complexity (Dale, 1969). The ability to evaluate requires much higher cognitive complexity, compared to the ability to apply. This provides insight into why students felt more prepared at practical skills requiring them to apply their knowledge to practical contexts compared to those that require students to evaluate practical work.

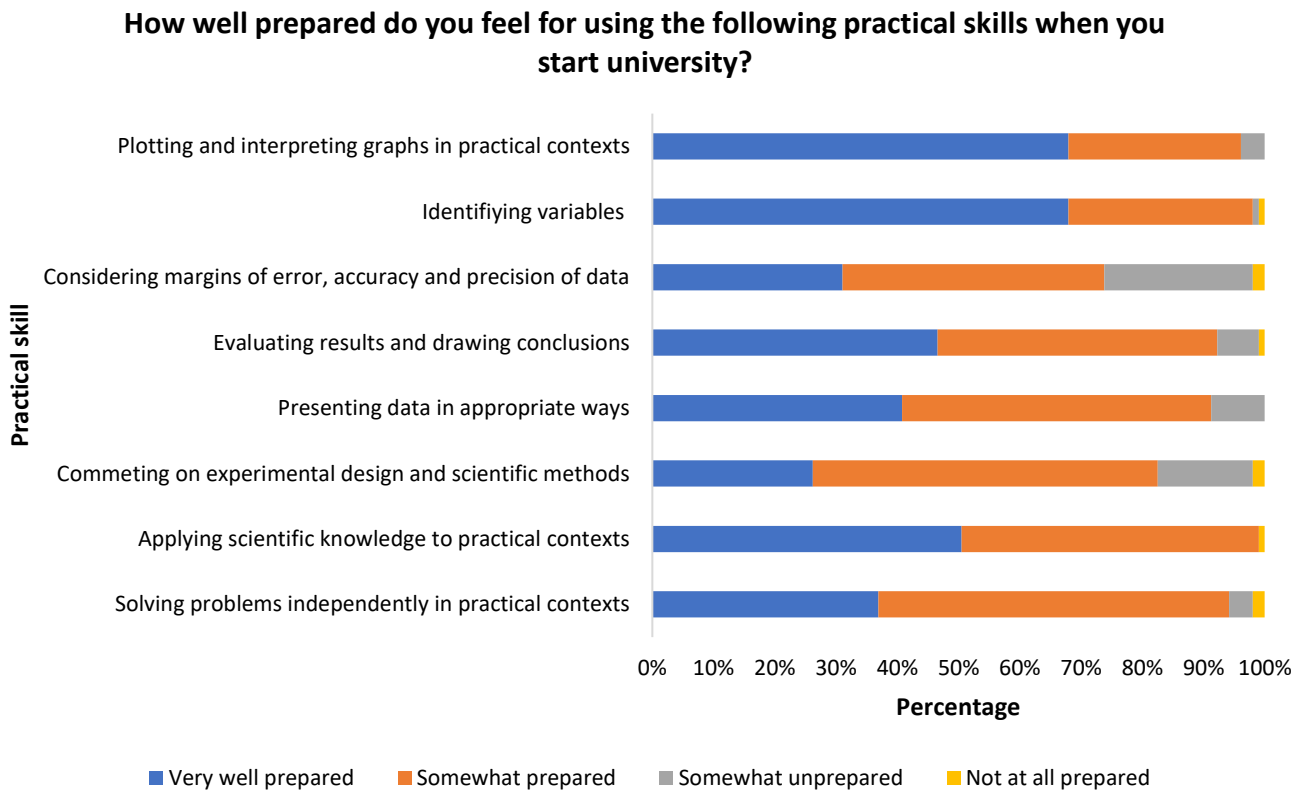


**Figure 7:** Stacked bar chart showing responses to how well prepared students felt for using a set of practical skills when they start university. These practical skills are assessed in A level Chemistry written examinations, accounting for at least 15% of the marks.

# CONCLUSIONS

## Conclusions to the research questions

Research question 1

Research question 1 is concerned with the impact of COVID-19 on the provision of practical work for incoming first year undergraduate Chemistry students at Durham University. We have quantified the impact of school closures on practical work, whereby the majority of students reported that their school had indeed finished all practical work planned by their school. However, a significant proportion of students did not finish all practical work. These quantitative results are consistent with the qualitative statements made in the Cross-board Statement. All respondents had not completed any hands-on practical work for more than six months. This would usually be the case as most schools would finished planned practical work before the examination period (i.e. before April 2020). However, the impact of school closures may have resulted in unfinished practical work that might have otherwise took place beyond March 2020, resulting in no students undertaking hands-on practical work beyond March 2020. The majority of students received no school-guided revision of Chemistry content during April 2020 – July 2020, likely due to A level examinations being cancelled. Most students had completed some self-guided revision of Chemistry content, but it is not possible to determine if revision covered practical work. Most students had completed all the A level required practical activities in a laboratory with the exception of weighing mass of solids using an analytical balance, which had a large proportion of students that had never undertaken or seen the practical activity at all.

Research question 2

Research question 2 is concerned with the impact of COVID-19 on students' preparedness for laboratory courses for incoming first year undergraduate Chemistry students at Durham University. The majority of students were either very well prepared or somewhat prepared for using the practical skills that feature in the A level required practical activities. In general, students' preparedness for these practical skills paralleled if they had completed the practical activities themselves in a laboratory. There was more variance in students' preparedness for practical skills that feature in the A level CPAC requirements. The majority of students were either very well prepared or somewhat prepared at following a set of instructions, working safely in a laboratory, making and recording observations and using laboratory equipment. There is a higher proportion of students that were either somewhat unprepared or not at all prepared at writing science reports or using IT tools to analyse data. The majority of students were also either very well prepared or somewhat prepared at using practicals skills that are tested in written examinations. There is a significant difference in students' preparedness of practical skills that involve applying and evaluation with students feeling less prepared for the latter.

## Limitations

Due to time constraints and deadlines, data analysis was completed with 103 responses, but the survey was kept online till October 2020. At the time of closing the survey, there was more than 120 responses. However, the 103 responses accounted for over 90% of responses, so it is most likely that these responses were representative of all responses. The survey was also not answered by every incoming first year Chemistry student at Durham University. The response rate was only approximately 50% of the total cohort of first year Chemistry students at Durham University. Furthermore, the majority of responses were from the United Kingdom with only four responses from international students. Only four respondents did not complete A level Chemistry, so it was not possible to make any conclusions regarding other Post-16 qualifications due to the small sample size. Hence, findings only apply to A level Chemistry and there may differences in findings with students that have completed other Post-16 qualifications.

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