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A Snapshot of Chemistry Teaching and Learning Practices in UK Higher Education as It Emerges from the COVID-19 Pandemic

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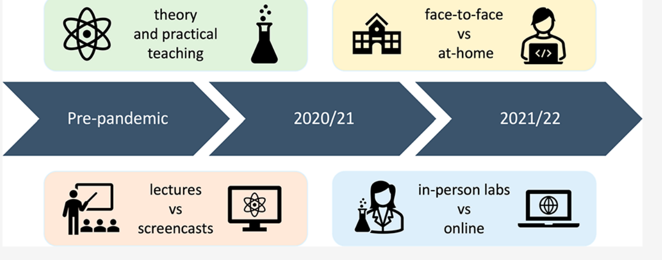
ABSTRACT: The start of the COVID-19 pandemic saw a change in the way chemistry education was delivered across the globe. As we emerge from the pandemic we can start to assess the medium to long-term impact it has had. In this study, we evaluated the teaching methods used by the UK Higher Education chemistry community over the past two years through the perspectives of students and instructors at UK institutions. We report how online and face-to-face teaching methods have evolved for both the teaching of chemical theory and practical work. We also present insights from instructors and students on how teaching through the pandemic has impacted their perception of students grades, knowledge, skills, and future plans.



KEYWORDS: *general public, first-year undergraduate/general, upper-division undergraduate, laboratory instruction, internet/web-based learning, distance learning/self instruction*

■ INTRODUCTION

The COVID-19 pandemic has caused unparalleled disruption to chemistry teaching and learning. With the need for governments to enact measures to contain the virus, institutions were required to pivot to online teaching at very short notice.[1] In the UK, the first wave of the virus coincided with the final few months of the higher education calendar, meaning a large proportion of teaching in the 2019/20 academic calendar was delivered using prepandemic methods. The 2020/21 academic year included an autumn and winter wave during which the UK Government mandated that all higher education courses, barring medicine and nursing, should be fully online in the first quarter of 2021. As vaccination rates increased in the country through the year, institutions could plan for more face-to-face teaching in the 2021/22 academic year, although still with measures to mitigate the spread of the virus.

This *Journal* has published a compendium of online teaching approaches used by instructors during the pandemic from March−August 2020.[2] The articles contained in the special issue *Teaching in the Time of COVID-19* largely covers moves to online teaching at the start of the pandemic.[2] Thereafter, there have been numerous reports of courses, experiments and other facets of a chemical degree delivered online through the past two years.

Perhaps it is no surprise that a large proportion of the chemical educational literature related to COVID-19 teaching covers the replacement of face-to-face laboratory courses with online alternatives.[3] These include asynchronous recordings of experiments,[4−12] synchronous viewing of experiments performed by an instructor in the laboratory,[11,13] being given sample data to analyze,[4−7,14−17] performing online simulations[18,19] and performing at-home experiments.[20] In a seminal review by Kelley, it was found that many of these approaches offered limited evidence about how effective they were as replacements for face-to-face laboratories.[3] The review focuses on reports with more robust data, and among them it was found that the evidence was unclear as to whether the replacements were better, worse, or the same as in-person experiments. Regardless of the type of instruction, students and instructors were overwhelmingly in favor of in-person laboratories.

For the teaching of chemical theory, there have been many examples of replacing the face-to-face experience with online alternatives. One of simplest pivots has been to replace in-person lectures with online synchronous delivery.[5,7,21,22] Prior to the pandemic some instructors have used asynchronous

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screencasts to deliver content, usually as part of a flipped approach.[23,24] Many instructors chose to deliver content through asynchronous videos during the pandemic, which students preferred due to increased flexibility over when they can learn content. Asynchronous videos were supplemented with interactive synchronous online classes. Some prepandemic precedent has been set with reports using technologies such as polling tools, but the pandemic has also led to instructors adopting new technologies such as online breakout rooms.[23]

Assessment has also been impacted by the pandemic.[25,26] There are fewer reports in the chemical literature that specifically address the impact on assessment due to COVID-19, but their approaches can in found within publications of teaching affected by the pandemic.[6−10,17,21] Traditional in-person exams have been replaced with remote alternatives such as open-book exams and online proctoring.[25] For laboratory courses, many were able to maintain assessment from laboratory reports, but some that were assessing hands-on skills in-person had to pivot online.[8,15]

Aims

As time passes, we can start to assess the medium to long-term effects that COVID-19 has had on chemistry teaching and learning. We wanted to gain insight into how teaching and learning of chemistry in the UK Higher Education sector had evolved during the pandemic years, and to learn which aspects of chemistry teaching were short-term fixes and what were the legacies from the online switch in early 2020. We also wanted to understand the impact on the perceptions of students' grades, skill development, and future career plans. If any parts of distanced learning were to remain in place, understanding what the advantages and disadvantages were would help instructors deliver high quality online learning in future. Thus, these are the aims of the study:

1. What methods of chemistry teaching and learning from the move online have been retained and what has returned to face-to-face in the UK Higher Education sector?
2. What are the perceived impacts of the pandemic on students' chemistry learning?
3. What did students and instructors perceive to be the advantages and disadvantages to distanced learning during this period?
4. What improvements could be made to deliver high quality distanced learning in the future based on these results?

■ METHODOLOGY

To achieve the aims of the study, two online surveys were developed through Google Forms; one for undergraduate students and one for chemistry instructors. The surveys used a combination of open answer, multiple choice, and Likert scale questions to collect both qualitative and quantitative information on experiences of distanced learning. Items for the survey were first created by the first author (Simmons) then reviewed and revised by the second author (Mistry). Items from the survey were then reviewed and revised further by two undergraduate students at the University of Leeds. Copies of the surveys can be found in the Supporting Information. Ethical approval to use these surveys for this study was granted by the institutional review board.

As the survey was designed for chemistry students and instructors in UK Higher Education, items were tailored for the way chemistry teaching and learning is delivered in the UK as directed the Quality Assurance Agency for UK Higher Education.[27] All students on chemistry or chemistry-related students will be majoring or exclusively studying within the subject. All students will study core physical, organic, and inorganic chemistry, and laboratory courses in their degree. Students on Joint Honors and Natural Science programs will also learn core chemistry theory and practical work albeit as smaller component of the degree. Therefore, the majority of students and instructors could answer survey items related to these aspects of chemistry teaching and learning.

All UK University webpages were reviewed to determine which ones offered chemistry or chemistry-related degrees. From this, 63 institutions were identified. For each department, the Director of Studies (or equivalent title), or a teaching-focused academic was contacted to request the survey's distribution among their students and instructors. Surveys were also distributed through Facebook groups created by the Royal Society of Chemistry for chemistry undergraduate students.

With both qualitative and quantitative data collected in this study, responses to different types of questions underwent differing analysis procedures. Open-ended questions were coded manually, then responses were categorized by recurring themes using the method of thematic analysis.[28] First codes were generated for the type of response and revisited until the codes were deemed robust. Then the codes were grouped together into themes. Both codes and themes were generated and checked by both authors for interrater reliability. Questions with quantitative responses or multiple-choice options were analyzed using SPSS, with statistical analyses to compare responses between academic years and type of institutions. All statistical analyses were run at the 95% confidence level, with Chi-Square tests used to compare results between nominal variables, Mann−Whitney U tests and Kruskal−Wallis tests used to compare results between ordinal and nominal variables, and Wilcoxon tests used to compare two ordinal variables.

Limitations

Control groups when studying the impacts of COVID-19 on chemistry education were not possible as the pandemic affected all educational institutions. To mitigate this, the surveys asked respondents to compare pandemic-affected learning in the 2020/21 and 2021/22 academic years to prepandemic learning for many questions. However, this does not show a direct comparison as students were at different stages in their studies.

To ensure participants' anonymity, data concerning disabilities, ethnicities, and similar categories which could put respondents at risk of identification and breach of anonymity were not collected. As a result, understanding how people of appropriate backgrounds were affected through distanced learning was more limited.

There could have been bias of responses in this study; the types of instructors and students who participated in this study were people more likely to have checked their emails, have sufficient time to complete these surveys, and have the motivation to complete these surveys. As such students and instructors who were less able or inclined to fill in these surveys may have had contrasting views and responses. With some few

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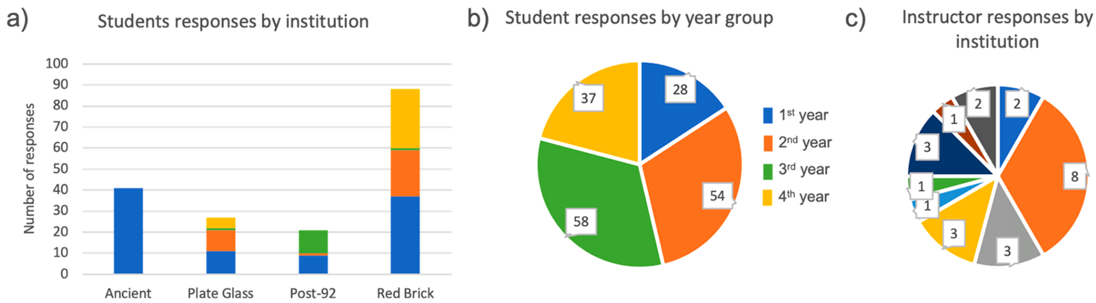

Figure 1. (a) Students' responses broken down by type of institution. (b) Students' responses broken down by year of study. (c) Instructors' responses broken down by institution.

or no responses from some institutions, it is possible that different results could have been obtained had more responses been received from institutions with low response rates.

RESULTS

211 responses were received for the student survey from 12 different institutions, of which 29 were either ineligible or not consenting to participate in the study, giving a final total of 177. The number of responses from each institution ranged from 1 to 41 students. 83% of students were studying for a Chemistry degree, 9% were studying applied chemistry degrees such as Medicinal or Analytical Chemistry, and 8% were studying on a Joint Honors or Natural Science degree with a chemistry major. To ensure that the results were not biased from institutions where the sample sizes were larger, we grouped responses together by the type of institution (Ancient, Red Brick, Plate Glass, and Post-92), as this was the type of commonality found in the institutions with small sample sizes (Figure 1a). Ancient institutions refer to the group of universities that were founded in the UK between 1096 and 1592; Red Brick institutions were given charters from the late 19th century to 1963; Plate Glass institutions between 1963 and 1992; Post-92 institutions were given royal charters after 1992. In the majority of cases, statistical analysis showed no difference between students by this type of institution, so for the purposes of this study, results of all students will be reported collectively except where statistical differences were found.

When analyzing responses by year group, it was found that there were reasonable numbers from each of the main year groups in a 3 year Bachelor's or 4 year integrated Master's degree program, albeit with more responses from second and third year students (Figure 1b). To ensure that our analysis only focused on HE experiences, results from first year students was omitted from our 2020/21 analysis and both first and second year responses were removed from prepandemic analysis. This resulted in N = 149 for the 2021/22 academic year and N = 95 for prepandemic data. Results from each academic year were normalized to a percentage so meaningful comparisons could be made. Statistical analysis was conducted for responses between each year. No difference for any item was found by year group; therefore, all results were analyzed collectively by year group.

A total of 24 eligible responses were received for the instructor survey from 9 institutions, 2 of which were different to the institutions given in the student responses (Figure 1c). This means that, collectively, there were 14 institutions represented between students and instructors. Instructors taught a wide range of chemistry subjects, with an average experience of teaching chemistry for 10−15 years. They were analyzed as one group, however it should be noted that 8 of the responses were from a single institution which may bias the results. In many cases instructor results were statistically similar to student results, and so only significant data from the instructor survey will be discussed in this report.

Theory Teaching and Learning

Students were asked to estimate the percentage of chemistry theory teaching that was online prepandemic, in the 2020/21, and in the 2021/22 academic year (Figure 2). While the

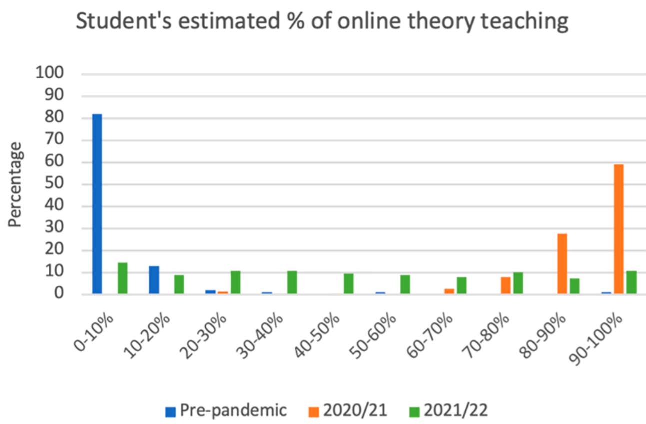

Figure 2. Percentage of online theory teaching prepandemic, in 2020/21, and 2021/22.

percentages are estimations by students, values close to 0 or 100% are likely to be quite accurate, and those values in the middle are mainly significant for indicating a mixture of online and face-to-face teaching. It was found that prepandemic the teaching of theory was mostly in-person. This shifted in the opposite direction in the height of the pandemic for the 2020/21 year which was either all or mostly online. In the 2021/22 academic year, there was much more variation. Some had returned 100% to in-person teaching, some had retained 100% online teaching, but the majority of students were experiencing a mixture of in-person and face-to-face teaching.

Students were asked to indicate the different modes of teaching they received for theory in the both the 2020/21 and 2021/22 academic years (Figure 3a). For the exam formats, students could answer if they were taking or online exams. Closed-book refers to students not being able to have notes or textbooks with them for the exam, whereas open-book means this was allowed. Here we saw statistical differences for the type of theory teaching students experienced by the type of institution they attended.

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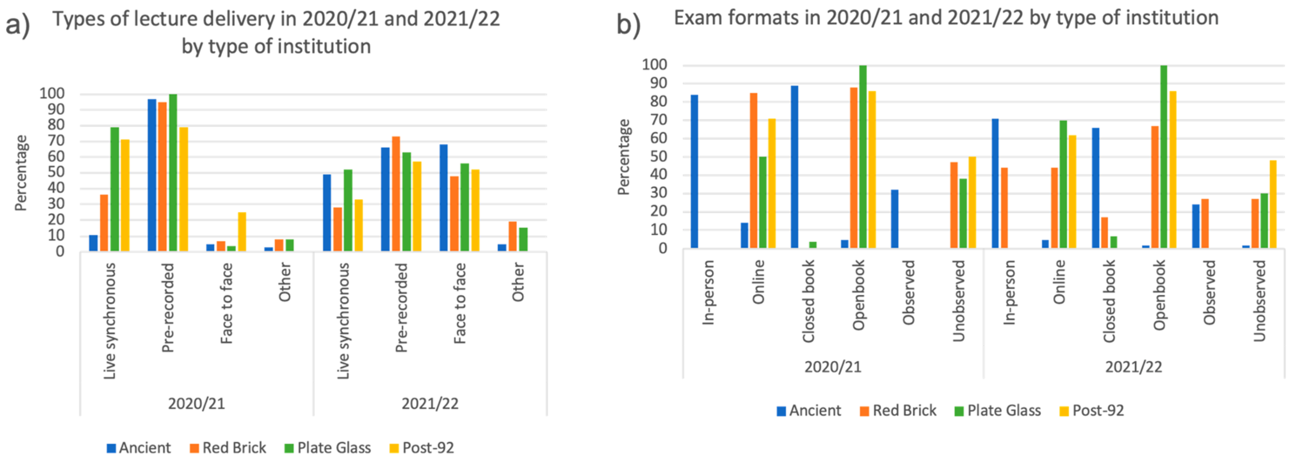

Figure 3. (a) Types of lecture delivery in 2020/21 and 2021/22. (b) Aspects of exam delivery in 2020/21 and 2021/22.

Table 1. Types of Workshop Delivery in 2021 and 2022

Institution	Year	Live synchronous (%)	Prerecorded (%)	Face to Face (%)	Other (%)	None (%)
Ancient[a]	2020/21	8	0	3	8	70
	2021/22	0	2	15	0	78
Plate Glass[b]	2020/21	97	0	17	4	4
	2021/22	48	7	66	7	6
Post-92[c]	2020/21	57	50	21	7	14
	2021/22	33	19	52	0	14
Red Brick[d]	2020/21	69	9	19	19	4
	2021/22	24	6	66	7	6

[a]N = 41. [b]N = 27. [c]N = 21. [d]N = 88.

Table 2. Types of Tutorial Delivery in 2021 and 2022

Institution	Year	Live synchronous (%)	Prerecorded (%)	Face to Face (%)	Other (%)	None (%)
Ancient[a]	2020/21	84	3	43	14	3
	2021/22	22	0	48	8	32
Plate Glass[b]	2020/21	79	4	54	0	8
	2021/22	48	7	56	4	11
Post-92[c]	2020/21	71	43	21	7	0
	2021/22	24	0	57	5	10
Red Brick[d]	2020/21	55	4	5	11	22
	2021/22	15	0	57	5	10

[a]N = 41. [b]N = 27. [c]N = 21. [d]N = 88.

In 2020/21, prerecorded lectures were the most common form of delivery (Figure 3b). There was more variation with the levels of online live synchronous lectures. They were commonly used by Plate-Glass and Post-92 institutions but less so by Red Brick and very little at Ancient institutions. In 2021/22 there was a decrease in the number of students being taught theory through prerecorded screencasts, but they were still the most common form of lecture delivery. For live synchronous lectures, there was a decrease in the amount of delivery in 2021/22 for students at Plate-Glass and Post-92 institutions, but a significant increase for students at Ancient institutions. The most significant change between 2020/21 and 2021/22 was the increase in face-to-face lectures which students from all types of institutions reported.

Workshops are a mode of interactive medium to large size classes based on students attempting questions. They were rarely used at Ancient institutions so no significant change was seen between the 2020/21 and 2021/22 (Table 1). For the other types of institutions, workshops were mostly delivered using online live synchronous classes in 2020/21 with students at Post-92 institutions also being taught with prerecorded material. In 2021/22, there was a large increase in face-to-face workshops ranging in 2020/21. Red Brick institutions were more likely to increase face-to-face workshops while decreasing live synchronous classes, while Plate-Glass and Post-92 institutions maintained more live synchronous workshops.

Tutorials are interactive classes in small groups of typically 2−6 students. For tutorials, the most common mode of delivery was online live synchronous classes in 2020/21 (Table 2). They were commonly used by Ancient, Plate-Glass, and Post-92 institutions but less so at Red Brick institutions. Ancient and Plate-Glass institutions were delivering some face-to-face tutorials, while Post-92 institutions were delivering prerecorded tutorials. In 2021/22, all types of institutions increased the amount of face-to-face tutorial teaching, although many students were still being taught with live synchronous tutorials.

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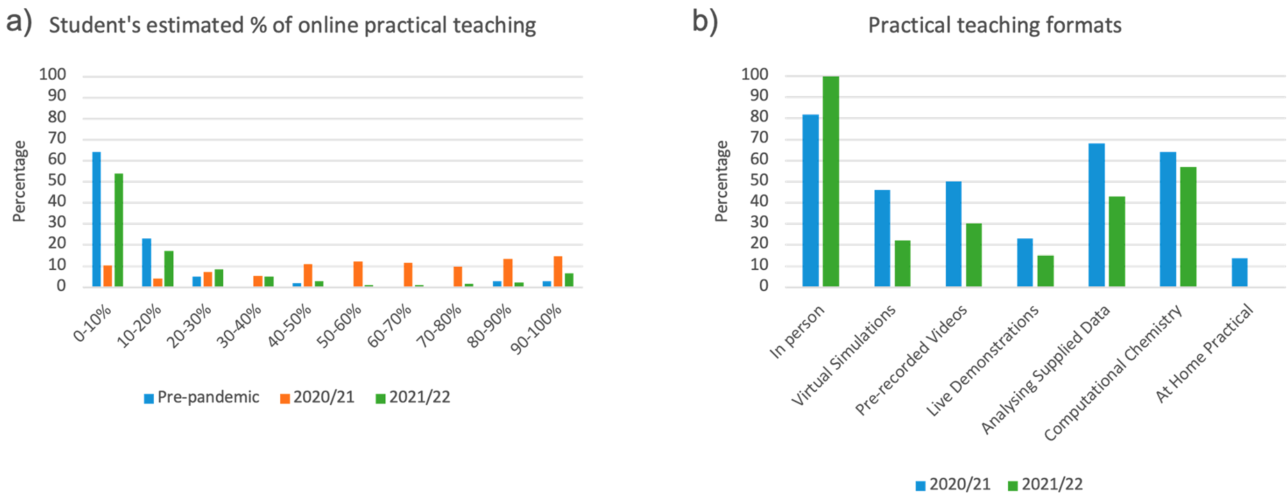

Figure 4. (a) Percentage of online practical teaching prepandemic, in 2020/21, and in 2021/22. (b) Types of practical teaching in 2020/21 and 2021/22.

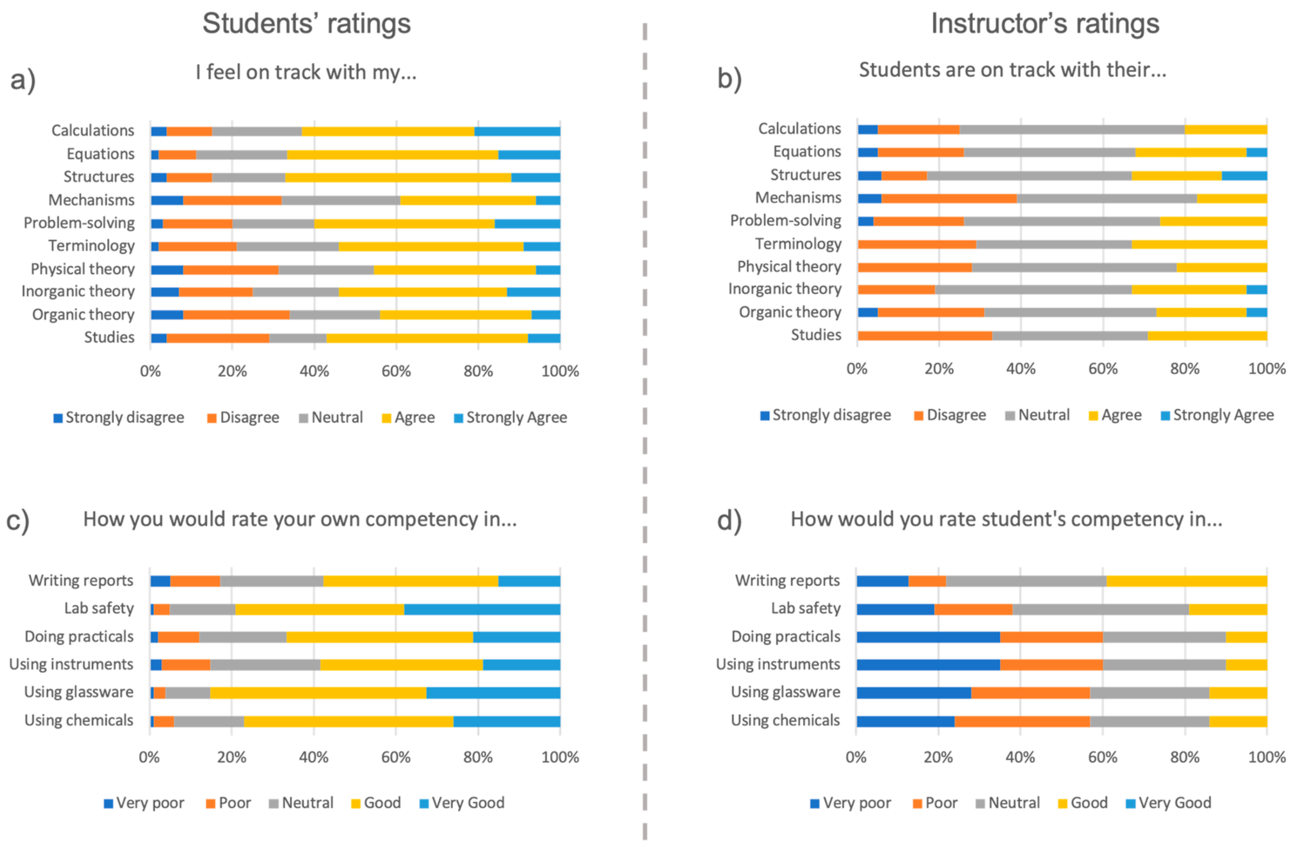

Figure 5. (a) Students' self-ratings of chemical knowledge and theory-based skills. (b) Instructors' ratings of students' chemical knowledge and theory-based skills. (c) Students' self-ratings of practical competencies. (d) Instructors' ratings of student's practical competencies.

For exam formats, students were asked to indicate different features of their assessment so we could build a picture of their exams (Figure 3b). Ancient institutions were more likely to use traditional in-person, closed-book exams during the pandemic years. Plate-Glass and Post-92 institutions were most likely to use open-book, online exams in both years. It was only Red Brick institutions that showed a statistically significant difference in how exams were delivered in both years. In 2020/21, Red Brick students mostly experienced online, open-book exams, however in 2021/22 there was a statistically significant increase in the number of students taking in-person exams. The increase in the closed book aspect was much smaller, so this indicates that for many students, the open-book aspect of exams has been maintained while being in a more traditional in-person setting.

Practical Teaching and Learning

As with theory, students were asked to estimate how much practical teaching and learning was online prepandemic, in 2020/21, and in 2021/22 (Figure 4a). Prepandemic practical teaching was fully or mostly in-person. At the height of pandemic in 2020/21, there was a large variation with how

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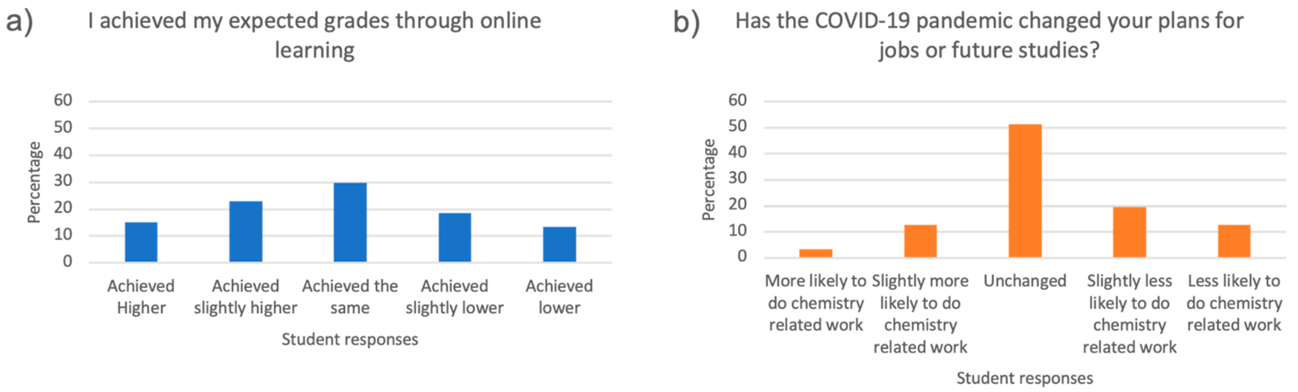

Figure 6. (a) Students' self-ratings of expected grades. (b) Student perspectives on future career and study plans.

much practical teaching was in-person or online. In 2021/22, even with some pandemic restrictions in place, the level of in-person practical teaching moved back to close to prepandemic levels.

Unfortunately, students were not asked to provide practical formats for both 2020/21 and 2021/22 years to compare, but instructors were to provide some insight into how practical teaching methods evolved (Figure 4b). A high percentage of instructors reported using in-person practical work, but this increased to all instructors reporting that in-person practical work was being taught on their courses. The next most common methods in 2020/21 were analyzing supplied data followed by computational chemistry exercises. Online virtual simulations, online prerecordings of experiments, and online live demonstrations of experiments were used less. A small percentage of instructors reported using at home practical work. What is noticeable about these alternative methods to practical teaching is they almost all decreased in their use in 2021/22 by statistically significant amounts with the exception of computational chemistry.

Perception of Online Teaching and Learning on Knowledge, Skill Development, and Future Plans

Students were asked to agree or disagree to whether they felt they were on track with their theory and practical development despite the disruption COVID-19 had caused to their studies (Figure 5). For theory-based knowledge and skills, most students felt their development from the theory portion of the degree was on track. For comparison instructors were also asked to agree or disagree if they felt their students were on track with the same knowledge and skills. Instructors were slightly more pessimistic about their student's theory development, with the majority view often being neutral.

For practical skill development, students and instructors were asked to rate their competence of various practical skills. Students rated their practical skills highly with a clear majority rating their skills to be good or very good. In contrast instructors were more pessimistic. and were likely rate practical skills as being poor or very poor.

Students were asked to report on whether online learning had affected their expected grades (Figure 6). The results were mixed with 38% of students feeling they achieved higher or slightly higher grades, 30% feeling it had no effect, and 32% of students feeling they achieved lower grades. When asked if the pandemic had affected their future plans, 51% of students said it had no effect, 16% said it made them more likely to study or work in chemistry, and 33% said it made them less likely to study or work in chemistry (Figure 6).

General Perceptions of Online Teaching and Learning

Both students and instructors were asked to give open-ended responses for the advantages and disadvantages of learning theory during the pandemic (Figure 7). These open-ended responses were coded into general themes as described in the Methodology section. The percentage of responses quoted

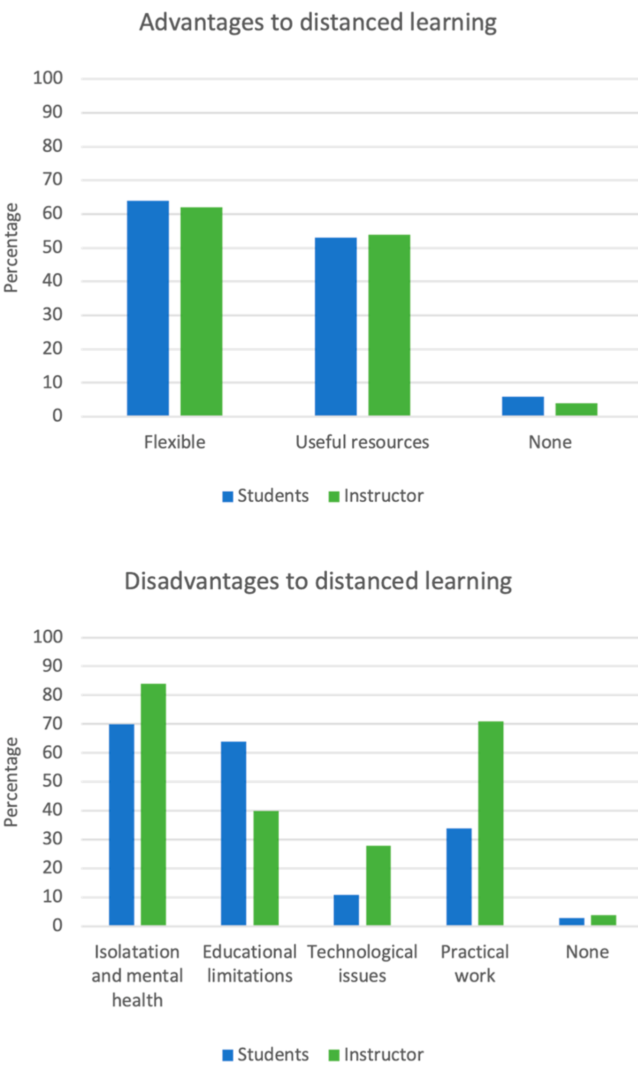

Figure 7. (a) Themes of students' and instructors' advantages to distanced learning. (b) Themes of students' and instructors' disadvantages to distanced learning.

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refers to the percentage of comments from the total number of students or instructors who completed the survey, despite not all students or instructors providing open-ended comments. For the advantages, both students and instructors agreed that the greatest advantages were the flexibility and improved learning resources that were produced due to online learning.

Under the theme of flexibility, many students reported that they liked being able to watch screencasts in their own time with a schedule that suited themselves. This helped with pressures such as commuting, lecture clashes, training, or work commitments associated with in-person teaching.

"I can rewatch the lectures, and do them in my own time which has allowed me to work, train and compete as well as study."

Under the theme of improved resources, many students reported that recordings of lectures allowed students to watch lectures at their own pace, and rewatch content if needed. The recordings were also thought to be better than recordings of in-person lectures in some comments.

"The strongest advantage has got to be the ability to add subtitles to recorded content and that we can watch the recorded content in our own time. [...] I used to have to attend lectures and then repeat them in my own time pre-Covid as I couldn't keep up, and now I can with recorded content."

Turning now to disadvantages, the main themes from students and instructors were isolation and mental health, educational limitations, and technology issues.

Students disliked the lack of social interaction with peers which impacted the ability for students to make friends in their course. Many reported that synchronous online classes were made it less easy to interact with others than in person. Being in a room and looking at a computer screen for a long number of hours were also commonly reported, leading to feelings of isolation. In many cases, the isolation had a negative effect on students' mental health.

"It is quite an isolating experience. I have not met many people on my course and it has an impact on my motivation to keep going with it sometimes."

The theme of educational limitations covered many comments where students found the educational experience of online learning challenging. Many students found the lack of interaction with instructors impacted their learning. They also found the use of online lectures made it difficult to structure learning in the way timetabled in-person classes would do, and that online lectures could take longer to learn material. Technological issues also impacted the ability to learn material.

"I found it harder to interact with tutors in tutorials—often felt more like a lecture and was less interactive. Also, harder to concentrate for long periods of time in online tutorials and lectures as could get distracted by phones/other people in the house etc."

With regards to practical work, no students or instructors gave an advantage, and students and instructors mentioned practical work as a disadvantage. Students showed their frustration with distanced learning, saying they did not learn practical chemistry effectively without sufficient access to in-person laboratories. For practical work, the comments from students and instructors were clear, that for students to gain the necessary skills and understanding, practical chemistry must be carried out in person.

"Practical chemistry learning was ineffective during the pandemic in my opinion. I have not retained any information from these sessions and the majority of people at my university do not need such an in depth knowledge of coding software to complete their master's research. I felt uneducated when I finally entered the lab to conduct my masters research as I felt unfamiliar with equipment and unable to remember key techniques for synthesis."

"The only useful sessions to me were covid-safe labs."

Finally, students were asked whether they agreed to having a high-quality education prepandemic, in 2020/21, and in 2021/22 (Figure 8). Prepandemic students mostly agreed (44%) or strongly agreed (35%) that they had a high-quality education. During the peak of the pandemic in 2020/21, this shifted into the opposite direction with an overall majority either disagreeing (35%) or mostly disagreeing (17%). In the 2021/22 academic year, the shift was back toward the majority either agreeing (37%) or strongly agreeing (25%) with having a high-quality education but not quite to the prepandemic levels.

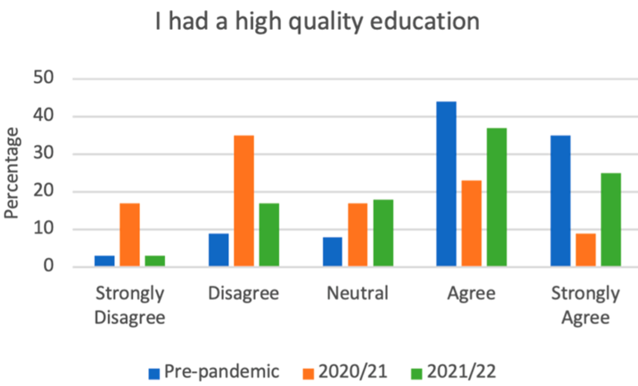

Figure 8. Student satisfaction with studies prepandemic, in 2020/21, and in 2021/22.

DISCUSSION

Theory Teaching and Learning

From our results, it appears that the teaching and learning of chemical theory in the UK shifted fully online at the height of the pandemic in 2020/21, but rather than returning to prepandemic levels of in-person teaching, the teaching of theory has retained a significant distanced learning element. Prerecorded lectures were the main portion of theory teaching that has remained online, while interactive types of teaching such as workshops and tutorials returned to face-to-face teaching. This is understandable as both students and instructors highlighted that one of the key benefits of online teaching was the flexibility provided by recorded lectures that allowed students to watch content in their own time and at their own pace. All types of institutions increased their tutorial teaching in 2021/22. This shows that tutorials are valued across the sector, but some institutions may felt that it needed to be delivered in person.

Providing interactive teaching in a distanced learning format was necessary during the height of the pandemic in 2020/21, but both students and staff felt that peer and student—staff interactions work better in-person. It appears that the flipped model of teaching, with recorded screencasts followed by in-person workshops, is being used by a large proportion of UK chemistry departments. From some of the issues students have raised, there is clear improvement that institutions can do to deal with the isolation and long hours of screen time that online teaching can lead to. Providing more structure (for example, timetabling when screencasts are to be watched), shortening screencasts, and providing increased mental health support would help deal with some of the disadvantages.

For assessment, it appeared that UK chemistry departments had different approaches to examinations. Ancient institutions maintained in-person exams in 2020/21 while online was favored at others. Some of those that used online in 2020/21 have pivoted back toward in-person exams while others have maintained the online format. One legacy of the pandemic is the retention of open-book element exams at some institutions, meaning students are being tested less on rote memorization and more on their application of theory.

Despite the significant changes to teaching during pandemic, the majority students do not feel like their theory-based knowledge and skills had been affected in a negative way. This could be because students were receiving the same content from instructors albeit in a recorded format. The benefit of being able to watch instructors' explanations of theory in their own time and pace could be why some feel their theory is on track or better than they would have anticipated

Practical Teaching and Learning

For practical work, it appears that the most distanced learning measures used in the UK during the peak of COVID-19 were temporary, and that face-to-face practical work returned as the primary method of developing laboratory skills. This was first shown by large pivot back in in-person teaching which was noticeably larger than its theory counterpart. Both students and instructors value in-person experiments as the best method for teaching hands-on practical skills and practice using instruments. These findings are in tandem with other students and instructor perspectives who have experienced COVID-19 laboratory courses.[3,10,11,16,19]

The decrease in prerecorded videos of experiments or supplying of data to analyze suggest they were temporary measures. Another possible driver for the increased in-person practical work is the requirement for Royal Society of Chemistry (RSC) accredited Bachelor's and Master's degrees to complete 300 and 400 h of practical work, respectively.[29] However, one of the main types of practical work which has remained largely unchanged is computational chemistry experiments/activities. This could because they teach valuable but different skills to hands-on practical experiments.

Following-up staff perspectives of practical teaching, it is unsurprising they feel that students have been negatively impacted by the lack of hands-on practical work and are behind where they would be otherwise. What is a surprising is students themselves do not feel they are behind on their practical skills development despite sharing the view that online alternatives were not replacements for hands-on practical work. If this cohort of students are behind on their practical skill development then it could have implications for employers in the chemical sciences when hiring graduates with the desired skills.

Perception of Online Teaching and Learning on Knowledge, Skill Development, and Future Plans

There is little agreement from students as to whether the pandemic had a negative, positive, or neutral effect on their grades. At the height of the pandemic it is clear that students were not satisfied with the amount of online teaching, but in the past year it appears that student satisfaction is returning to prepandemic levels. On long-term impacts, most students do not feel as if the pandemic has had an effect on future career plans, but it is noticeable that more students are less likely to want to go into a chemistry career or further study than are more likely to do so. This could have long-term consequences on the chemical industry if the number of graduates going into chemistry-related jobs declines as a result of the pandemic.

Finally, a note of caution from this study. We will not know until further into the future what the long-term implications of the COVID-mitigations are on the teaching and learning of chemistry. Therefore, as the title of *this article* suggests, these results should be interpreted as a snapshot of teaching and learning practices coming out of the pandemic.

■ CONCLUSION

We have been able to ascertain how Higher Education chemistry departments in the UK have evolved their teaching methods through the pandemic, and how both students and instructors across the country have felt it has impacted the teaching and learning of chemistry. During the peak of the pandemic the teaching of theory was mostly online, but since the pandemic has receded, many UK chemistry departments have maintained a hybrid approach of teaching theory, whereby content/lectures are being delivered using prerecorded screencasts and interactive modes of teaching are back to being delivered face-to-face. Both students and instructors believe prerecorded screencasts are a good thing that provides students with greater flexibility to view an instructor's explanations of content.

For practical work, it is clear that online alternatives have not replaced in-person lab skills. Some form of in-person laboratories were maintained at the height of the pandemic by most institutions and most courses have are returned to prepandemic levels of face-to-face teaching. Both students and instructors thought online alternatives were not adequate replacements for in-person laboratories.

Despite the significant disruption that students have experienced to their undergraduate education, the majority do not feel they behind on their understanding of theory or development of practical skills. Instructors were more pessimistic and feel that online learning has had a negative impact, especially for the development of practical skills.

This study provides some useful insight into how chemistry departments have adapted and evolved their teaching through the course of the pandemic. The most recent academic year reported (2021/22) was taught with some COVID-19 measures in place in the UK, such as mask-wearing and social distancing. Our goal is to continue evaluating how tertiary chemistry education evolves until COVID-19 no longer requires any mitigation. We will then be able to ascertain what the long-term impact of the pandemic has been.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.2c00676.

Student and instructor survey questions (PDF) (DOCX)

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Notes

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