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A Snapshot of UK Prelab Practices and Instructor Perceptions of their Purpose and Effective Design

Cristina Navarro, Benjamin E. Arenas, Mairi F. Haddow, Anna J. Kirkham, and Patrick I. T. Thomson*

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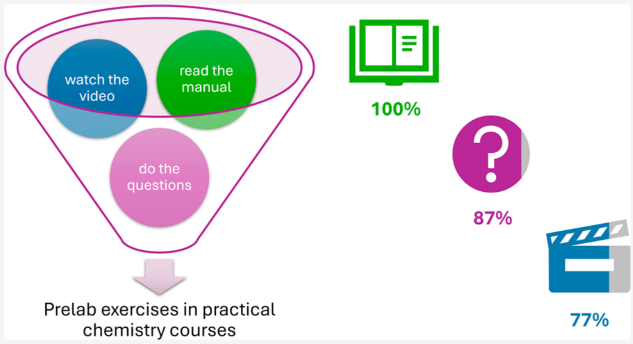
ABSTRACT: Prelaboratory exercises are a widely used and powerful method of supporting and maximizing laboratory learning. In this work, we took a snapshot of current prelab practices in the United Kingdom by surveying instructors responsible for running lab courses. We found that prelabs very often took the form of three core activities of "read the manual, watch the video, do the questions", with about half additionally employing digital lab simulations and a marked decline in traditional prelab practices of live demonstrations or formal lectures. We also investigated the factors that influence prelab design, the challenges of designing or using prelabs, and what instructors felt the purpose of a prelab was. Main challenges were seen as lack of time or resources to design consistent, effective prelabs, and difficulty in ensuring meaningful engagement from students. Instructors felt that prelabs had a number of purposes, such as improving operation of a lab itself or improving students' learning and affective outcomes by reducing stress or anxiety.



KEYWORDS: *Prelab Exercises, Laboratory Instruction, First-Year Undergraduate/General, Second-Year Undergraduate, Upper-Division Undergraduate*

■ INTRODUCTION

Prelaboratory exercises (prelabs) have a long history in UK (United Kingdom) chemistry higher education. Advocated by Johnstone and Wham in their 1982 work on the cognitive demands of practical work and well-supported by later general theories of cognitive load from Sweller et al., prelabs were established good practice by the end of the 20th century, with the Royal Society of Chemistry commissioning Carnduff and Reid to publish a book-length practical guide to prelabs in 2003.[1−4] Since then, chemistry education research has investigated the effective design and function of prelabs, culminating in a highly influential series of works from Seery et al. which surveyed the publication landscape and reasserted the role of prelabs as a foundational aspect and guiding principle of good lab design.[5−7] The content and design of prelabs themselves have also evolved over the years, advancing with emerging technologies that reduced barriers to assessment, feedback, or the easy creation and distribution of multimedia resources.[5]

A previous comparative study of prelabs between chemistry and bioscience departments collected data from 30 UK chemistry departments in 2016, providing the most recent previous snapshot of UK prelab practices.[8−10] In that study, Rayment et al. mostly focused on bioscience but also collected data on the broad categories of activities used in chemistry prelabs. These prelabs typically took the form of a sequence of reading a protocol, watching a video, and answering assessed questions, alongside aspects of safety or calculation practice. Our first aim was therefore to investigate the current UK chemistry prelab landscape and obtain a fresh snapshot of activities and practices, exploring more deeply the structure and demographics of chemistry lab courses and the design principles of their prelabs.

Prelab exercises do not exist in isolation—as with any teaching material, they are created by instructors to meet their educational goals. DeKorver and Towns found previously that instructor goals can often be misaligned with student goals—sometimes leading to a failure to achieve meaningful learning.[11] Their study recommended design changes to laboratories to promote goal alignment, highlighting the ability and power of instructors to influence student behavior through activity design. However, to effectively design learning activities that align with student and instructor goals, instructors may need specialist pedagogical training. A recent investigation of introductory chemistry instructors in the United States showed broad

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knowledge of pedagogically sound learning strategies, despite variable levels of implementation and low levels of explicit pedagogical training for staff.[12] More broadly, there is a large body of literature studying the beliefs of trainee secondary school teachers in educational theory, demonstrating clearly the fundamental impact of those beliefs upon their practices.[13−16]

These and many other studies highlight the influence that instructor beliefs have on the content and design of their own courses, an influence that extends in turn to laboratories and prelab exercises. Our second aim was therefore to explore the factors influencing the instructors who design or curate prelabs.

RESEARCH AIMS AND RESEARCH QUESTIONS

In this article are presented the findings of a recent project that sought to take a snapshot of current UK prelab practices and explore what factors influenced their design by lab instructors. These aims allowed the definition of the following two research questions:

RQ1:
What practices, techniques, and designs are currently used in prelabs throughout the UK?

RQ2:
What factors influence the instructors responsible for creating or updating prelabs?

METHODOLOGY

To achieve the aims of the study, an online survey for chemistry instructors was conducted during summer 2024. The survey was built on Microsoft Forms and consisted of a combination of open-answer, multiple-choice, and Likert-scale questions. This allowed the collection of qualitative and quantitative information on prelab practices from chemistry practical course organizers from higher education institutions throughout the UK. The survey was distributed through the authors' professional networks and advertised on the Royal Society of Chemistry's Higher Education Group (RSC HEG) LinkedIn page and newsletter—a large and pervasive community of chemistry educators in the local sector.

A copy of the survey can be found in the Supporting Information (SI). Ethical approval for this study was granted in June 2024 by the Department of Pure and Applied Chemistry Ethics Committee at the University of Strathclyde (DEC24/PAC03). To meet the requirements of this ethical approval, the first page of the survey acted as a combined participant information sheet and consent form and required participants to give consent before the rest of the survey was accessible.

For numerical data, Wilcoxon Signed Rank tests were conducted in IBM SPSS, first converting responses to a 1-n scale. For free-text data, each set of answers were separately analyzed using inductive thematic analysis. Individual responses were coded according to the methodology of Bree and Gallagher, following a similar six-phase process to Braun and Clarke's, adapted for physical science education research.[17,18] One investigator (PT) read and reread all data, producing initial codes and themes (Phases 1 and 2). These themes were repeatedly sorted and recategorized, identifying new themes or merging previously distinct themes together (Phases 3 and 4). Themes were given placeholder names and expanded to a rich one-sentence description during coding. At this point, themes and raw data were reviewed together by all coauthors, and findings were in broad agreement. Finally, when themes and subthemes had settled, graphical and written outputs were generated, supported by appropriate extracts (Phases 5 and 6).

Limitations

The survey was distributed among the colleagues and professional networks of the authors, and it was advertised through the Royal Society of Chemistry's Higher Education interest group, which could contribute to the bias in the responses. The participants are those who were engaged with those professional networks and with the online presence of the RSC HEG, who would have had adequate time and motivation to complete the survey, and who saw the potential value in sharing their practices. Information on practices and design decisions different from those presented here might, therefore, not have been gained from the scope of this survey, specifically practices outwith the UK.

The responses to the survey were anonymous, and as a result, the effect of participants' background or previous experiences could not be linked explicitly to their practices. The effect of the length of their previous experience could be estimated from the answers to the question "How many years of experience do you have in running or designing a lab module, in general?" There could be no link established between practices and the types of higher education institute surveyed, as no information regarding which institute each lab course was hosted at was recorded. It is possible that several responses were collected from different instructors running different lab courses at the same institution, so the number of responses may not be indicative of widespread multi-institution practices. Further to this, the results might have differed had responses from more institutes been collected and analyzed. However, the response rate corresponds to over 50% of the chemistry departments in the UK, so some measure of representativeness can be inferred.

Local Context and Typical Lab Structures

The survey responses related to 30 chemistry teaching lab courses taught by 28 different instructors across the UK, and additionally collected a range of descriptive data about lab course size, duration, staffing model, and the way prelabs were used by staff and students (full questions and responses can be found in the Supporting Information). These "demographics" may be of utility to those wishing to contextualize these results for other national systems of education.

Almost two-thirds of the surveyed lab courses were multidisciplinary Foundation or Year 1 courses, with the remainder split across a full range of subdisciplines, in line with previous findings where prelabs tended to be concentrated in the earlier years of a degree.[9] A typical lab hosted 120 students, and the format for just over half (57%) of the courses comprised half-day sessions (2.5 to 4.5 h) with the rest consisting of full days. Most of the lab courses were staffed by experiment-specific, group-specific, or floating graduate teaching assistants (GTAs; also called demonstrators, tutors, or laboratory facilitators), with half of the courses having a dedicated academic member of staff being present. Most also had a dedicated technician or technical team.

RESULTS AND DISCUSSION

Thirty-nine responses were received, each corresponding to a different individual laboratory course. Nine responses to the question "Does your lab use prelabs?" were "No, we don't do prelabs", where the survey ended early without collecting further data. This gives a complete data set of 30 responses. No conclusion can be drawn about the overall prevalence of prelabs from this discard rate, since the initial recruitment message focused explicitly on prelab supported courses.

Prelab Structure and Student Engagement

The majority of lab courses (27 out of 30) have specific prelab activities for completion before most or all practical sessions, and virtually all of these were assessed with instant formative feedback being made available to the students. Some survey participants mentioned that in-person feedback was also provided to students from teaching assistants early on in the practical session. Engagement with the prelab activities, and attainment within them, were often (57%) incentivized by gating access to the laboratory, with access restrictions usually justified on health and safety grounds. Prelab completion contributed to an overall course's pass or fail in 20% of courses, with about a third also contributing over 5% to the final lab grade. Most prelabs were very well utilized by students, with a median uptake of 95%. Two-thirds of the lab courses reported that prelabs were used formatively, either not generating a grade at all, or a grade that was only used to determine overall engagement. Engagement often fed into the aforementioned access-gating policies, ostensibly on health and safety grounds as prelabs often included safety content.

Prelab Design Principles, Content, and Inspiration

The design principles of prelab activities were probed by asking respondents to indicate which categories of information were included in the activities. The survey cited the following descriptions, derived from Seery's 2017 categorization.[5]

- Procedural—such as descriptions, demonstrations, or videos of a specific technique or instrument, with a focus on practical operation;
- Supportive—such as the operating principles of a specific practical technique or instrument;
- Theoretical—such as curly arrow mechanisms or derivations of formulas, thus exploring chemical theory;
- Safety—such as chemical safety not otherwise covered by instructions.

As shown in Figure 1, all of these categories were well covered in the lab courses surveyed. The focus on preparation for the practical session is clear, as the vast majority of the lab courses (90%) reported using prelabs in all or most of their experiments. Procedural, supportive, and safety information were well-represented in these prelabs, with procedural being the most used category (present to some extent in all but one lab course and present for most experiments in nearly 80% of responses). Safety information is also widely included (87%), which chimes well with the justification of gating access to the lab based on prelab completion. There was a weak statistically significant difference between procedural and theoretical prevalence (Wilcoxon, $p = 0.033$, $Z = -2.134$, see SI for details) and procedural and supportive prevalence (Wilcoxon, $p = 0.028$, $Z = -2.203$, see SI for details), indicating that prelabs slightly favor the delivery of procedural information, i.e., a higher prevalence of prelabs that may only contain stepwise operating instructions or similar. However, the sample size is relatively small for this test, the differences were small, and the prevalence was broadly consistent between categories. Specific pedagogical design of the prelab therefore seems to be much less distinctive or influential than whether a prelab exists at all.

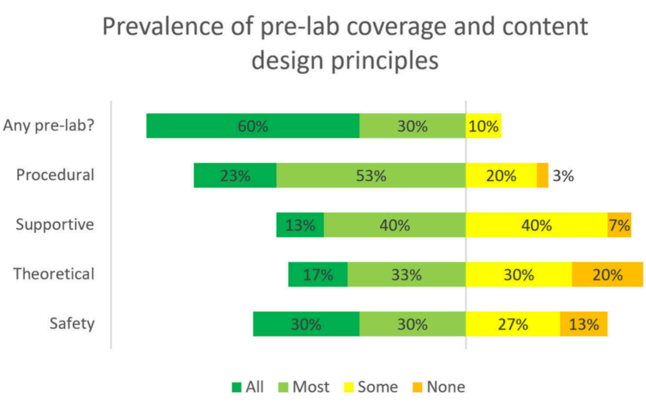

Figure 1. Response to questions which ask how many individual experiments within a course had any prelab at all, and the prevalence of four specific categories of information. Note that the first question, "Any pre-lab?" had no option for "none" ($n = 30$).

The methods used in prelabs include both passive and active learning activities, as can be seen in Figure 2. Every course required students to refer to the laboratory manual entries for the specific experiments, and more than 85% of responses indicated that students are required to answer assessed questions. Locally filmed prelab videos (77%) complete the classic trinity of the most common activities of reading, watching, and questioning, similar to prior findings.[9] Use of virtual simulations (44%), including LabSims from LearnSci, had markedly increased from an estimated 5% uptake in 2016, an eight-year period which saw the rapid rise of remote teaching and associated technologies due to the COVID-19 pandemic.[9,19,20] LearnSci's commercial offerings were explicitly mentioned in the free-text comments, and several UK institutions have also recently developed in-house lab sims, virtual reality sims, or video-based interactive environments.[21−25] A recent snapshot by Mistry and Simmons described how many instructors had adopted virtual laboratories out of necessity during COVID-19, but quickly pivoted back to in-person teaching. It seems, therefore, that many instructors since then have retained simulations as a newly integral part of the prelab landscape.

Overall, the five most popular activities are those likely to be delivered in a fully online flipped format, far more popular than in-person demonstrations (27%) or live lecture briefings (33%). The much higher use of locally filmed video versus external existing resources is interesting, given the high initial effort required to create videos. Some free-text responses from later in the survey cited the necessity of keeping videos up to date to reduce student cognitive load. This was a neat demonstration of the personalization principle, which has previously been used to suggest that prelab videos are more effective when recorded in the local context that learners then experience.[5,26,27] External resources would be unlikely to reflect the idiosyncrasies of local equipment or procedures, anecdotally a universal feeling among the authors of the current study.

Asking students to actively create something was most often achieved by requesting all or part of a written procedure (40%), sometimes specified as a risk assessment. However, two courses (7%) required students to create a video or other graphical output based on the upcoming lab. This is a low occurrence, but could show the impact of prior scholarship from around student-generated prelab videos.[28−30] In these works, Gallardo-Williams describes prelab videos that were scripted, acted, and narrated by recent graduates, and Smith describes more general teaching

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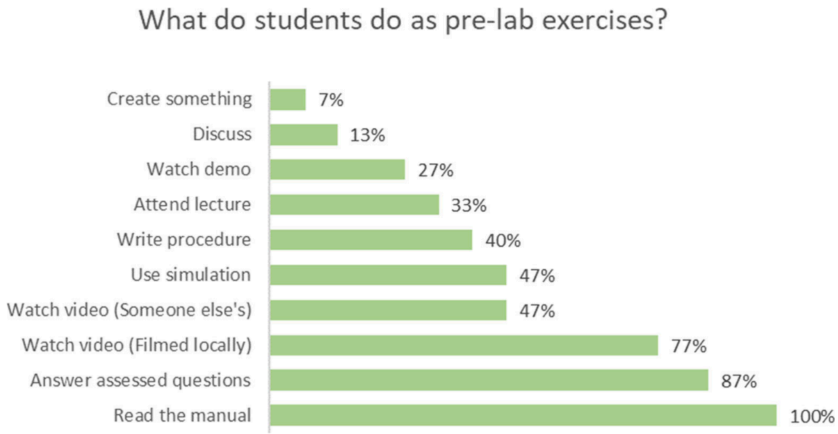

Figure 2. Occurrence of types of prelab tasks within a given lab course ($n = 30$).

activities that have students create video as part of an assignment itself.

Lab coordinators cited a range of influences on their prelab designs (Figure 3). Local colleagues were the most popular resource (82%), followed by previously existing prelabs (64%). Pedagogical and practice papers, conferences, and conversations with colleagues in other institutions were also sources of inspiration for around 50% of the responders in each case.

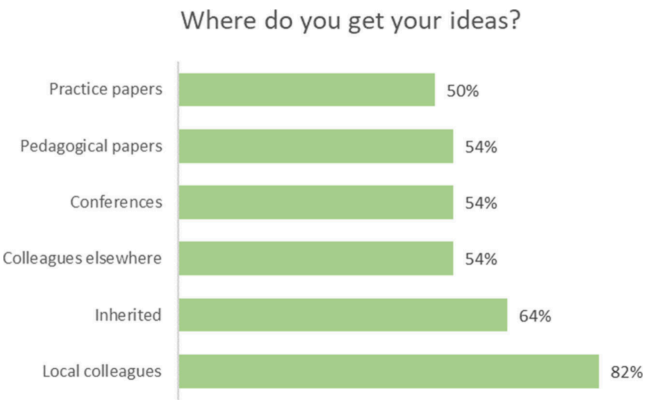

Figure 3. Lab coordinators cited a range of influences on their prelab design practices ($n = 28$).

Instructor Beliefs and Practices

To further investigate the factors that influence instructors, respondents were asked what they thought the purpose of a prelab was (Q22) and what they saw as the main challenges in designing or using prelabs (Q25). Responses to the questions were coded separately using inductive thematic analysis and distilled to two sets of themes and subthemes (Figures 4 and 5, below). Frequencies of each code are listed in the SI.

On the perceived purpose of prelabs, three main themes were identified: Supporting cognition by providing information in advance, smoothing workflow management during and after a lab, and improving student outcomes.

For providing information in advance, this fell along either supportive (15 responses) or procedural (21 responses) lines, with procedural information including general lab familiarization and induction; the slightly higher prevalence of procedural-aligned themes matches the quantitative results

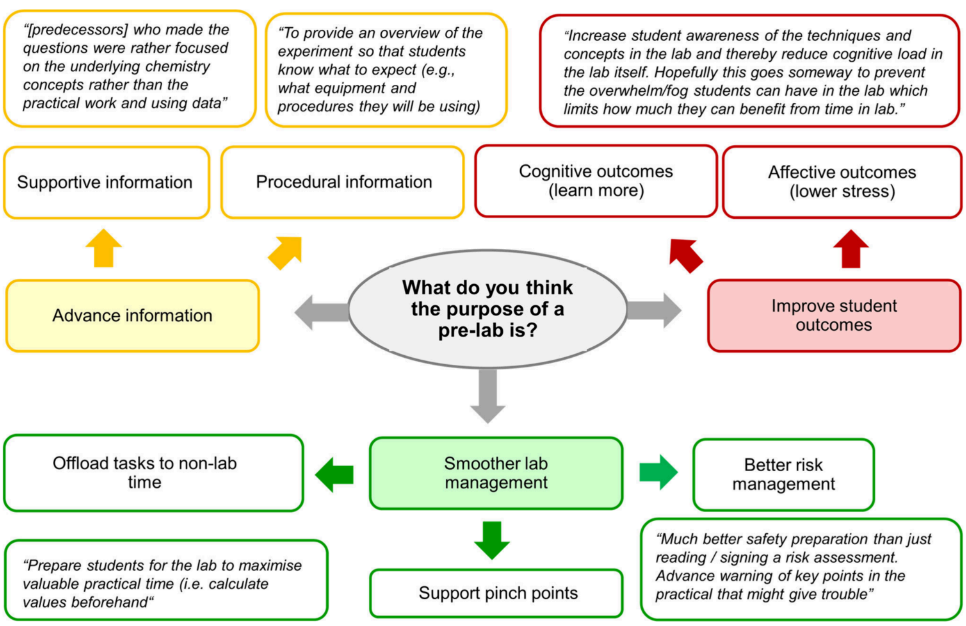

Figure 4. Thematic analysis of free text responses on instructor perceptions of the main purpose of a prelab.

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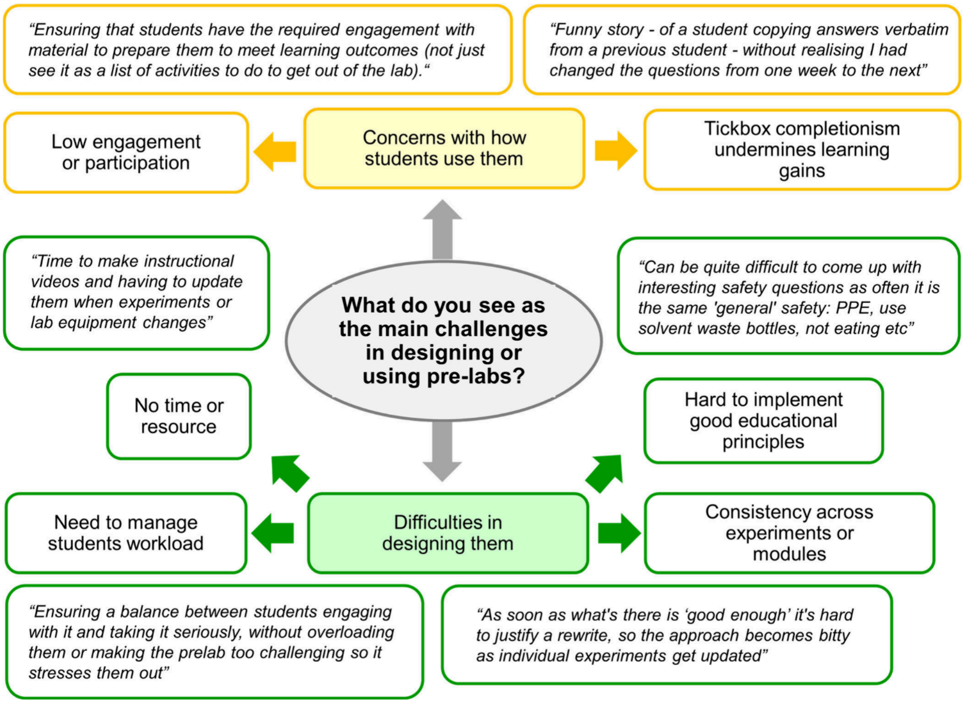

Figure 5. Thematic Analysis of free text responses on instructor perceptions of the main challenges in designing or using prelab activities. "Bitty" (bottom-right) is an informal UK term for "fragmented".

(Figure 1). In one particularly evocative example, an instructor recognized an existing inherited prelab as focusing on purely theoretical skills, rather than laboratory-specific ones. This again reflects literature around the differing views of what the purpose is of a given piece of teaching.[11]

> *To provide an overview of the experiment so that students know what to expect (e.g., what equipment and procedures they will be using)*
>
> *[predecessors] who made the questions were rather focused on the underlying chemistry concepts rather than the practical work and using data*

For workflow management, prelabs were seen as making best use of limited lab time by offloading activities elsewhere (5 responses), enhancing risk management and safety preparation (15 responses), or presupporting or highlighting pinch points to reduce extraneous cognitive load (8 responses). Cognitive load theory was sometimes mentioned explicitly, but usually responses focused on outcomes such as better use of time or safer working practices.[5]

> *Prepare students for the lab to maximise valuable practical time (i.e. calculate values beforehand*
>
> *Much better safety preparation than just reading/signing a risk assessment. Advance warning of key points in the practical that might give trouble*

For improving student outcomes, we saw coverage of both cognitive (6 responses) and affective (8 responses) aims, with the former relating to performance and increased grades and the latter relating to lowered anxiety and increased confidence. These aims were often explicitly linked by instructors with the notion that excessive cognitive load would increase student stress, anxiety, and feelings of being overwhelmed. This interplay between cognitive and affective aims reflects recent scholarship focusing on the affective dimensions of laboratory learning, as they relate to overall student success.[31−33] These works explore the impact of affective experiences on laboratory students, suggesting how negative affective factors can impact lab experiences by cognitive or sensory overload.

> *Increase student awareness of the techniques and concepts in the lab and thereby reduce cognitive load in the lab itself. Hopefully this goes someway to prevent the overwhelm/fog students can have in the lab which limits how much they can benefit from time in lab.*

For the perceived challenges of using prelabs (Figure 5), we saw responses split across two themes, with concerns about how students use (or do not use) prelabs, and the difficulties in designing them well. In the first theme of student use of prelabs, there were subthemes with concerns around low levels of student engagement or participation (8 responses), "tick-box" style completionism, or even active subversion of a no-low-stakes assignment leaving the purpose of the prelab unfulfilled (8 responses). This reflects prior research around student goals for lab learning, where those goals are often misaligned with instructor goals, and aligned to "finishing quickly".[11] Respondents here similarly viewed this misalignment in a negative light.

> *Ensuring that students have the required engagement with material to prepare them to meet learning outcomes (not just see it as a list of activities to do to get out of the lab).*
>
> *Funny story—of a student copying answers verbatim from a previous student—without realising I had changed the questions from 1 week to the next*

The most prevalent theme, though, was concerns around ensuring the design itself was effective, with four clear subthemes. First, instructors often reported simply not having the time or resource to create or update prelabs or inability to purchase third-party resources such as simulations (8 responses). This reflects broadly reported national trends of resource and time shortages.[34]

> *Time to make instructional videos and having to update them when experiments or lab equipment changes*

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The second subtheme was pastoral, concerned with avoiding creating excessive workload and causing the same kind of negative consequences as the prelabs had been designed to mitigate (8 responses). While this reflects the recent and growing impact of affective chemistry education research, it may also simply reflect the long-standing caring instincts of the staff themselves.[31]

> *Ensuring a balance between students engaging with it and taking it seriously, without overloading them or making the prelab too challenging so it stresses them out*

A third subtheme highlighted difficulties in maintaining consistency with other modules, either to satisfy institutional policies or student expectations (6 responses). This was often recognized as a consequence of the earlier theme of instructor lack of time for redesign.

> *As soon as what's there is 'good enough' it's hard to justify a rewrite, so the approach becomes [fragmented] as individual experiments get updated*

The final subtheme related to concerns about effective design, with instructors aware of the difficulties of making questions useful or engaging and often linking to the first main theme of student tick-box completionism (9 responses). In one case, "interesting" was presented as a route to authentic student engagement beyond just completionism. This tension between "completing" and "learning" has been long understood, with a recent study by Miller and Wu identifying how teaching materials and GTA guides often steer laboratories toward completionist approaches.[35]

> *Can be quite difficult to come up with interesting safety questions as often it is the same 'general' safety: PPE, use solvent waste bottles, not eating etc.*

A third free-text question asked respondents, "How and why do you design your prelabs the way you do?", aiming to explore instructor motivations and beliefs and specifically to elicit a discussion of the instructors own pedagogical reasoning, philosophical stance, or theoretical frameworks. However, most responses (22 of 24 responses, 92%) mostly or exclusively described student-oriented goals, which had already been identified in the other responses, such as safety or general class logistics. Some comments (8 responses, 33%) alluded to educational theories using terms like "scaffolding", or expressed a desire to get students to understand what they did in the lab. However, these were short, not reflective, and mostly restated responses from the "hard to implement good educational principles" theme identified in the "challenges" question. A single comment touched on personal motivation: "[I use] what I know works". However, the aim of this question was overall not met, instead eliciting the same responses as other questions and is therefore a potential area for future investigation.

■ CONCLUSIONS, POINTS TO CONSIDER, AND FURTHER WORK

The current work provides a summer 2024 snapshot of UK-wide prelab practices and the factors that influence the instructors responsible for developing and maintaining them. We found that prelabs are widespread across UK chemistry courses, usually woven fully throughout a lab course and supporting all or most of the experiments therein. Prelabs most often took the form of three complementary tasks of instruction reading, watching locally filmed videos, and answering assessed questions. The use of interactive simulations was common, with nearly half of all lab courses using them. Virtually all prelabs provided instant formative feedback, but only about a third of them contributed to an overall lab grade. Student engagement was instead usually incentivized by the use of prelabs as an access requirement to the lab itself, with very high levels of engagement as a result.

Looking at trends over time since the 2016 snapshot by Rayment et al., the most popular prelab contents remain broadly unchanged: a locally filmed video, assessed questions, and a requirement to read text from the lab manual, and with a reasonable focus on safety. The most notable trend over time is the use of simulations which rose almost 10-fold in the space of eight years, likely due in part to COVID-19.[9]

Those responsible for designing and maintaining prelabs cited a wide range of sources of influence over their design such as colleagues, conferences, and the educational literature. Prelab designs were often justified by improved student outcomes, with smoother-running laboratories that deliver more practical learning objectives in smaller time windows. These are broadly in line with the literature findings. suggesting that this literature revealed existing good practice and/or exerted a positive influence on instructors.[5] Instructors also often felt that their use of prelabs was hampered by pragmatic concerns around effectiveness and student workload. One significant, but not surprising, finding was the extent to which older prelabs are reused even with perceived shortcomings, due to the time required to prepare new material.

The current work is only a snapshot of current practices, rather than any judgment over whether those practices are effective or not, so no good practice recommendations can be made. Nonetheless, observation of widespread practices leads to some points which might be useful to consider for anyone designing prelabs in the future. First, it would be useful to consider what the purpose of the prelab is and work backward from those goals. Second, make good use of recent relevant literature on prelabs, professional development opportunities, and colleagues to identify likely problems and challenges in a local context, and the existing good practice that can mitigate them.[5,6,9,21,22,24,28] Lastly, recognize that any newly created prelab should be made long-lasting, as it could be reused for many years.

For future research in this area, a natural recommendation would be to conduct further snapshot studies, to build a better picture of the evolution of prelab use over time. One aim of the current study was not met, so another promising avenue would be to investigate instructor beliefs and motivations more fully through interviews or focus groups, probing the relationship between instructors and common sources of influence, such as professional networks and the educational literature.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.5c00321.

Survey text and full numerical and response data (PDF, DOCX)

■ AUTHOR INFORMATION

Corresponding Author

Patrick I. T. Thomson − *Department of Pure & Applied Chemistry, University of Strathclyde, Glasgow G1 1XL, Glasgow, U.K.*; orcid.org/0000-0001-9831-9199; Email: patrick.thomson@strath.ac.uk

Authors

Cristina Navarro − *School of Natural and Environmental Sciences, Newcastle University, NE1 7RU Newcastle upon Tyne, U.K.;* orcid.org/0000-0001-5816-0531

Benjamin E. Arenas − *EaStCHEM School of Chemistry, University of Edinburgh, EH9 3FJ Edinburgh, U.K.;* orcid.org/0000-0001-9471-778X

Mairi F. Haddow − *EaStCHEM School of Chemistry, University of Edinburgh, EH9 3FJ Edinburgh, U.K.*

Anna J. Kirkham − *School of Law and Policing, University of Central Lancashire, PR1 2HE Preston, U.K.*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemed.5c00321

Notes

The authors declare no competing financial interest.

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