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Using H5P to design and deliver interactive laboratory practicals

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Abstract

We describe the use of HTML5P (H5P) content collaboration framework to deliver an interactive, online alternative to an assessed laboratory practical on the Biomedical Cell Biology unit at the Manchester Metropolitan University, UK. H5P is free, open-source technology to deliver bespoke interactive, self-paced online sessions. To determine if the use of H5P affected learning and student attainment, we compared the student grades between three cohorts: the 18/19 cohort who had "wet" laboratory classes, the 19/20 cohort who had "wet" laboratory classes with additional video support and the 20/21 cohort who had the H5P alternative. Our analysis shows that students using the H5P were not at a disadvantage to students who had "wet" laboratory classes with regards to assessment outcomes. Student feedback, mean grade attained and an upward trend in the number of students achieving 1st class marks (≥70 %), indicate H5P may enhance students' learning experience and be a valuable learning source augmenting traditional practical classes in the future.

Introduction

Laboratory practical sessions are an integral part of Life Science education (1) and biological science students benefit from active, student-centred learning activities (2, 3). In practical classes, students can develop science knowledge through problem-solving and testing of concepts (4). Gaining practical competence on lab equipment and tools helps students become independent workers and this improves their career prospects. Despite concerns that virtual and/or online practical classes deprive students of essential psychomotor skills, their implementation in curricula has been steadily increasing over the years (5-8). The Covid-19 pandemic forced a sudden shift to online teaching and a need for laboratory alternatives. Various approaches, including "at-home" practical kits, third party virtual laboratory software and remote laboratory sessions were all implemented in response to Covid-19 (9-12).

Practical delivery

During the academic year 2020-21, we provided H5P online content as an alternative to the assessed 'Red Blood Cell' (RBC) "wet" laboratory practical for final year Biomedical Science students on the Biomedical Cell Biology Unit (module) at Manchester Metropolitan University. The "wet" RBC practical is an investigative case study involving blood sample analysis to identify the health conditions of four hypothetical patients: a normal healthy control, a patient with polycythaemia and erythrocytosis, a patient with a non-haemolytic anaemia (such as vitamin B12 or iron deficiency, dilutional anaemia or trauma with significant blood loss) and a patient with haemolytic anaemia (for example sickle cell anaemia, thalassaemia, or autoimmune haemolytic anaemia). This practical builds on topic content introduced to students in the second year of their Biomedical Sciences undergraduate degree. However, this is the first time the students will be introduced to several of the practical techniques, protocols and specialist equipment e.g., a microhaematocrit centrifuge, light microscopy and haemocytometers to count red blood cells. Students collect their

experimental data and calculate haematocrit, red blood cell count, total and plasma haemoglobin levels, and the degree of haemolysis for each blood sample.
Some of the techniques are complicated to explain both verbally and in written form and it is difficult for students to visualise unfamiliar techniques. Consequently, in the academic year 2019-20 we provided instructional videos of key laboratory techniques alongside the laboratory protocol ahead of the laboratory sessions.
Students have a single opportunity to attend the RBC practical class. The content of this practical is assessed as part of a summative multiple choice (MCQ) test, which is 30 % of the final grade. The MCQ has 40 MCQ questions, of which 20 questions are specific to the RBC practical. Aligning with the higher order thinking in Bloom's taxonomy (13-16), the MCQ tests students' problem-solving skills e.g., dealing with different scenarios and covers theory, experimental design, data analysis and interpretation. An example is "*Which blood samples (A, B, C, D detailed below) have a high red blood cell count? Sample A: Hct = 0.38; Sample B: % PCV = 47%; Sample C: Hct = 0.51; Sample D: % PCV = 44%. (Hct is the haematocrit and PCV is the packed cell volume)*". Students are provided with five options from which they have to select the single best answer. The MCQ has a 40 minute time limit. Students can use their notes/textbooks during the MCQ (open book), but it is held under exam-like conditions (i.e., timed, invigilated). During the lock-down, students completed the MCQ from home.
Herein, we describe our experience with H5P, a JavaScript based free and open-source content collaboration framework (17) to replace a "wet" laboratory practical and discuss its potential future applications.

Methods

In line with university and ethical guidelines, MCQ grades for the different academic years were obtained from the University's Student Record System and anonymised prior to analysis. A one-way ANOVA was performed to compare the MCQ mean grades of the 18/19 ("wet lab"), 19/20 ("wet lab" with additional video support) and 20/21 (H5P) cohorts using Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC. The data for all data sets followed a normal distribution. The total number of students in each cohort with grades in the band grades 0-39 %, 40-49 %, 50-59 %, 60-69 %, 70-79%, 80-89% and 90-100% was used to calculate the percentage to allow comparison between the cohorts and student attainment. An increase in the percentage of students with a grade of 70-100 % and a reduction in the percentage of students with a grade of 0-49 % is considered a measure of improved student attainment.
Student activity is measured by the number of students' first completion of H5P activities which is recorded with a grade.
In line with University feedback protocols and ethical procedures, student feedback for the different academic years was collated during mid-unit and end of session feedback surveys, and responses anonymised.

Findings

H5P allows the design of bespoke content

We initially reviewed third-party virtual labs and simulations (Labster, www.labster.com; LearningScience, www.learningscience.co.uk) that are accessible via an institutional license to effectively replace our RBC laboratory during Covid-19. However, the third-party material did not fit well with the bespoke unit content and did not meet the pre-defined unit and practical learning outcomes (Figure 1). This made us rethink our strategy leading to the use of HTML5P (H5P).

As our institution uses Moodle, we have access to H5P through the Moodle plugin, but H5P is also compatible with other virtual learning environments (VLEs) including Blackboard and Canvas (17, 18). Using the resources available from H5P (17), we were able to familiarise ourselves with the main H5P functionalities within days and designed an H5P that follows the order of the RBC practical protocol (Figure 1). In fact, we found that using an investigative case study provided an excellent basis for the H5P design. The different H5P applications (e.g., course presentations, integrated videos, quizzes) provide flexibility to design and deliver bespoke interactive sessions. We used the "course presentation" content type, which consists of interactive slides. These slides contain either background information and experimental detail (text), embedded videos or links to online resources, or quiz activities (multiple choice and true/false questions, drag and drop, fill in the blanks) (Figure 2). The activities were set up to provide students with immediate feedback and an option to see the correct answer. All students used the same data set in the H5P. Our technical team video-graphed experimental steps e.g., use of the microhaematocrit centrifuge, and the subtitled videos were embedded into the H5P.

As the final activity, students followed a link to a formative Moodle MCQ, which was designed to test their results and receive feedback on the data analysis. We could have designed this MCQ within the H5P environment but decided to use the Moodle platform to help students familiarise themselves with the format of the summative MCQ for this practical.

H5P facilitates self-directed learning

Staff delivered a preparatory lecture online, via MS Teams, before the release of the H5P. Once released, students could work through the H5P at their own pace and with unlimited number of attempts for quizzes. The H5P focusses on data interpretation, analysis and problem-solving skills i.e., diagnosis of a condition. Experimental techniques are demonstrated in the associated videos, with some interactive activities, such as lining up haematocrit samples and readers, and performing a haemocytometer count. To facilitate peer-learning and collaboration, we set up a Moodle Q&A discussion blog. Using the same data set, students can directly compare their results. All students and staff enrolled on this unit received an email copy of the Q&A blog which made monitoring easy, kept everyone updated, and allowed a timely response from staff as required. There was no set deadline by which students had to complete the H5P. Students' activity using the H5P was the highest after the release of the H5P, with 25 % of the students completing it within the first week. This was also reflected in the number of questions/responses on the Moodle blog. The activity logs indicated that students accessed the material multiple times over the duration of the unit with 14.5 % of students working through the H5P activities in the week of the assessment. We did not experience any technical issues and students who responded to the end of session feedback surveys were positive about using H5P (Figure 3). Whilst all of the student feedback received relating to H5P was positive, the sample size of students who submitted feedback was small (<10%), and therefore may not be representative of the entire cohort.

H5P supports student learning

To assess the effectiveness of H5P versus laboratory sessions, we analysed students' performance on the summative RBC MCQ of cohorts from the academic years 18/19, 19/20 and 20/21. Student grades for the RBC part of the MCQ (20 questions) follow a normal distribution for all cohorts and there is no significant difference between the year groups (Table 1). There appears to be a steady increase in the mean grade attainment for the RBC practical MCQ over the last three years, but this is not statistically significant. The median grade has remained the same (Table 1, FigureFigure 4). It is noteworthy that from 18/19 to 19/20 more supporting material (i.e., videos of equipment use) were available to students (Table 1), which may be a contributing factor. Comparing the 19/20 (pre-Covid) with 20/21 (H5P) cohort, the percentage of students achieving between 0-39 % or 40-49 % decreased by 13.5 %, whereas the percentage of students achieving a grade between 50-59 % and 70-79 % increased by about 6 % and 3% respectively. This trend may be explained by H5P's easy, on demand accessibility to review the material. The completion of the RBC practical was 20 % higher with H5P in the 20/21 academic year than with the "wet" laboratory practical of the previous year.

Contribution to the field

Blending traditional with virtual learning methods has been recommended (19) and online teaching alongside face-to-face sessions may be a permanent post-Covid-19 adaptation (20, 21). Online teaching has the potential to increase accessibility, including remote areas of the world, reduce attainment gaps, and address organisational, logistic and financial challenges of running laboratory classes for large cohorts (22). Hence, an evaluation of online alternatives for "wet" labs, such as H5P, is timely and necessary to inform our teaching strategy. With most universities using a compatible VLE, H5P is an option to deliver bespoke interactive online sessions that can augment teaching, not just laboratory practical classes.

Conclusions

Our case study shows that H5P can be used effectively to deliver interactive online teaching and meet learning outcomes. It may even be argued that students performed better with H5P compared to laboratory practicals alone (5, 23) In our case, H5P was the most appropriate solution, but one should consider all available options (for example see (24, 25).

Using H5P, students are in control over their learning and can work through the material at their own pace. The immediate feedback from quizzes allows students to review their progress and reattempt exercises as necessary. This aligns with the idea of independent and self-directed learning as proposed by Knowles (26). The associated Q&A blog allows students to peer learn and contact staff for practical focused assistance. Embedding videos specific to the process is a successful tool to communicate complex topics and can improve student learning and engagement (27). Using audio-visual media aligns with Paivio's 'dual coding theory' which proposes that providing the same information in two different ways (verbal v. non-verbal), enhances the working memory capacity and ability to create meaning (28). Although both the introduction of supporting videos (19/20 cohort) and H5P (20/21 cohort) showed a positive effect on student learning, we cannot comment on whether these two methods can be considered interchangeable/at-par, as the possible effects of different learning environments, face-to-face versus online delivery, cannot be assessed with the existing data.

Using the same data within the H5P facilitates a student discussion of the results and overcomes any concerns of experimental error due to lack of face-to-face supervision. As facilitators to learning we can be confident that students have the correct example data for analysis and interpretation. However, if analysing and comparing characteristic and uncharacteristic data was desirable (19), it would be possible to provide different data sets and additional activities to interpret and analyse outliers and unexpected results.

We used H5P for final year BSc Biomedical Science students, but H5P is suitable for other subjects and study levels (29, 30). However, there is a strong case to provide "wet" laboratory practical sessions to foundation/first year students to allow them to acquire hands-on experience and skills (31).

As we move forward in post-Covid-19 teaching we propose that incorporating bespoke H5P online laboratory material will provide additional support for students, their learning, and their assessments. We continue to use the H5P to augment the laboratory sessions in 21/22 for the Biomedical Cell Biology unit. We have also introduced H5P as an extra resource for second year students, who value H5P as an additional support to help them with laboratory techniques, evaluate their laboratory results in comparison to the expected results and support their data analysis (Figure 5). This helps students achieve the learning outcomes for the practical element that focus on describing methods and carrying out data analysis

Online teaching can facilitate inclusive learning and teaching (32) although some reports suggest this may not apply to widening participation (33). Biomedical Science at Manchester Metropolitan University prides itself in its diverse student population. In 2019/2020, 61 % of students in our faculty identified as Black, Asian and minority ethnic. The H5P packages (in addition to "wet" labs) ensure inclusion of all our students, offer access to relevant study material, should students be unable to attend the laboratory classes, and provide an additional level of support. The University has provisions to ensure all students have access to the internet and IT equipment to support them with their studies. It will be of interest to analyse if H5P in addition to laboratory labs helps close the attainment gap between student groups.

Although we successfully used H5P instead of "wet" labs during Covid-19, we do not conclude that H5P or other online alternatives could or should replace laboratory practical entirely in the future. There is evidence that use of pre-lab simulations can enhance students ability to carry out techniques (34), but to which extent this meets learning outcomes that are tied to specific practical skills will require further evaluation. We however strongly support the use of H5P as an additional learning aid for undergraduate students on practical based courses.

Summary points

- "Wet" lab practical classes are an important part of HE teaching but their delivery and overall student experience can benefit from using supporting interactive online platforms.
- Appropriate H5P designs can effectively deliver online practical classes, without negatively impacting student attainment, if necessary
- A review of the long-term effect of online learning, using platforms like H5P, on student attainment will be necessary to help inform inclusive, interactive learning strategies.

Ethical Approval

Ethical approval was provided via the Manchester Metropolitan University Faculty of Science and Engineering Research Ethics and Governance Committee (Reference Number: 2021-33448-26223).

CRediT Author Contribution

Amanda J. Unsworth: Conceptualization, Writing – review and editing, Formal analysis, Investigation**. Mareike G. Posner**: conceptualization, Writing – original draft, Writing – review and editing, Formal analysis, Investigation, Visualization

Competing Interests

The authors declare that there are no competing interests associated with the manuscript.

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Tables

Table 1 Summary statistics for the 18/19, 19/20 and 20/21 cohorts. The MCQ mean grades of the 18/19 ("wet lab"), 19/20 ("wet lab" with additional video support) and 20/21 (H5p) cohorts were analysed using a one-way ANOVA. Mean and median grades are based on the RBC element of the summative MCQ only.

Cohort	n	Mean grade	Std. Dev.	Median grade	Practical delivery	Additional support and material
18_19 cohort	93	60.43	19.98	65	"wet" lab	Introductory lecture
19_20 cohort	101	63.07	17.63	65	"wet" lab	Introductory lecture Videos of experimental elements made available before practical sessions
20_21 cohort	96	65.62	16.13	65	H5P	Introductory lecture Videos of experimental elements made available before the practical session and as part of H5P interactive session
Total	290	63.07	18.02			

Analysis of variance					
Source	**MS**	**df**	**MS**	**F**	**Prob > F**

Between cohorts	1274.81014	2	637.40507	1.98	0.1404
Within cohorts	92543.8106	287	322.452302		
Total	93818.6207	289	324.631906		

Figures

Figure 1 Overview of the H5P design and learning outcomes. Students are working through the different activities and can check their data before moving to the next aspect. The final multiple choice requires students to review their results and provide a possible diagnosis for the patients' conditions. The material covered and exercises align with the unit's learning outcomes.

Figure 2 Examples of H5P activities. A) Pictures of the microhaematocrit centrifuge with instructions and a link to a video showing the use of this specialised equipment. B) – C) is an example of a drag and drop exercise. Students are asked to determine the haematocrit values (B); Once students proceed to attempt the exercise, the possible areas to drop the tube are highlighted by boxes; D) Shows a correct alignment. Students use this chart to read off the % haematocrit values.

Figure 3 Examples of student feedback on using the H5P instead of laboratory practical sessions on the Biomedical Cell Biology Unit in 20/21.

Figure 4 A: Boxplot of the percentage (%) grades of students for the cohorts 18/19, 19/20 and 20/21. **B**: Bar chart showing the distribution of students per grade band (%) for each cohort.

Figure 5. Student feedback from 2nd year students (21/22 cohort) on using H5P in addition to laboratory practicals on the Blood Science Unit on the Biomedical Science Programme at Manchester Metropolitan University.

Figure 1

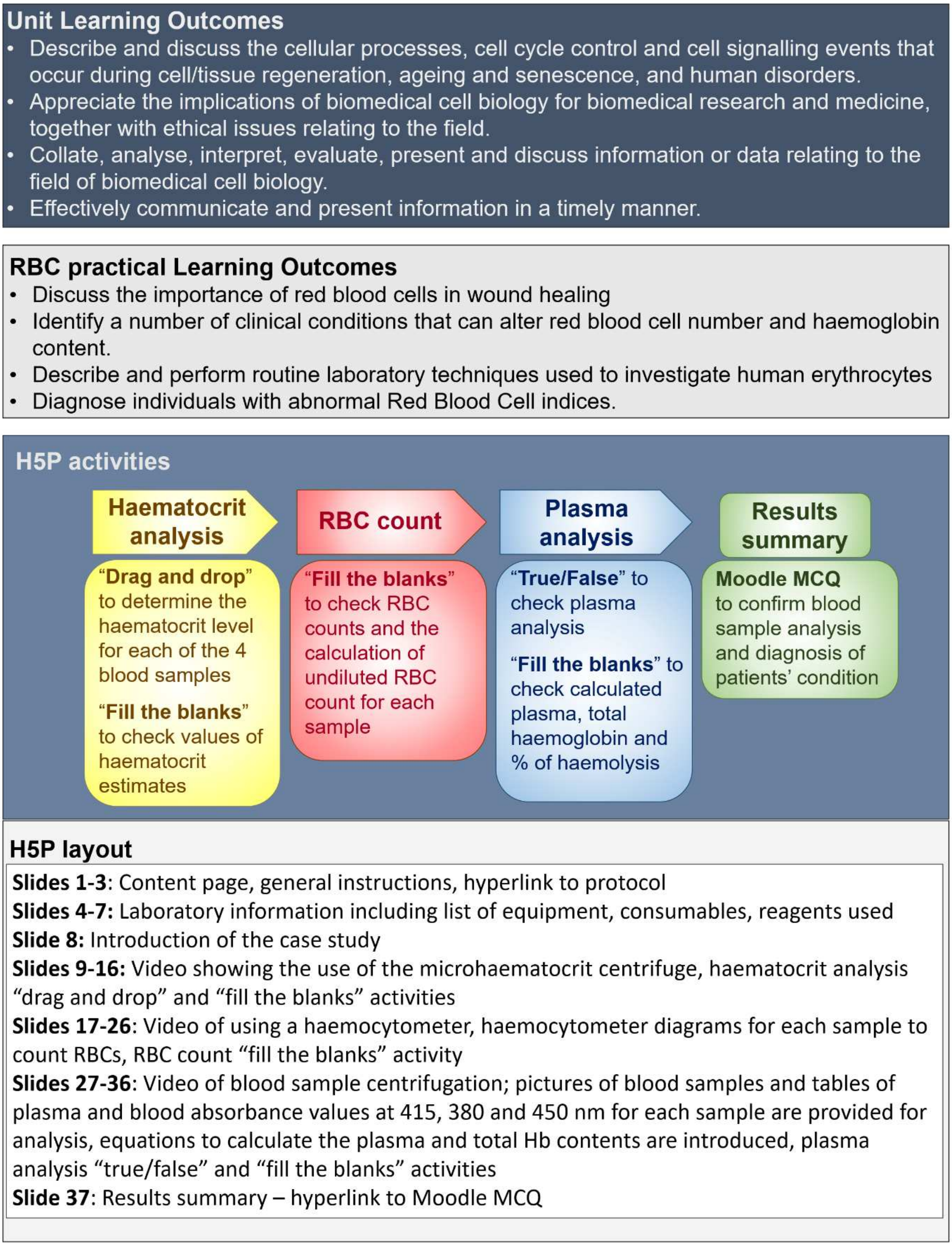


Figure 2

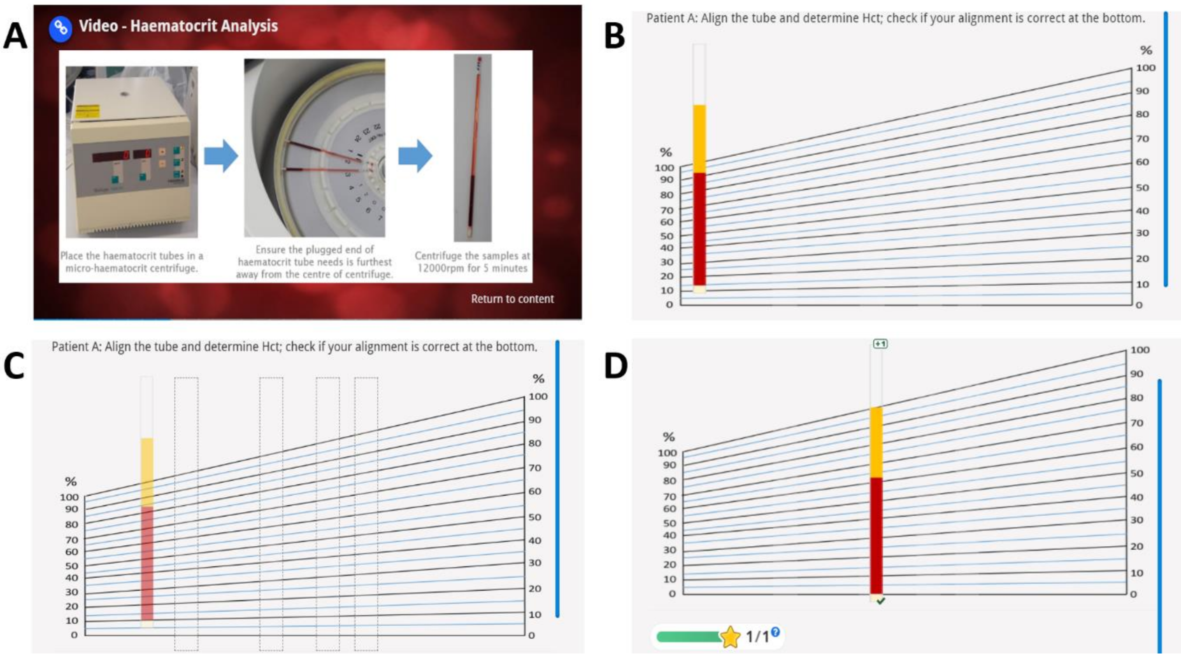

A
Video - Haematocrit Analysis
Place the haematocrit tubes in a micro-haematocrit centrifuge.
Ensure the plugged end of haematocrit tube needs is furthest away from the centre of centrifuge.
Centrifuge the samples at 12000rpm for 5 minutes
Return to content
B
Patient A: Align the tube and determine Hct; check if your alignment is correct at the bottom.
C
Patient A: Align the tube and determine Hct; check if your alignment is correct at the bottom.
D
1/1

Figure 3

I found it extremely useful, it was the best alternative that could have been provided seeing as we couldn't physically go into the labs. I particularly liked the way it followed through, right from the 'content' page to the end where it lead nicely onto the practice MCQ's on Moodle. It was easy to work through and all the sections made sense. I would give this a 5/5. In terms of future use, I think it would be useful along with F2F practicals, as it gives students a chance to get their head around the principles of the practical and work through examples in their own time and space.'

'I really enjoyed the Red Blood Cell practical, the Labster (commercial online) practicals are a bit more professional but I found it just as helpful when preparing for the practical MCQs. Even if we were able to be in the labs, I would have found this extremely helpful as extra support, as you can go back over the practical before exams and I found the questions useful.'

Figure 4

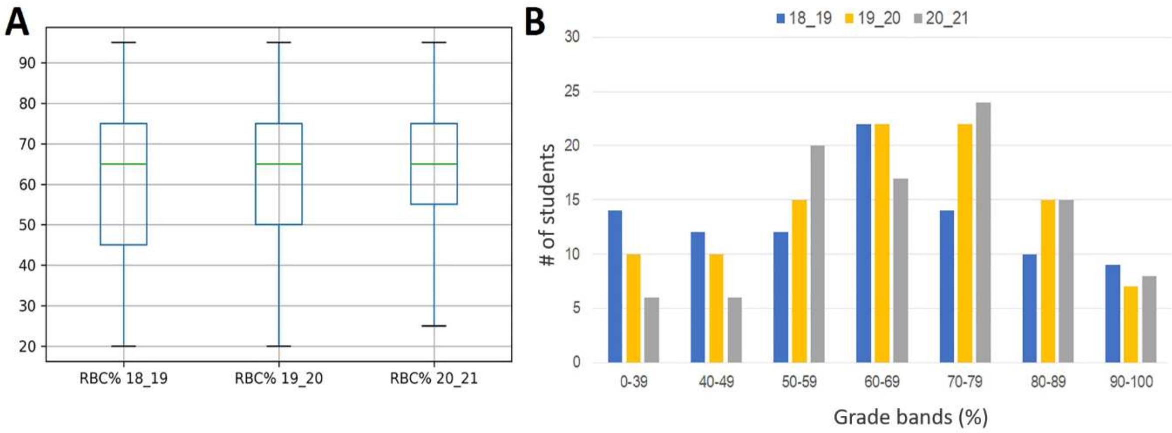
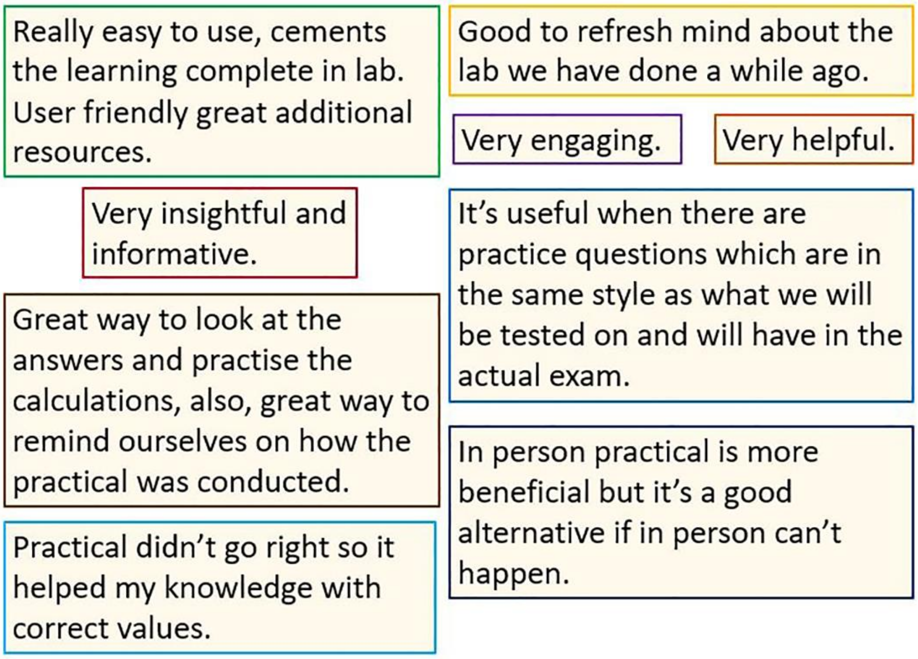

A
90
80
70
60
50
40
30
20
RBC% 18_19
RBC% 19_20
RBC% 20_21
B
18_19
19_20
20_21
30
25
20
15
10
5
0
# of students
0-39
40-49
50-59
60-69
70-79
80-89
90-100
Grade bands (%)

Figure 5



Really easy to use, cements the learning complete in lab. User friendly great additional resources.
Good to refresh mind about the lab we have done a while ago.
Very engaging.
Very helpful.
Very insightful and informative.
It's useful when there are practice questions which are in the same style as what we will be tested on and will have in the actual exam.
Great way to look at the answers and practise the calculations, also, great way to remind ourselves on how the practical was conducted.
In person practical is more beneficial but it's a good alternative if in person can't happen.
Practical didn't go right so it helped my knowledge with correct values.

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