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Remotely Teaching Practical Science in Student Kitchens

BETHAN GULLIVER AND KELLY EDMUNDS
University of East Anglia

The challenge of teaching practical skills to students on a Foundation Year biology course within the constraints imposed by the Covid-19 crisis required the adoption of innovative teaching strategies. A series of kitchen practicals were devised to support the curtailed or streamed laboratory practical sessions. The activities were delivered through asynchronous, collaborative Padlets accompanied by synchronous workshops and support sessions. These activities involved applying abstract scientific ideas to familiar contexts. Engagement with these activities required the students to work individually. However, the Padlets enabled students to share their methods, results and experiences with their peers and teachers. The kitchen practical activities were popular with students and led to high levels of engagement and achievement. This article explores the reasons for the success of our strategy and argues that similar methodologies for practical teaching have their place in practical teaching post-pandemic.

Introduction

One of the advantages of a foundation year for students is the increased confidence that it provides for their Year One studies. While this often manifests as a greater willingness to ask for support compared to their peers from more conventional backgrounds (Hale, 2020), in science an additional advantage is the practical laboratory experience that students gain. Consequently, practical sessions and the teaching of practical skills form a significant and important component of most Foundation Year biology courses. Requirements for social distancing during Semester One of the 2020-21 academic year and the announcement in January 2021 that university-based teaching for science courses in England would not take place until late April 2021, required us to innovate and develop pedagogical strategies appropriate to a pandemic.

During the first semester we planned for shortened, socially-distanced practical sessions, supported using practical 'learning strips' (Fig. 1). Each practical learning strip consisted of a series of activities presented through a Blackboard module page. These activities led students through formative tasks culminating in the laboratory-based practical session. This method was adapted in Semester Two to allow for formative and summative assessment of the practical work.

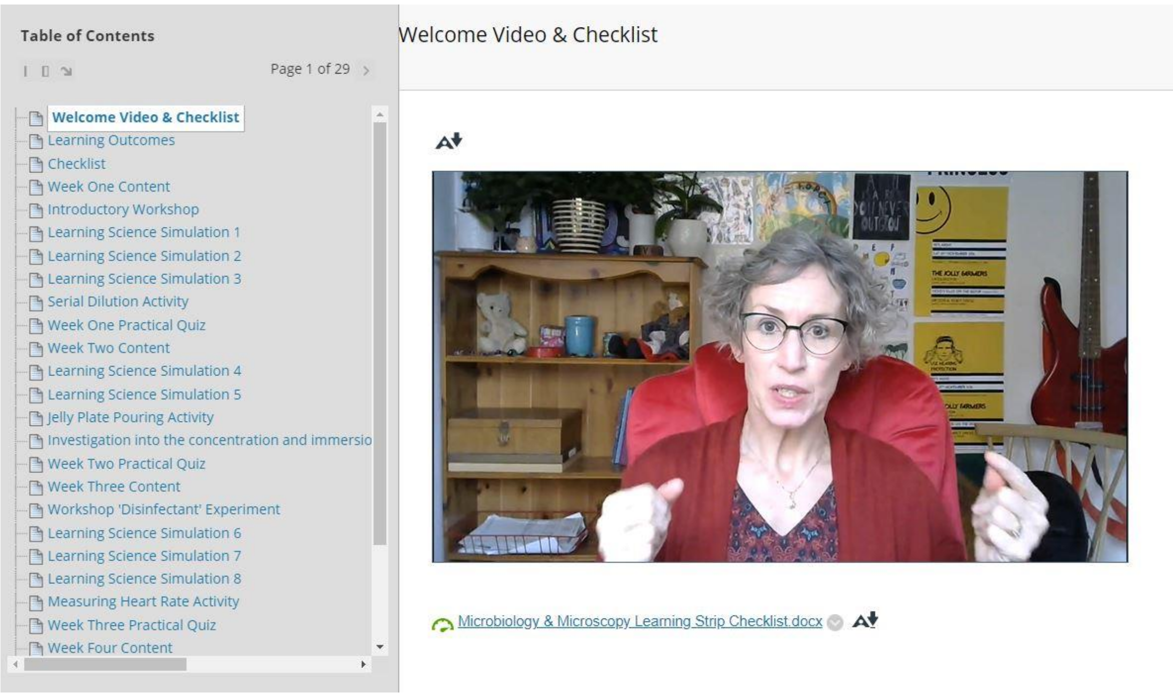

Figure 1: The Learning strip for Semester Two's formatively assessed microbiology and microscopy practical.

A range of resources and platforms were used to create activities in the learning strips including the commercially produced Learning Science laboratory simulations and Padlet. The table of contents on Blackboard linked directly to these activities. Achievement of the learning outcomes and assessment objectives in the formative and summative assessments was met through completion of a skills portfolio and practical proforma as shown in Figure 2a. The skills portfolio required completion of 'kitchen biology' tasks, engagement in online synchronous workshops, the completion of laboratory simulations, and collecting and presenting data gathered from online synchronous practicals. The practical proforma provided a scaffold for students to present their work in a standard format as would be expected in level four courses. A marking rubric (Fig. 2b) was released to students before the submission date and detailed where credit would be given.

BIO-3001B 2021 Further Biology

Submission day April 28th 2021 3pm

This is a Summative Assessment worth 40% of your BIO-3001B grade.

Word count: 500 word limit, not including tables, figures, references and appendices.

Enzymes practical report

Download this proforma, complete it using an appropriate word-processing package, e.g. MS word. Once completed save as a PDF document and submit via blackboard as a PDF.

Remove the comments and instructions that are in red but retain all the headings and layout. Please write in full sentences!

If you find your word processor will not let you work within this layout, you may copy the section headings into a fresh document, but please leave a wide right-hand margin for marks and comments.

A: Skills Portfolio

No.	Skill	Activity	Achieved	Evidence Provided
1	Gain practical knowledge	Watch Learning Science Activities	**Y/N**	Write completion date here
2	Apply knowledge theoretically	Complete practical quizzes	**Y/N**	Write completion date here
3	Apply knowledge practically	Write method for laundry detergent practical	**Y/N**	Attach method as an appendix
4	Apply practical knowledge	Complete laundry detergent practical	**Y/N**	Attach photograph of results as an appendix
5	Calculate concentrations	Workshop 15th March 2021	**Y/N**	Attach photograph of calculations as appendix
6	Draw a calibration curve	Workshop 15th March 2021	**Y/N**	Attach photograph of graph as appendix
7	Gather experimental data	Collaborate Lab session 24th March 2021	**Y/N**	Attach photograph of results table from lab book as an appendix
8	Present experimental data correctly in a table	Collaborate Lab session 24th March 2021	**Y/N**	Attach photograph of results table from lab book as an appendix

BIO-3001B 2021 Further Biology

B

Aim

Clearly state the aim of this experiment.

Results

Refer to an appropriate appendix with your raw data.
Present a clear table showing the data (absorbance readings for all tubes).

Refer to an appropriate appendix with your calibration curve.
Refer to an appropriate appendix showing your derivation of values for reaction rate by using the calibration curve.
Refer to an appendix with your hand drown graph with a plot of **reaction rate** (in micromoles sucrose converted per min) against **substrate concentration**.

Discussion

Discuss your graph of reaction rate against substrate concentration, clearly comparing the curve you obtained to the pattern you would expect from previous studies of enzymes (reference the source for your expectation). Discuss possible sources of inaccuracy or anomalous results.

Conclusion

Summarise the relationship between rate of reaction and substrate concentration in an enzyme-mediated reaction, as shown in this experiment (i.e. put into words what your graph shows). Give an estimate of the maximum reaction rate from your graph, and the substrate concentration at which this is reached. This is a summary so keep this clear and concise.

Reference

Give the reference for the source of your information on what the shape of the line on the graph should be.

Appendices:

All appendices should be clearly titled.

Figure 2: Practical skills portfolio, proforma and rubric. a) Practical skills portfolio and proforma

Student Number: **BIO-3001B Summative Practical Report Feedback & Marking Criteria**

Strengths of the report:	
Areas for improvement:	

Criteria	40%	40 - 55%	56 – 69%	≥70%
Aim	No aim or the aim has no relevance to the experiment.	The aim relates to the methods used rather than the purpose of the experiment.	Aim relates to the purpose of the experiment. Wording could be improved.	Clear, concise, specific and scientifically appropriate aim.
Results	Data missing or inaccurate. Lacking in evidence which shows an understanding of the results.	Results presented but with several inaccuracies. Some errors in calculations. Units not given. Appendices referred to.	Results presented but with some minor inaccuracies. Calculations are correct with units given. Appendices referred to.	Results clearly presented. Calculations performed correctly. Units correctly given and appendices referred to.
Discussion	Little to no discussion of results. Inaccuracies and anomalies overly focused on.	Results stated with some discussion. Reference to expected results. Inaccuracies and anomalies overly focused on.	Detailed discussion presented with logical explanation and reference to expected results. makes general suggestions to improve the investigation.	Detailed discussion commenting on all aspects of the reports in a logical manner. Suggests specific changes that would improve the investigation. Reference cited.
Conclusion	No appropriate conclusion or estimates made.	Conclusion made but does not relate to aim. Graph referred to.	Reasonable conclusion, relating to aim. Graph referred to.	Clear, concise, specific and scientifically appropriate conclusion. Graph referred to.
Organisation	Presentation of work lacks coherency and contains several errors.	Work mostly presented coherently and correctly with some inaccuracies	Work consistently presented coherently and correctly with only some minor errors made.	Work presented coherently and correctly. All graphs, tables and appendices correctly titled.
Quality and Clarity of Writing	Need to improve on the use of units and the appropriate use of scientific language.	Language used appropriately but some areas could be improved or have greater clarity. Units used correctly.	No errors in scientific notation and appropriate use of scientific language with only minor errors. Writing is mostly concise with a clear scientific message.	Excellent use of scientific language with clarity of writing and scientific notation used appropriately. Correct units used.
Appendices	Absent	Present, with significant error or unreadable.	Present with only minor inaccuracies.	Present and correct.
Skills Profile	Appropriate evidence for less than four skills submitted correctly.	Appropriate evidence for a minimum of four skills submitted correctly.	Appropriate evidence for a minimum of six skills submitted correctly.	Appropriate evidence for all skills submitted correctly.

b) Practical skills rubric

Kitchen Practicals

In Spring 2019 the New Science Building (NSB) at UEA was opened by Jane Goodall. The teaching laboratories were designed for the effective teaching of classes of up to 160 students. However, the need to socially distance reduced the maximum number of students able to use each laboratory to 42. Our cohort now required six laboratory sessions to complete a practical rather than the two sessions of previous years. Extra time was also needed between laboratory sessions to allow for hand washing, mask changing and sanitising of the workspaces. The consequence of these Covid restrictions meant that each group would only have one, one-hour session in the laboratory for each practical activity rather than the two, two-hour sessions planned. Additionally, group work could not take place meaning that students would need to work individually.

Planning focused on how best to use the available laboratory time to the greatest effect. The first practical of the year was an estimation of the water potential of potato tissue, a topic familiar to many of our students. Choosing a familiar topic allows learning to be focused on the use of practical equipment and the presentation and analysis of results without the additional burden of the cognition required when introducing new biological concepts and understanding (Paterson, 2017).

Figure 3: Laboratory set up for socially distanced osmosis practical.

In a level three course, practical skills can be thought of as divided into:

1. Planning of experiments and investigations
2. Collecting, recording and presenting of observations, measurements and estimates
3. Analysis interpretation of data to reach conclusions
4. Evaluation of methods and quality of data.

We wanted to ensure that students addressed the full range of practical skills. The kitchen biology tasks in Semester One were designed to address skill one, the planning of experiments and investigations as well as the completion of full investigations, including the preparation of samples. A significant amount of time in a biology laboratory practical is spent preparing samples and incubating. To minimise the amount of students' time spent on these necessary but repetitive tasks, the technicians and teaching staff spent hours cutting and weighing thousands of potato disks and incubation was done prior to the arrival of the students. This allowed us to concentrate the students' time in the laboratory on skill two, collecting and recording data using the university standard equipment available. Workshops and Padlets allowed for the development of skills three and four, analysis and evaluation.

In the first kitchen biology task students carried out a series of serial dilutions using glasses and fruit squash. Preparation of serial dilutions is straightforward. However, students often have trouble in using these dilution factors correctly in subsequent calculations. Performing the dilutions using micropipettes and Eppendorfs in university laboratories in the company of your new peers and tutors masks the simplicity of the task and can induce an anxiety that impairs learning. The same is not true in the student's own kitchen. Repeatedly diluting blackcurrant squash by a factor of two provides a standard dilution series which can be seen. Pairing this with a laboratory simulation on serial dilutions allows the student to make the link from the serial squash dilution to the procedure they would be carrying out in a laboratory. Kitchen biology activities provided concrete experiences on which to build and layer knowledge gained from laboratory simulations, laboratory practical and theoretical work.

The kitchen biology activities allowed the students to experience completing full practicals. In the first and second semester a kitchen biology practical was assigned to the students prior to the laboratory sessions so that they could apply the knowledge gained from that task to the laboratory practical. A Padlet provided a basic protocol and short explanatory video that outlined the method. Padlets embedded within Padlets allowed the students to upload risk assessments, photographs of their equipment, pictures of their results, and tables and graphs. Links were made to useful resources such as those of the UEA Learning Enhancement Team to support the presentation of data. Workshops for subject cohorts (typically containing a maximum of 50 students) provided support with calculations, writing discussions and conclusions.

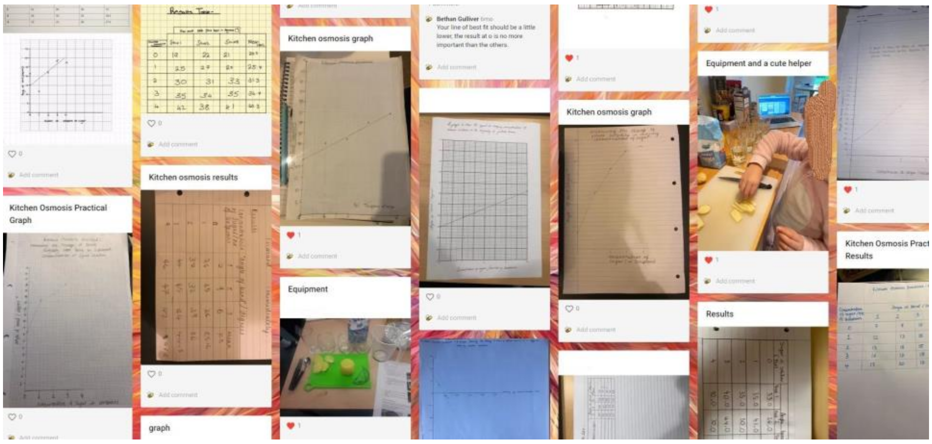

Figure 4: The results Padlet, embedded in the Kitchen Osmosis Padlet from Semester One. Students were provided with the method, guidance resources and even printable protractors to measure the bendiness of their potatoes.

Delivering the osmosis practical as a learning strip increased its complexity. What had been a simple three-hour laboratory based practical became a series of activities spanning several weeks and multiple platforms. Students had multiple opportunities to reach the learning outcomes through the range of online, synchronous and asynchronous activities. Skills were separated out and each given attention. The kitchen biology activities lent themselves to this well. For example, the need to control variables becomes a much more pertinent conversation when held between two students in different kitchens, with different types of potato and size of chip. The many variables that may bring about differences in results are both more obvious and more relatable to the laboratory practical. However, for some students the increased complexity of the practicals provided an organisational challenge. Much work was done to ensure that communication with the students was effective and to model good organisational strategies, resulting in the production of weekly checklists and checklist videos to provide clear pathways through the material (Edmunds & Gulliver, 2021).

Table 1: Practical Schedule

Semester	**Practical**	**Delivery**	**Kitchen Biology Padlet Task**	**Assessment**
1	Osmosis	1 hour laboratory practical	Serial Dilution	Informal
	Anatomy	1.5 hour laboratory practical	Osmosis in Potatoes	Informal
2	Microscopy & Microbiology	2 hour streamed laboratory practical + 1 hour preparatory workshop	Jelly Plate Streaking	Formative
	Enzymology	2 hour streamed laboratory practical + 1 hour follow up workshop	Laundry Detergent Enzymology	Summative (40% of module total)

Table 2: Delivery of skills through the osmosis practical

Skill	**1** **Planning of experiments and investigations**	**2** **Collecting, recording, and presenting of observations, measurements and estimates**	**3** **Analysis and interpretation of data to reach conclusions**	**4** **Evaluation of methods and quality of data**
Activity	• Kitchen biology osmosis task	• Kitchen biology tasks • Laboratory experiment	• Workshop	• Laboratory discussion • Workshop • Padlets

Padlets

Padlets were chosen as the platform for the kitchen practicals as these provided an accessible method of sharing information with students. Students were able to upload photographs of their work quickly from mobile phones using the app and had the choice of uploading anonymously. The Padlets became part of our learning community operating as informal shared spaces where students could obtain information from us and share information with their peers. Informal 'assessment' by comment and emoji allowed speedy acknowledgement, recognition and appreciation of the work completed by students.

Engagement with the kitchen osmosis practical was very good with more than half the two hundred strong cohort posting results, graphs and/or discussion on both the kitchen biology and the laboratory biology results Padlets. A significant proportion of students were making multiple posts. This represented a very high level of engagement with what was an unmonitored, informal exercise. In the laboratory sessions, engagement with the discussion was of a higher quality than previously observed and it was clear that students were making links between their experience in the kitchen and those in the laboratory.

It became apparent early on that students were using the posting of photographs of their equipment and their results to express their individuality. It is notoriously difficult to get students to post pictures of themselves on welcome boards or to put their cameras on in synchronous online sessions, often for understandable reasons. When reviewing the first kitchen biology Padlet we noticed that dilutions were being made in a variety of different glasses; shot glasses, wine glasses, champagne flutes or even a range of mugs. Vessels were positioned in front of windows to showcase gardens or cityscapes. Pets or enthusiastic offspring or younger siblings acting as helpers were visible in many pictures. The students were taking ownership of their work and using this opportunity to share information about themselves in a manner and a format where they had control and in which they felt comfortable.

This personalisation allowed us to get to know our students. Our online sessions often started with a few minutes of informal chat as the students 'checked-in' and the shared Padlets lent depth to these online conversations as students commented on someone's 'fancy' glasses or discussed pets. The warmth and humour apparent in these conversations led to a sense of the module being a caring, learning community which we feel was important to establishing student confidence and trust in us as well as supporting their wellbeing. Additionally, the Padlets provided useful learning opportunities for the students, with engaging activities related to their goals. Some students carried out quite complex investigations with the laundry detergent practical leading to some excellent and well-designed practical work. By encouraging and providing opportunities for students to engage in deep learning, successful learning strategies were modelled, and student wellbeing promoted (Marton & Saljo, 1984; Alt & Boniel-Nissim, 2018).

It is worth noting here that engagement with the Padlets was entirely positive. The Padlets were set up to replace any inappropriate language with emojis and were monitored regularly for negative or potentially offensive comments. However, no negativity occurred, which is striking in such a large cohort. Considerable work had been put into building a sense of community (Edmunds & Gulliver, 2021) and on the very few occasions where inappropriate comments were made in synchronous workshops, these were pointed out as unprofessional and lacking in respect. As a significant proportion (approximately 40%) of the cohort were studying foundation courses leading to healthcare professions, this language carried weight.

Bugaric *et al.* (2012) discuss the way in which recipe-style practicals, designed to give reliable results each time, can limit an individual student's ability to contribute scientifically to the practical learning process. The kitchen practicals required the students to alter the method, to customise the practical, to problem solve, to adapt and to create their own individual work. In this way the students were creating their own models to aid their understanding and their own 'knowledge structures' (Harel & Papert, 1991) and were becoming involved in the construction of their knowledge. The use of Padlets gave them ownership over how these structures were made public. The photographs of the serial dilutions or bendy chips became their 'objects to think with', providing the key to learning necessary to the constructionism approach as described by Papert (Ackerman, 2001).

It has been observed that students often struggle to make links between learning in one situation with that in another (Brown and Collins, 1989). Padlets allowed for explicit links to be made between the learning carried out in the students' kitchens, their online learning and the learning carried out in the laboratory. Workshops and the weekly synchronous Q&A sessions further strengthened these links and the individuality expressed in the Padlets fed into the sense of community fostered in these sessions. The kitchen biology tasks also moved learning away from the computer screen allowing a 'digital detox' which has been linked to both a lessening of cognitive overload and increased feelings of well-being (Schmitt *et al*., 2021).

Laboratory Sessions

The laboratory sessions run in Semester One were well received. UEA ran its own Covid testing system for those on campus and students were supported in isolating after contact with a Covid positive case. This meant that numbers attending practicals were not as high as expected and considerable flexibility was required. However, students engaged well with the practical activities and clearly welcomed the opportunity to familiarise themselves with the laboratory and the equipment. Students were encouraged to collaborate in these sessions through the need to share and discuss their results and observations.

In Semester Two data collection was carried out through synchronous streamed practical sessions. The practical was conducted live in the laboratory by one of the academic team with cameras set up in such a way as to allow the students to collect the data themselves. Over 200 students joined the two-hour sessions using Blackboard Collaborate, the same format as used in their weekly workshop sessions. The chat box and write-on slides were used to allow students to interact anonymously or by name. As well as one of the team in the lab, a second academic provided support from home and was able to answer questions while the practical took place. For the summative practical, an additional member of the academic staff provided support in the laboratory, too.

Figure 5: Streamed microbiology and microscopy practical session

By this stage of the course students were very comfortable with the format of the workshops and participation was excellent. We had decided against using synchronous online lectures as the cohort size was too large. Synchronous workshops supported asynchronous lectures instead. These sessions were highly interactive, and students were used to participating fully in synchronous sessions. This led to a very active sessions as almost 200 students made observations or sought answers to their questions. In the summative practical the understandable desire of the students to 'get it right' meant that anxiety levels were also high. In response, following the sessions the streamed practicals were made available as unedited recordings and online workshops and support videos were provided to support the analysis of their results, guiding students through the calculations and analysis required. Drop-in online Q&A sessions were held for those who had been unable to attend the synchronous session due to illness or isolation.

By the spring break the Covid situation had evolved so that in April 2021 optional practical sessions could be offered to all students to give them the opportunity to use the skills that they had learned remotely during the semester, in the laboratory setting. These sessions were very well attended, and students carried out tasks related to the formative and summative practicals individually and shared results to obtain full sets of results. The focus was very much on the experience of using the equipment to obtain meaningful results rather than the interpretation of the data. The sessions allowed us to assess the efficacy of our approach that year. The laboratory sessions were 'low stakes' and those attending were keen to participate and talk about their experiences of the year. Informal feedback given at these sessions reflected that given in the module feedback: the range of practical activities offered throughout the academic year were felt to have been beneficial and had raised the confidence of students.

Consequences

The 2021 pandemic provided us with the opportunity to rethink the practical activities and the practical experiences we offer to our students. Several benefits emerged. By deconstructing our practicals, separating out the learning skills, and in moving some of the practical learning out of the laboratory, we raised the profile of practical learning. This resulted in a change in the role of the laboratory, which became a space for data collection and for social learning, a space where synthesis of practical knowledge took place.

A commonly communicated fear from our students throughout this academic year was the concern that they had missed learning opportunities and would be at a disadvantage compared to those students joining them from schools and colleges in their level four courses. It is our feeling that our students will be in many ways more prepared than in previous years. They have had to continually apply their knowledge in new and varying situations, applying what is learned online to what is learned and applied in the kitchen to what is applied in the lab. This continual application of knowledge and their construction of knowledge frameworks based on concrete experiences should lead to a deeper understanding of the techniques and methods used, as well as an understanding of the resources available for support.

Many of us who are used to leading and participating in laboratory sessions have observed those individual students who fail to actively engage with the practical work. The move towards working in pairs or small groups in practical sessions over recent years has allowed this to become a more widespread issue. The need to socially distance and to work alone in their kitchens and the laboratory reduced this risk of disengagement as the laboratory practicals and the Padlets required students to share and discuss their results with others. In laboratory practical activities this meant that every student had a personal responsibility for gathering and recording data. For those of us observing the students in the practical, this appeared to increase participation by those students who may have previously taken a back seat, and as a consequence raised the importance of effective written and verbal communication. We also observed that the students most engaged with the Padlet Biology tasks were not only those most confident in the laboratory; for some the Padlets appeared to provide a safer and more private space for experimentation and expression of enthusiasm.

Back to the future

Kitchen practicals may provide a useful step in teaching the full range of practical skills and in preparing students for practical enquiry-based learning. The move of practical teaching out of the laboratory and into the wider environment shifted the emphasis of practicals away from 'getting' the expected results towards the promotion of curiosity, investigation and fun. The individuality and novelty of the kitchen experiments meant that students became the experts in their own investigation. Practical science became something that anyone could do, echoing the rise of citizen science projects over the time of the pandemic.

This project raised interesting questions about the motivation of students to engage with laboratory and wider practical learning, the benefits of practical experiences outside of the laboratory to support practical skills, and the barriers to participation. The need to rapidly respond to the changing situation brought about by the pandemic meant that we did not have time to gain the ethics permission necessary to investigate these topics through discussion with the student cohort.

It is our hope that, despite the many challenges that were presented during the 2020-21 academic year, our student cohort move on to their future studies feeling confident in their ability to approach the laboratory setting and with a growing curiosity to investigate the world of science – and that we as educators continue to think imaginatively about the teaching and learning strategies we employ.

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About the Authors

Dr Bethan Gulliver is currently a Lecturer at the University of East Anglia based in the Norwich Medical School having moved from the School of Biological Sciences in July 2021. She has a background in 16-19 teaching in schools, Further Education and Higher Education. She is passionate about teaching and learning and widening participation and inclusivity in education.

Contact Bethan on b.gulliver@uea.ac.uk

Dr Kelly Edmunds is currently a Senior Lecturer at the University of East Anglia based in the School of Biological Sciences. She is the Programme Director for the Science Foundation Year courses and has taught Foundation Year students for almost a decade. As the first in her family to go to University, she is driven by ensuring that anyone interested in pursuing studies in Higher Education, has the opportunity to do so. She is passionate about promoting science to young audiences and is a Director at a publishing company (Paramecium Press) that specialises in books which introduce children to the world of microbiology.

Contact Kelly on k.edmunds@uea.ac.uk

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