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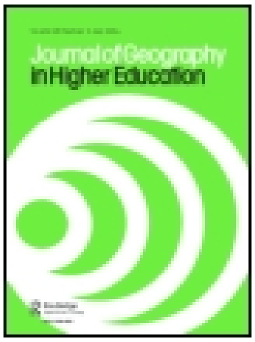

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Engaging geography students through innovation in statistics teaching

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ABSTRACT

Geography undergraduate students have broad academic backgrounds; consequently, teaching statistics can be especially challenging. Unfortunately, there is a lack of up-to-date and geography-specific literature on the pedagogies of statistics instruction on an undergraduate geography degree course. In this paper we detail, discuss, and reflect on a range of innovative attempts to improve engagement and attainment. Many of the examples revolve around technological platforms to enhance student engagement, but also to improve and simplify module management, an under-valued part of delivering a team-taught module. We discuss a variety of quizzing platforms as effective ways of engaging students with content, but, also, as a method of scaffolding teaching, whereby student comprehension is gauged, and content is adapted on-the-fly. We also highlight that use of frequent formative quizzing can increase module engagement through a substantive increase in attendance in an era of lecture recording. We also reflect on differences in engagement pre-and-post pandemic. Overall, we highlight the benefit of incorporating technology into teaching geographical statistics, but caution that this must be on a case-by-case basis and should be used for clear pedagogical reasons.

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Introduction

Methods training is a core part of a geography degree programme (Graves, 1975), however, much of the literature discussing geographical methods pedagogies in relation to statistics is from decades ago (e.g. Gregory, 1978; Neville, 1982; Silk, 1979). There is a need to update our discussion with new developments in pedagogical approaches and teaching technologies. It is worth focusing on the teaching of statistics within geography programmes, given that there is often trepidation or outright anxiety on the part of both students and staff when it comes to quantitative methods (Onwuegbuzie & Wilson, 2003; Zieffler et al., 2008). As Warwick and Ottewill (2004, p. 338) note, the "dreaded statistics course" can often gain a reputation as something of a problem module. This can in some part be due to the broad academic background of students taking a geography degree; from those who continued maths beyond sixteen and to those who stopped at this stage. The preparation of teaching materials for statistical analysis then has to be suitably

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tailored to build the groundwork for those who may have done very little, to those who may want more challenge within the content (Chapman, 2010); a considerable pedagogical task. In addition, the teaching of any methods has to be tied with current thought and practice at the time (see current debate on *p*-values [Leek & Peng, 2015; Wasserstein & Lazar, 2016]), which can rapidly evolve. This necessitates flexibility in the design and implementation of modules which can be changed and adapted as needed. We can further add the importance of teaching students the most relevant and up-to-date software in the field, and the consequent need for staff to be constantly keeping up with the rapid state of change. Finally, within all of this, we have to make sure that we are assessing students appropriately and effectively (Brian et al., 2000), consistently linking back to core goals and real-world reproducibility, i.e. how will the skill be used in the degree and beyond?

This paper details a series of pedagogical techniques and ideas that revolve around the effective use of technology for engaging students in the essential methods and statistics aspects of a geography degree programme. In particular, we unpack two main technological pedagogical approaches which are covered extensively for other subjects in the literature – 1) the use of in-lecture quizzing software, e.g. (Ataş & Delialioğlu, 2018; Dunn et al., 2012; Heaslip et al., 2014), and 2) formative quizzing, e.g. (Beesley et al., 2018; Bälter et al., 2013; Cohen & Sasson, 2016; Gikandi et al., 2011; Hatziapostolou & Paraskakis, 2010; Ogange et al., 2018). Of these Bälter et al. (2013) illustrated that short formative quizzes were appreciated by students, even though feedback was limited to a binary correct or incorrect response. In this work, we take this further by illustrating the use of more detailed feedback alongside frequent short formative quizzes, as this has been shown to enrich student learning and material comprehension (Kulamakan & Rangachari, 2018). Indeed, the purpose of formative assignments in general is to reinforce course content in a relaxed non-summative environment, which has been illustrated to have marked benefits in attainment (Dobson, 2008; Kibble, 2007; Petrović et al., 2017), with an albeit low correlation ($r = 0.34$) between formative and summative quiz marks in one particular study (Kibble, 2007). Overall formative assessments have been demonstrated to have a broadly positive effect in other areas, including enhancing self-directed learning (Kulamakan & Rangachari, 2018; Nagandla et al., 2018), module engagement, and also with module management by implementing automated systems (Schaffer et al., 2017).

In our discussion, students on the degree programme are either on a BSc Geography or BA Geography track, and hence are either more physical geography or human geography focussed, respectively. However, methods and statistics training are often conjoined, with Level 1 and Level 2 students taking combined modules. Throughout, we refer to the idea of "scaffolding" to summarise our general approach (Hill et al., 2017; Kalman & Leng, 2007; Priya & Hannafin, 2007). We follow Priya and Hannafin (2007), p. 29) and conceptualise this as providing "technology-mediated support to learners as they engage in a specific learning task", using it to provide "procedural and metacognitive support". Such an approach also contains an emphasis on "fading out" the scaffold as students demonstrate competence, to support the move to independent learning. Here, we make a key observation that whilst this scaffolding is phased out for student-facing activity, behind the scenes the functions and flexibility of digital technology can in fact "scaffold" the management element of a module as well. This is not faded out, and we reflect on how this can be overlooked, but is in fact a powerful tool for module delivery. We finish with wider reflections on pursuing these attempts at innovation within university structures; whilst our experience is from the UK, we expect it will translate to multiple contexts in which universities are undergoing neoliberal change (Johnson, 2018).

Motivation, course background, and innovation methods

The motivation for this paper stemmed from a desire to modernise, engage, and energise methods and statistics teaching across a geography degree. The packaging of material (particularly statistics) appeared to lead to student anxiety over content before it had even been attempted (Chapman, 2010; Zieffler et al., 2008). Where possible therefore, methods and statistics were rebadged as "handling data" alongside an emphasis that the important skills gained, be they mathematical (numerical) or not, go far beyond the use of statistics. The changes made across year groups were considered alongside the need to provide a joined-up and scaffolded approach; assessments were designed to progress students from Level 1, where learning an academic writing style and incorporation of methods may be new, to Level 2, where more detail and specialism is needed, through to Level 3 where these skills should be most comprehensively demonstrated in the dissertation. For instance, at Level 1, when students are tasked with a 2000-word report (in addition to formative and summative quizzes), detailed guidance on content, style, and structure is provided in the form of a template which guides students through desired aspects of the piece (provided on a Google Doc). Rather than focussing only on techniques, there is also a specific geographical focus that covers human and physical interests, in this case flooding in the city. There is therefore a requirement to put statistical analysis conducted as part of this project into context, i.e. bringing in reference to the literature. At Level 2, less guidance is given, alongside a more basic template. The assessment involves a dataset revolving around analysis of specific human or physical geography issues (survey data on sustainability attitudes and volcanic eruption data respectively), along with more freedom to choose the statistical methods. The end goal is a journal article style report, more like a dissertation. Anecdotally, there were far less enquiries at Level 2 on the writing and construction of a report having been guided through the previous year.

Both authors of this article are heavily engaged with methods and statistics teaching across a geography degree programme covering physical and human geography, responsible for the convening of methods at Level 1 and Level 2, and the teaching of statistics at Levels 1, 2 and Masters (one of us is a volcanologist, the other a political geographer). At each level, teaching is split between lectures (50–150 students), computer practical sessions (30–100 students), and small group seminars (20–30 students). At Level 1 and Level 2 the majority of methods and statistics teaching is conjoined with both physical and human geography, which itself prompts questions of applicability of all material for all students, and the ability of students to specialise in their discipline whilst providing a degree of flexibility.

Methods of measuring the success of content and innovation include module evaluations for individual modules (see Appendix for questions), student marks for individual assignments, and bespoke feedback forms. Methods of effective measurement will be detailed in each section. The issues with student evaluations are well known (Boring, 2017); however, open comments and informal interactions during teaching contact time are a valuable resource and can be useful when gauging success of specific changes or aspects of modules. After a quick overview of some of the technology used, we structure the remaining discussion into our teaching ideas which didn't work or only sort of worked (Section 3) and aspects which did work (Section 4), along with specific examples of each. Note that, unless illuminating, we don't use module feedback or methods of measurement for every section, preferring a description of our experiences and a more qualitative approach given the inherent difficulty of measuring the success and getting students to conduct detailed feedback activities (Weng et al., 2014). Indeed then, much of what follows is our experience and critical reflection based on a significant investment in the subject area, which we hope is of use to colleagues who teach in this area. At specific points, we use descriptive statistics to explore and frame the discussion and point to potential patterns, rather than making any substantive claims regarding grade improvement or attainment.

Overview of technology used

Much of the innovation incorporated during teaching delivery revolved around the use of free-to-use software. This was our approach pre-pandemic, and this background knowledge became helpful in the shift to online teaching. Software used included Kahoot (https://kahoot.com/), Socrative (https://socrative.com/), Poll Everywhere (https://www.polleverywhere.com/), Google Forms (https://www.google.co.uk/forms/about/), Google Docs (https://www.google.co.uk/docs/about/), Blackboard (https://www.blackboard.com/en-uk), YouTube (https://www.youtube.com/), and mQlicker (now discontinued).

Kahoot is an interactive software (see Figure 1) which allows quite large groups of students, useful for lecture theatre sizes, to be quizzed. Students login using a website or mobile application and then answer questions by pressing relevant shapes on their device. The software allows the setting of time limits and the use of graphics in questions (see Figure 1) and participants are then provided with instant results as desired in a competition-like scenario. Kahoot imposes a maximum of 50 students on their free version, with an option to extend with a paid version.

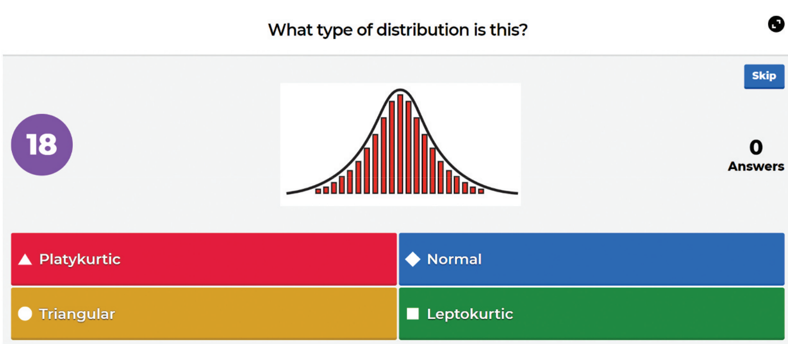

Figure 1. A screenshot from a Kahoot quiz in progress, showing use of image with question across the top. Purple circle indicates time remaining for students to answer.

Socrative provides a little more functionality (but also has restrictions on numbers of users for the free version) and works in a similar manner to Kahoot with a mobile and web application-based system. Socrative allows simple true/false or multiple option-based quizzing, but also provides the ability to include open-comments and short answers, which can then be validated to assess correct answers without the input of a teacher (although correct syntax and formatting can be an issue). There are also functionalities which allow any content to be either teacher-paced or student-paced, which gives a little more pedagogical flexibility.

Poll Everywhere can be used for free text entry or voting but is more difficult to extract data and has response entry limits. It can be embedded in Microsoft PowerPoint (although we found this was clunky to use and often didn't work on the university-managed computer systems in lecture theatres). mQlicker was very versatile and provided the ability to show real-time changes to student responses to interact with in-lecture; unfortunately, the software has been discontinued.

Google Forms, which may traditionally be used to request information, also has a quiz mode. On quiz mode, there is flexibility to choose a range of questions; multiple-choice, true/false, short statement; and also, the ability to allow students to attach files or graphics, along with an option to provide differential feedback for correct and incorrect answers. All the aforementioned software allows the extraction of information and statistics on performance on an individual student and per question basis.

Blackboard quizzing capabilities were also used given their incorporation with university student management systems for calculating module grades. There is a suite of functionality available but overall, it is a little unintuitive. We used Google Docs, an open document software for simultaneous document collaboration and sharing on the cloud. Google Docs functions much like Microsoft Word but can be open in more than one place at once, allowing for simultaneous edits. In addition, there is a chat-box feature, which isn't recorded, allowing discussion on the same page as the open document. Finally, YouTube, the video sharing website was used as a space for sharing videos, whilst pre-video formatting was often conducted in Adobe Premiere Pro.

In summary, we experimented with several different software packages. It is important to detail this variety as technological know-how can often be a barrier to the successful use of different platforms. It is clear from this overview that keeping on top of options is a requirement when innovating with digital technology, as packages that start off free-to-use often limit their free elements as they become more popular. This can be somewhat frustrating and time-consuming. Relatively simple functionality you come to rely on in one app is not always available in another. Our experience has been that, as a teaching team across multiple modules, we have (inadvertently) taken on different roles when it comes to the technology, with one of us learning and teaching the other the new software, and the other trying to squeeze more out of the software that we have more guaranteed access to through our institution (i.e. G Suite, Google). This is only possible as we have similar levels of technological know-how and work consistently together. Many characters of teaching in higher education settings conspire against this, which we return to in our final reflections.

What didn't or only sort of worked?

In this section, we detail examples of innovation which didn't work or didn't quite fulfil its purpose. At the end of each sub-section, we summarise the pros and cons of each pedagogy, and where applicable, offer suggestions for potentially more effective use.

Click-this-click-that walkthrough videos for software

For our Level 1 module we recorded walk-through videos for the statistics software that students were asked to learn (videos made using Adobe Premiere Pro and hosted on YouTube). Students then brought headphones with them to sessions and followed the video to complete the tasks. A worksheet was provided which asked students questions related to the work and aligned with stoppages in the video. Each video was between 5 and 10 minutes long. There were 150 students in the course and these were split across five or six individual hour-long practical sessions. The general aim of this approach was to scaffold the tutoring of software through video material over fewer sessions whilst providing a resource that could be accessed and re-used at a later date (by staff and students). In summary, our pros, cons, and suggestions related to this approach are:
Pros:

- Compared to written instructions, the videos allowed instructors to discuss and outline nuances in software to large groups – no more answering the same question over and over in workshops.
- Provided for a wide range of learning styles when used in combination with a worksheet and for large cohorts.
- Good for distance learning and mature students. Indeed, there were clear benefits to this approach during the pandemic in terms of course delivery, and no observable negative effects on marks.

Cons:

- Need to constantly update videos as software changes or as content alters, putting a significant burden on staff time.
- The potential issue of 'click-this-click-that' students (discussed below).
- Under normal (i.e. non-pandemic) conditions, students did not see the need to attend practical sessions, and just worked remotely, leading to a reduction in interaction with students around methods.

Suggestions:

- Can still be used as small soundbites, but not as the central method of delivering content.
- Remains useful if there is no option but to teach remotely.

On reflection, whilst useful in discrete instances for some more complex statistical methods, overall, our pedagogical experience of using videos was, to our surprise, broadly

Table 1. A summary of data for four weeks where a video walkthrough accompanied a practical and where one did not. Note that the difference in sample size is because more students did not complete all the weekly formative quizzes with an associated video walkthrough.

Video	Min	Mean	Median	Max	N
Yes	52%	78%	78%	96%	34
No	23%	67%	69%	100%	43

negative for a number for reasons. Firstly, as we have also seen with lecture recordings, attendance clearly fell in workshops as result of this resource (Edwards & Clinton, 2019). Furthermore, for those who did attend, the heavy emphasis on video material seemed to have a distancing effect between staff and students, as well as between students themselves. Concerning distancing between students, workshops can in fact create quite open and informal space for students to learn from each other; nothing quite bonds a peer group like shared animosity towards learning a new software, especially if coupled with statistics. In a normal workshop many difficulties students faced were solved by asking their friend sat next to them. When a space is encouraged to be very informal, small groups will huddle to fix an issue. However, the video and headphones combination instead locked students to their own screens.

On the distancing between staff and students, workshops are a chance for staff to have detailed conversations with students and explain much of the nuance of statistical analysis and research that is not possible to cover in material delivered via a lecture (Webb et al., 2009). They also allow staff to show that they are human. A slick, professional video can give the impression that using the software is easy, and that nothing goes wrong. In contrast, a staff member working with a student to fix an issue, maybe being stumped at points, having to stop, think, and try things, helps break down barriers. It shows that our own practice is not in a finished state, but always needs working on.

Whilst there is always a need to remind and refresh students on software between years of teaching, the use of videos seemed to negatively affect retention and familiarity with of software when they returned in Level 2. It could be possible that the knowledge that a full walkthrough of an activity was on-hand meant that engagement and concentration on learning the skills at the time was reduced – therefore this scaffolding resource did not fade out. If it felt like a permanent resource at the time, students might not have paid the same amount of attention as they would have otherwise. There is also arguably something to be gained from going over a practical multiple times and learning how to handle software in your own way. Such "attrition", especially at the start of a course, seems to improve confidence and mastery over time (this remains, however, something difficult to reassure students of in the moment) (Scheyvens et al., 2008). Our video guides seemed to dissuade and undermine this behaviour, producing what we thought of as "click-this-click-that" mindsets with a superficial understanding of the software.

We further investigated the COVID year, analysing the formative weekly quiz (more detail in section 4.3) between the week with an associated video (Week 5) and the mean marks for weeks without an associated video (Weeks 1 to 4), see Table 1. The Week 5 data were not normally distributed (Shapiro-Wilk, $p < 0.05$), a Mann Whitney test was therefore run and determined a significant difference between mean marks over weeks with a video walkthrough and the one week without ($p < 0.05$), implying that the week without video walkthrough was either more difficult or students struggled without the "click-this-click-that" approach. Therefore, when it comes to remote learning, video materials such as these walkthroughs likely play an important role in student learning. However, when the option is available for face-to-face activities, our experience and perception of student learning was that the pedagogical process was better without the video walk-throughs.

Self-generated student statistics for use in lectures and practicals

During the first lecture of a block on statistics at Level 1, students were quizzed in-lecture and asked to make guesses around a range of questions concerning different data types such as: what is the age of the Earth, how many parks are in the city, what is your eye colour? Using the software mQlicker, it was possible to show these data live and interact "on-the-fly" with the students to instruct on data distributions, measures of central tendency and variability and dispersion. The aim of this pedagogical method was to engage students with statistical data by having them generate it themselves. These data were then used in examples within lecture slides (see Figure 2) and throughout the practicals, supplementing geographical data.
Pros:

- Students were engaged with the material in the lecture.
- Real-time interaction with datasets.

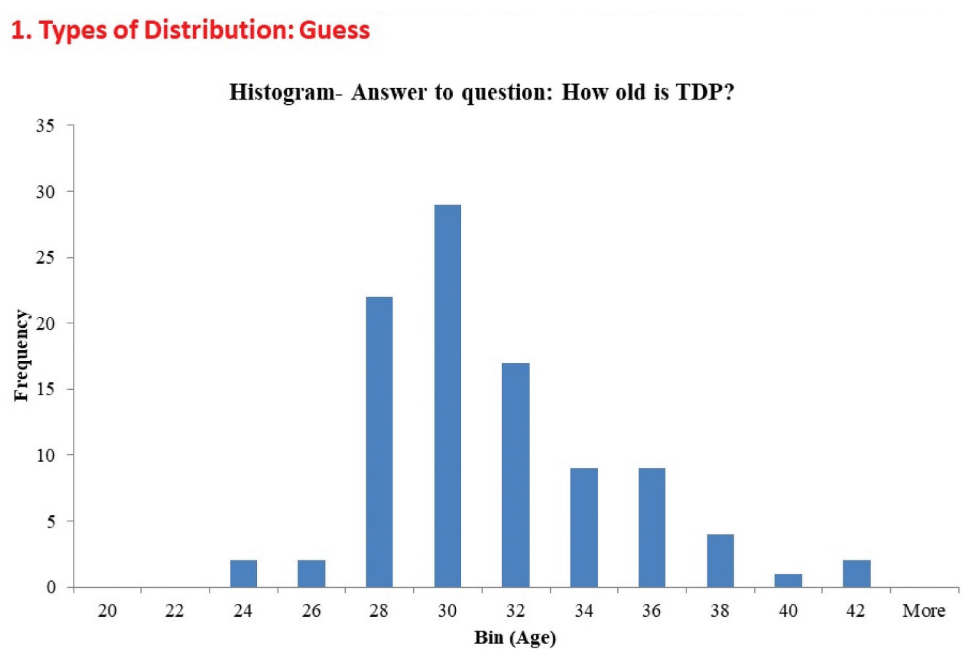

Figure 2. Example lecture slide on data distributions using responses to students guesses on age of the lecturer.

Cons:

- Required yearly updating of lecture material and datasets.
- Drew away from use of solely geographical data and focussed too much on just the techniques rather than their application.

Suggestions:

- Could be used effectively in small scenarios when putting across teaching points – but appropriate software would need to be used, given the discontinuation of mQlicker.

Whilst students appeared engaged and appeared to comprehend the material, there was an impact on the amount of time students spent engaged with geography-specific datasets, which had the potential for a knock-on effect later in the student's degrees. This stemmed from the need to ask generic and somewhat simple questions which could be responded to on-the-fly in a lecture scenario, and hence would not be possible to produce rigorous geographical datasets to experiment with during practicals or discuss during lectures. During practicals, there then appeared to be a disconnect when addressing the geography-specific examples. Undermining this further was the large amount of time "in-the-background" spent by the leading academic downloading data and re-designing practical documents to refit the new datasets generated.

What did work?

Here, we detail innovations and use of technologies which were successful in engaging students with methods and statistics.

In-lecture quizzing

Quizzing software such as Kahoot (Figure 1), Socrative, and Poll Everywhere make it possible to provide in-class interaction in a structured way. From our experience, each software has its own unique pedagogical setting. The objective of using in-lecture quizzing capabilities was to engage students and to test comprehension of subject material. Kahoot was used to provide a fun and anonymous (if desired) way of answering questions (which was sometimes accompanied with chocolate-based prizes). This setting also allows the students to bring some personality to the lecture room by using amusing names (with clear boundaries set before on being appropriate!), which lightens the mood, a useful endeavour when it comes to testing on statistical content (see Figure 1). Socrative and Poll Everywhere were used for scenarios where more discussion may have been needed. We found therefore that Kahoot can be used effectively throughout the degree programme, but is especially useful at Level 1 where students may be a little more restrained in answering open questions. Indeed, there was a noticeable progression when considering in-class interaction, moving through from use of individual-based Kahoot, through to more discursive Socrative and Poll Everywhere, eventually allowing free-and-easy non-tech-based interaction within the lecture theatre by the end of a lecture series, moving away from a "cold-calling" approach (Dallimore et al., 2004). In addition, we felt that exposing students to such interaction earlier on in a degree helps feed through to the rest of the degree programme and other modules.

Pros:

- Enables reactive teaching (Duke & Madsen, 1991), for example if a question is answered incorrectly by a majority of students, subsequent teaching can then be tailored to this.
- If poorly answered themes can be discovered and focussed on in later lectures, additional quizzes can also be tailored, leading to dynamic content adaptation (Courts & Tucker, 2012).
- The software programmes are easy to use, and once written, small tweaks are quick and simple.
- Provides an interactive environment.

Cons:

- Overuse of a specific software program can lose effectiveness, e.g. interactive "fun" software can lose its appeal.
- There are limitations to quiz use, surrounding complexity of questions.

Even when a good level of rapport is built up with a lecturer and their class, it is notoriously difficult to get students to offer answers in large class-room settings (Heaslip et al., 2014). This issue is arguably amplified when teaching statistics, as responses can be far more incorrect in a black and white manner, leaving little space or wriggle-room for a lecturer to put a positive spin on an inaccurate response. Indeed, experience has told us that such direct questioning on the topic is rarely fruitful. However, it remains the case that an entire lecture broadcasting information can be daunting for both staff and students, and here the ability of quiz software offers up a lot of space to create a more dynamic and engaging teaching environment (Ataş & Delialioğlu , 2018; Dunn et al., 2012; Heaslip et al., 2014). Indeed, the Kahoot-based method provides a fun and interactive way of "testing" in-lecture with colourful graphics and the chance for students to interact, congratulate or commiserate together. Vitally, it also provides a way for students to remain anonymous as these skills are being learnt.

Statistical challenge applied to a real-world scenario

Small group seminar or workshop-based sessions concerning statistics can often, but not exclusively, be based upon reading and interpreting journal articles. As an alternative, a new session was devised in a workshop style which incorporated the interpretation of a journal article with the application of statistical methods and volcanic eruption forecasting. Designed to reflect a clear and tangible real-world scenario, it was hoped that the students could see the use of statistical material and therefore become more engaged. The students' first task was to extract important information about a particular volcanic parameter from a journal article concerning the behaviour of a volcano. They then had to consider how this may help forecast a change in eruptive style and explore what statistics may be of use in such a situation. With the help of the Socrative app groups of 3–6 students were led interactively through a series of questions. They were then set a number of tasks aimed at helping them understand a developing (fictitious) volcanic crisis. The teams competed against each other in a "space race" adding a bit of fun competition to the challenges, which involved selecting the correct statistical techniques and calculating the correct answers to progress (see Figure 3).

Students were then asked to give individual and anonymised feedback specifically on the use of the interactive software via Google Forms. Overall, the students found this an effective way to begin applying their statistical knowledge to a believable, albeit fictitious, scenario, with 100% strongly agreeing/agreeing that the interactive software leading them through questions, incorporating the competitive element on screen, helped their engagement in the workshop and 94% strongly agreeing/agreeing that they would like to see similar sessions around statistics. But importantly, as a pedagogical exercise 16.4% strongly agreed and 65.7% agreed that the workshop helped their understanding of what they learnt in statistics from the previous year and up to that point in the current module (at the cohort level). See Table 2 for results of other feedback questions. In the "open comments" students identified these themes, including: "useful to talk to people about work", "a very good session, more like this please!", "I liked the seminar. It helped me to consolidate information by applying it to practical problems in a group. It puts me under pressure to answer, which is good because this is how I learn best by making some mistakes and learning from them".

Figure 3. The "Space Race" element of the seminar, displayed on screen. A competitive format alongside the statistical content and challenge helped engage students in the seminar.

Pros:

- Smaller seminar groups enabled tailored help and teamwork.
- Students apply knowledge to a real-world scenario and are hence more engaged.
- The "Space Race" aspect, whilst fun for students, also provided a way of identifying student groups which may have been struggling and needed help.

Cons:

- Relies on continuity of software.
- Groups could be dominated by those who understand the content.

Of all the pedagogies, this was the most innovative (in our opinion) and broadly well received as an individual teaching event. Students appeared to effectively grasp the purpose of statistical content covered prior to the seminar, and to certain extent saw the actual real-world value of rigorous use of statistics. This was potentially helped by the

Table 2. The results of feedback collected using Google Forms, the percentages are based on 67 student responses over 3 years of holding the same seminar. SA = Strongly Agree. A = Agree. NA/ND = Neither Agree nor Disagree. D = Disagree. SD = Strongly Disagree.

Question	SA	A	NA/ND	D	SD
Did the interactive software help your engagement with the seminar?	38.8%	61.2%	0%	0%	0%
Did you enjoy using the interactive software "Socrative"?	38.8%	56.7%	4.5%	0%	0%
Did the on screen "race" element help your engagement with the seminar?	47.8%	34.3%	14.9%	3%	0%
Would you like to see more interactive seminar sessions using the same or similar software within statistics?	44.8%	49.3%	4.5%	1.5%	0%
Did the seminar help your understanding of statistics from the 1st year and the current module?	16.4%	65.7%	14.9%	3%	0%

nature of the volcanic topic, which is often easy to sell as exciting and to make engaging. Crucially, the seminar gave students the chance to *apply* their statistical knowledge, whilst getting feedback and help as needed in a non-assessed environment. The "space race" element also allowed monitoring of group progress, allowing the instructor to focus attention on the groups which needed it most. Frequently, the only time we, as academics, assess students use of statistics is through formal assignments, perhaps more use of informal formative sessions such as this could be beneficial to students overall.

Google forms as dynamic feedback tools and incorporating quizzes as assessment

Previous practical content had been conducted using worksheets, which were filled in manually, or using pre-recorded videos as described in Section 3.1. A change in approach which allowed students to assess their comprehension of lecture material and practical content (including software use) was desired, whilst improving engagement and attendance across Level 1 and Level 2 core modules. Typically, students vote with their feet if something is perceived as optional or overtly difficult (Kottasz, 2005). Practicals were therefore conducted as hybrid lecture-practicals (a practical workshop which details statistical content, involves a live software walkthrough and discussion, concluded by student problem-solving), with some introductory materials and stepping through of software as a group, with an accompanying handout for reference if needed.

A new "Your-Turn" aspect of the practicals was then introduced revolving around the use of Google Forms and the quiz option, essentially a form of formative assessment, e.g. (Dobson, 2008; Kibble, 2007; Schaffer et al., 2017), although these were not badged as any form of assessment. Google Forms was used to ask questions surrounding recent lecture content relevant to the practical and to get students to test their software skills. On submitting the quiz, the student receives a mark and individual feedback based on question responses (via tailored response for correct and incorrect answers). It is then possible to export a summary of statistics of student performance by question (as a whole group and individually), which allows the lecturer to see where students may have struggled or need extra help (a common theme of many of the innovations discussed in this paper), a form of reactive teaching (e.g. Duke & Madsen, 1991). Email addresses are also collected which help for assessing practical attendance. As a result of this change, attendance and engagement improved from 10–30% without forms to 55–90% at Level 2 (this is technically a proxy, as students could fill out of the form at any point, but here we only use forms submitted during the time the workshop was on). This varied year on year: 2018/2019–69–90%, 2019/2020–88–95%, 2020–2021–55–81%. Whilst workshop attendance has improved, the return to in-person lectures after COVID has not seen sustained attendance, we expect predominantly because of lecture-capture (Edwards & Clinton, 2019).

Coupled with the above in-practical changes, alterations to the assessment style were also made across Level 1 and 2. Prior to acquiring module convenorship, Level 1 assessment involved an end-of-year written multiple choice quiz (which was manually marked), while Level 2 was assessed with a 500-word statistical report (based on stats analysis) and a written end-of-term exam, involving written responses. The report aspect will be discussed in the next section (4.4). On reflection, a statistical exam seemed to be an ineffective method of assessment, particularly for those who have less training in mathematics or are not adept at mathematical-based content, and can therefore be quite stressful (Chapman, 2010). Indeed, when thinking about the purposes of understanding statistical methods, it is their correct application and interpretation that is important, along with ability to use software, and not the ability to recall statistical knowledge in a high-pressured exam setting. Furthermore, there tended to be a large number of fail marks within this specific assignment (26 fails out of 154 students, 17% failure rate, in year prior to switch), and it was the most commonly failed exam in the department. This meant the exam gained a reputation for being extra tough and so, after talking across their year groups, students had preconceptions about an entire module before even starting it.

A switch of the exam to multiple online quizzes (via Blackboard) was therefore made (three individual quizzes at Level 2 which formed 55% of the overall module mark, with the remaining assessment being a report). The quizzes included use of software, analysis of datasets, and answering questions around the lecture content. Online quizzes therefore provisioned for assessment of software use abilities and their spreading out across the length of the module kept students engaged and led to only 3 fails of specific quizzes (total students = 148, 2018–2019). This reduction in fails also led to knock-on effects with administration, reducing the number of fails and resits during the summer. In addition, this lowered staff time associated with the marking of assignments and could therefore be seen as an efficiency saving. Furthermore, the Google Form quiz conducted alongside each practical acted as preparation for the quizzes, students therefore felt more prepared. Pros:

- Google Form quizzes can be attempted remotely and taken as many times as desired.
- Google Form quizzes allow students to self-assess knowledge and inform lecturer, without requiring direct contact, on poorly understood areas.
- Replaced statistics exam with multiple quizzes better suited to those with diverse backgrounds in maths and statistics.
- Improved attainment and confidence in use of statistics and methods.
- Enables dynamic feedback.

Cons:

- Quizzes could be seen as too easy to achieve highest marks (although given that there is generally a lack of grey area, achieving perfect marks in quizzes shouldn't be discouraged and/or content shouldn't be adapted to prevent this).
- There is the chance of collusion, minimised by small windows to take the test and emphasis that this is an individual task.
- High initial time input for creating Google Form quiz material.

Overall, from the module evaluation (N = 67, 45% responded) students felt that technology was used appropriately at Level 1, with 97% agreeing and strongly agreeing at Level 2. In additional analysis of results on the first cohort to use this approach suggested a (tentative!) link between practical attendance and the mean results of online assessments (Figure 4), whereby higher marks are only achievable through attendance at all (or only missing one) of the practicals.

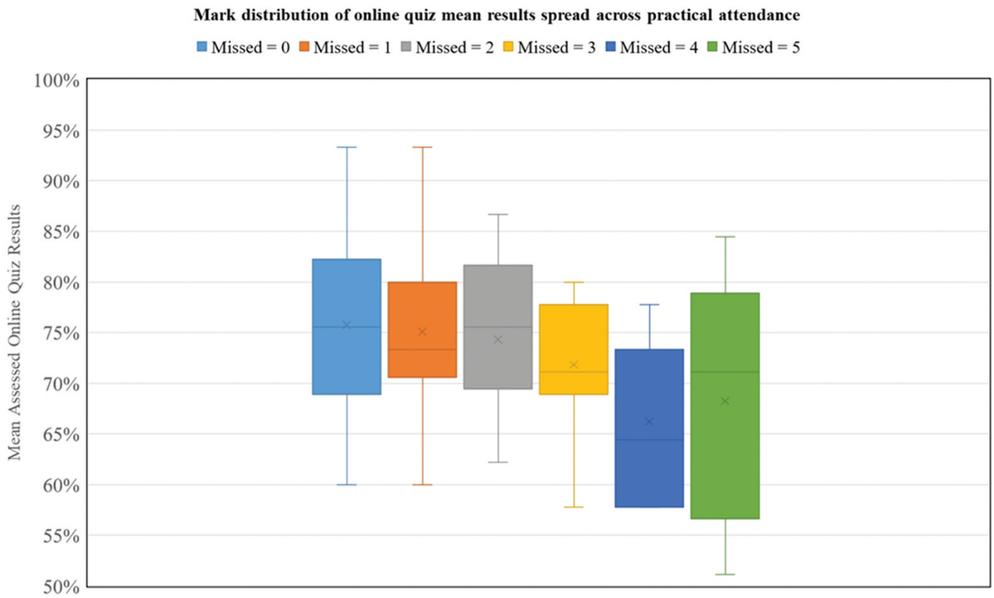

Figure 4. Boxplot of mean assessed online quiz results compared to number of practicals missed, with median (central bar) and mean (cross) indicated. Results indicate that to achieve the highest marks, attendance at all practicals is necessary (i.e. whiskers only reach higher grades where fewer practicals are missed).

Statistical analysis of Level 1 course

We compared the performance of students over four years prior to any changes were made to statistics teaching at Level 1; in these first four years (Pre 1 through 4) statistics teaching was conducted through a single ten-week module with a written statistics exam and a report. Following this there was one year where a new overarching skills module was introduced, where statistics was constrained to a three-week period, with an invigilated statistics quiz. In that particular year, unfortunately, no data for final marks are available. Under the same structure, the following year (Vid 1), these three weeks were followed by a single dedicated online statistics quiz. In these two years walkthrough videos were used alongside practicals. Following this, we ran two video-free years (No Vid 1 & No Vid 2) accompanied with live demonstration and the "Your Turn" approach described in Section 4.3. We also add data for the course in the pandemic year (COVID) which was taught fully remotely. See Table 3 for a full results summary and Figure 5 for a visual overview. Our results suggest a significant difference (Kruskal-Wallis, $p < 0.05$) between the "Pre" approach and the "Post" approach, although we note the difference in assessment style as a possible driver in marks. However, we note that there is no significant difference between years where a video walkthrough was used (Vid 1 and COVID years), indeed mean marks were even slightly higher in those years.

Statistical analysis of Level 2 course – pre- and post-COVID

Data for the Level 2 module from three specific years (1,2,3) were cross compared. Year 3 was remote learning because of the COVID pandemic, meaning that all practicals were conducted in the students' own time using a practical worksheet and/or a video

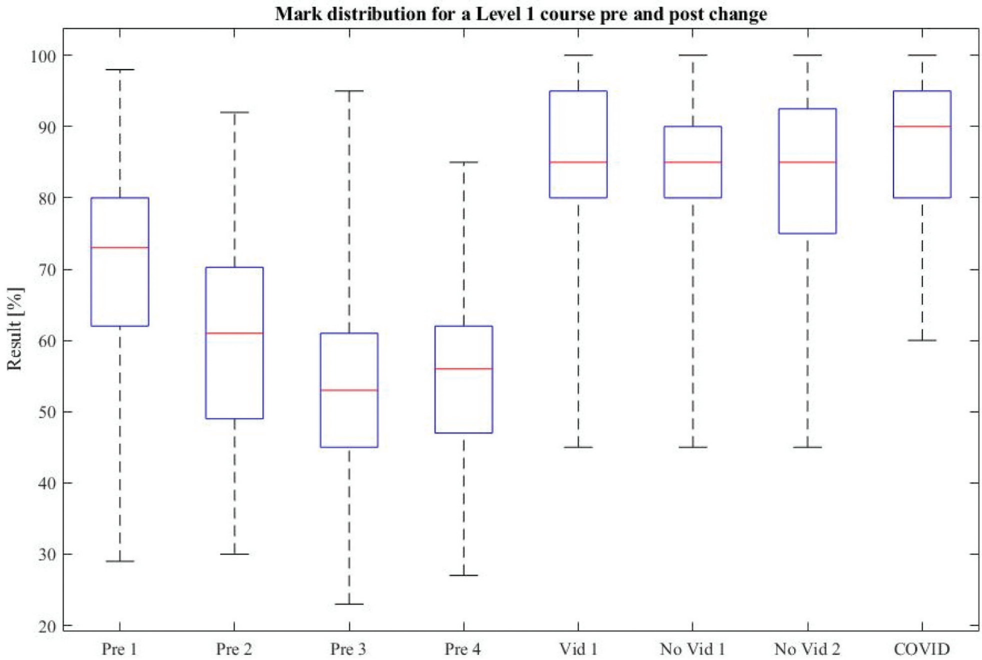

Figure 5. Boxplot of mark distribution for a Level 1 course pre and post changes made to a statistics course. The changes are split into those with videos (Vid) and those without (No Vid), also included is a year where learning was completely remote (COVID).

walkthrough. In addition, in Year 3 change in staffing led to an altered teaching approach where only half of the module used the weekly formative quizzing approach (five weeks with quiz, five weeks without).

Completion of the "Your Turn" aspect of the practical is therefore a proxy for full practical completion rather than attendance in the COVID year group. The main finding is that, for the first four weeks of the module, practical completion dropped every week −81% to 66% to 64% to 55%. Over the course of the module, there were three quizzes. Quiz 1 and Quiz 2 covered material with associated "Your Turn" formative quizzes, and Quiz 3 did not. The results for 47 students who completed each quiz are analysed for significant difference using Kruskal-Wallis given that the distribution of results was not normal (Shapiro Wilk test, $p < 0.05$). This result suggested that there was no significant

Table 3. A summary of marks pre and post change of a Level 1 course, including a year where learning was completely remote because of the pandemic (COVID).

Period	Min	Mean	Median	Max	STD	N
Pre 1	29	70.9	73	98	1.3	146
Pre 2	30	60.3	61	92	0.9	221
Pre 3	23	54.0	53	95	0.9	201
Pre 4	27	54.9	56	85	0.8	172
Vid 1	45	86.4	85	100	0.8	146
No Vid 1	45	83.3	85	100	1.2	85
No Vid 2	45	81.9	85	100	1.9	48
COVID	60	86.4	90	100	1.2	64

Table 4. A summary of summative quiz statistics in a COVID year.

Quiz	Min	Mean	Median	Max
1	25%	77%	85%	100%
2	40%	77%	85%	100%
3	0%	63%	70%	90%

difference between Quizzes 1 and 2 results, but there was a significant difference between Quiz 3 and Quizzes 1 and 2 at $p < 0.01$, see Table 2. Whilst there are several possible reasons for the difference, e.g. alteration in teaching style between lecturers or fatigue in general associated with the pandemic, it is also possible that the formative quizzing supports attainment. Indeed, it is intriguing that mean and median marks between Quizzes 1–2 and that of Quiz 3 are markedly different (see Table 4) when coupled with written feedback for the module which in fact suggested that the content covered in Quizzes 1 and 2 was "more difficult". The mark distribution for each quiz is portrayed in Figure 6.

Finally, as with Level 1 data exploration, we look across multiple years of attainment to see if there might be any patterns of note. In Table 5, Pre-Change 1 and 2 refer to the module before we took over, which featured a written stats exam and 500-word statistical

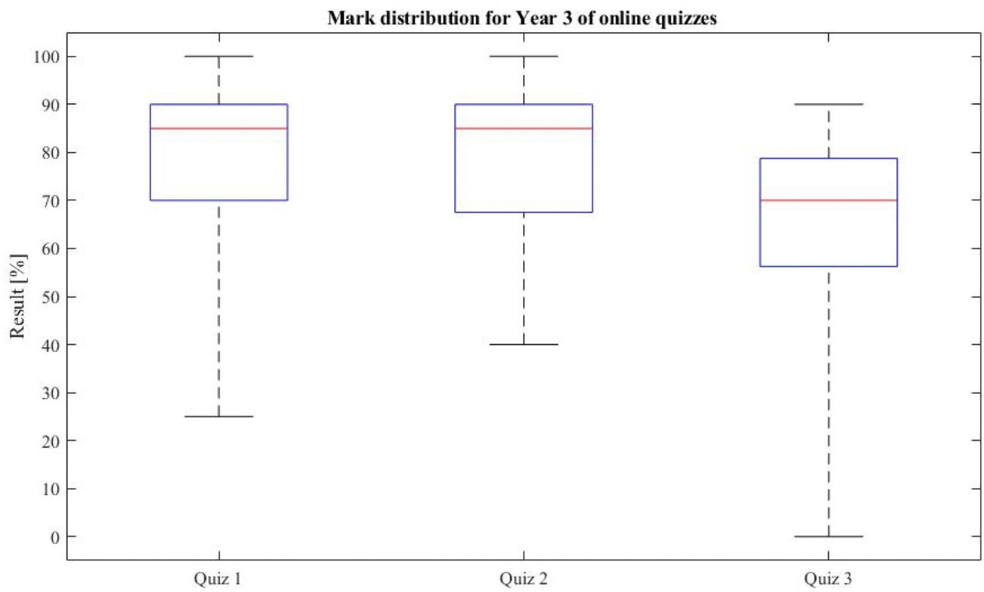

Figure 6. Box plots showing mark distribution across the three summative quizzes included in the module.

Table 5. A summary of module marks pre and post changes for a Level 2 module.

Period	Min	Mean	Median	Max	STD	N
Pre-Change 1	16	59.1	60	82	11.2	176
Pre-Change 2	18	56.0	55	82	13.2	146
Year 1	43.9	66.5	67.8	87.1	8.4	139
Year 2	40	71.8	73	91	7.8	89
Year 3	40	67.6	69	91	9.8	45

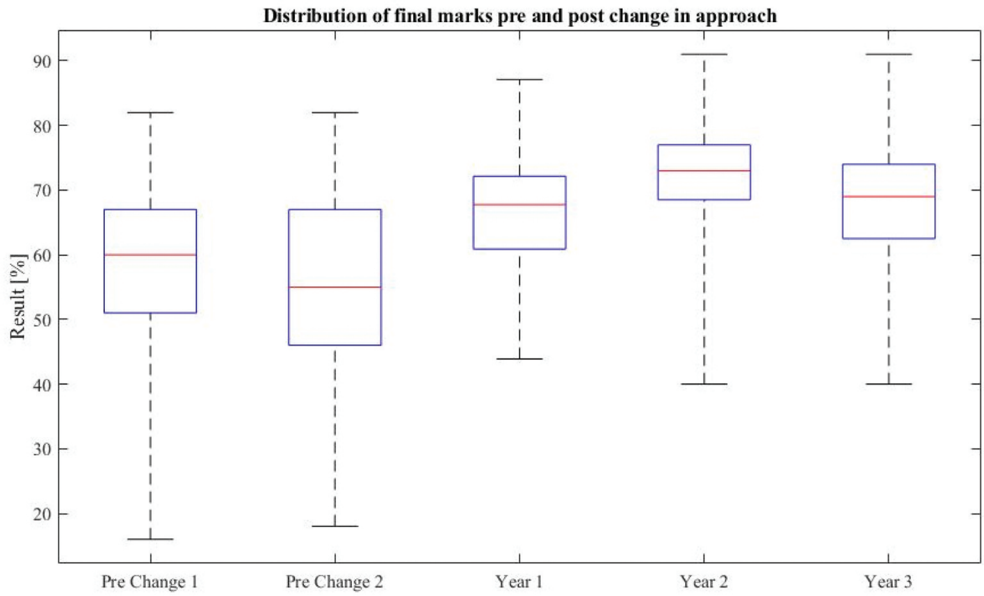

Figure 7. Boxplots showing mark distribution pre and post change for a Level 2 statistics module.

report. Mark distribution for each year is featured in Figure 7. Years 1, 2 and 3 refer to the module changes which included the move to online quizzes and an expanded report. Broadly in line with our conclusions at Level 1, there is a statistically significant different ($p < 0.01$) between the modules pre and post changes. This also involved a reduction in fails.

Overall, the key changes made across Level 1 and Level 2 were tailored to providing the students with additional confidence in selecting appropriate tests and in using software to make sense of their data and conduct robust analysis. We sought a joined-up approach from a highly supported Level 1 to a more flexible Level 2, with the aim of getting students to the position to independently conduct a research project. Working closely as a team and over time on these modules therefore allowed us to pursue a scaffold approach *across* levels, not just within modules; aspects of this way of thinking was also part a university initiative at the time, referred to as a "programme-level approach" (which we'll return to). We now move to situate these changes by critical reflecting on the context in which they were conducted, and the importance of technology "behind the scenes".

Discussion

Technology, module delivery, and organisation

Crucially, as part of our reflection, we also considered the use of more "mundane" or "back office" use of the various digital technologies as integral to enabling changes and a scaffolding approach. It can sometimes be easy to overlook the small opportunities provided by new technologies with live collaborative features. Here, we focus on the flexibility provided by using Google Docs through two short vignettes (of course, the following applies to any software with collaborative live editing functions).

Firstly, Google Docs was used across modules as a "live" space for staff to share marking feedback with each other. In this case, whenever shared marking was conducted, a Google Doc was created for staff to drop in examples of feedback that was coming up frequently. This allowed staff to address common issues using consistent language and improve the overall coherence of feedback completed via multiple markers. The chatbox facility also provided a good space for colleagues to discuss the marking process in an informal manner (and vent if need be!) without clogging up email inboxes. In our experience, this made marking feel like a less isolated process. Finally, once marking is complete, the document provides a good foundation for writing a "general feedback" document to provide students an overview of the assessment that adds more detail and context to their grading, rather than only specific feedback they receive on their own assignment. This helps contextualise their mark. This document is quick to produce from the comments staff make whilst marking. By then sharing the report in Google Docs you can look at viewing figures to see if students are engaging, as it is often not clear if students are reading or even opening feedback beyond checking the grade. A recent example of this for a qualitative methods module saw 50% of students open the document, which demonstrates the potential for this to be a useful resource. Furthermore, if the assessment stays the same or similar the following year, this becomes a new resource and guide for the next cohort of students to read whilst they are tackling the assessment.

Google Docs have also been used to provide easily updated Q&A or FAQ documents. This idea is a simple one but can considerably cut down on time spent emailing or monitoring forums. Students are provided with a Google Doc link that only staff can edit; whenever a question is emailed to staff or asked in a lecture that is deemed useful for all students, it is added to and answered in the Q&A document (with any anonymising if need be). Students are encouraged to consult this document, which gets updated over the course of the module, *before* they email staff with questions. If a student does email a question that is already covered, a friendly but very short email reply simply guides them to the Q&A.

Experience suggests this approach cuts down on emails and provides a useful live repository of all questions and advice that is useful for both students and other staff on the module. Quickly checking the document can also mean that staff do not give conflicting advice. Furthermore, it becomes a useful document to help new staff taking over a module so that they can be prepared on what to expect, as well as being used to feedforward into changes to assignment guidelines and advice the following year. It can also be a useful source of evidence to demonstrate that advice has been provided on a topic to the whole course should a student complain in a module evaluation that it has not. Finally, whilst some online systems, such as Blackboard, provide a form of message board for this sort of activity, we have generally found them unsatisfactory. They are time-consuming to monitor, clunky, and the threading of messages often means that in fact they do not cut down on repetition. We have also heard from other colleagues examples of message boards becoming used as very negative spaces which have featured highly critical points made against staff. In contrast, the Google Doc approach gives staff much more control to tailor and streamline the process to provide the most effective Q&A document.

Benefits of technology-enhanced statistics teaching

Throughout this paper, detailing our attempted innovations in teaching statistics, a core message is that technology and informal quizzing software proved extremely valuable for engagement. Google Forms proved integral to our successes, offering a potential solution to dwindling attendance in the lecture-capture era. These quizzes support continued evaluation of student understanding, allowing the tailoring of later lecture and practical material, i.e. helping us to pursue reactive teaching through near real-time content adaptation and dynamic feedback. Furthermore, the quizzes act as weekly formative feedback for students, assessment preparation, and a record of module attendance. It could be argued that this approach risks over-quizzing students, particularly with weekly Google Forms. However, the students didn't appear to be overwhelmed and we think a key element to this is that the quizzes are formative and do not count towards grades – rather they are provided as clearly integrated into a practical session that supports the learning of statistical analysis in software. Given that feedback can also be weaved into Google Forms, students have much more perceived interaction with the contact and feedback from the lead academic, even though this is pre-programmed. Technological incorporation has enabled the creation of streamlined assessments and those which are more appropriate for the material, including the use of Online Quizzes which can incorporate testing of software skills. Through a structured report requiring guidance at Level 1, to a semi-structured report at Level 2 a programme-level approach enables a clear pathway to create a Level 3 Dissertation. We also outlined aspects which didn't work: YouTube videos which created click-this-click-that students and in-lecture statistics generation for use in practicals.

We would emphasize that much of this innovation was only possible in a stable team with similar levels of technological know-how. Indeed, for our final section, we reflect less on the specifics of using technology, and more on the wider attempt to innovate in our teaching. Before we begin this section, we feel it pertinent to point out that whilst these critiques are borne out of our experiences in a particular department at a particular university, we know from previous experience and discussions with colleagues elsewhere that these are not unique. Indeed, in relative terms, we think we are working in a supportive environment, which we suspect only means these concerns may be more pertinent elsewhere.

The difficulties of innovating in a university system

Firstly, we think it is important to note that much of the innovation and development contained within this piece was conducted on temporary lectureship contracts. This is challenging, especially when it is uncertain whether a colleague will be able to contribute to the development of a module the following year. In our eyes, the proclaimed wants of the HE sector, to improve the overall student experience across their degree through a programme-level approach whilst encouraging innovative teaching approaches, clearly conflict with the casualization of teaching contracts (Williams, 2022). It is much harder to make such changes, or to invest your time in upskilling staff in the use of technology, when unaware if you are teaching the module the following year – or even have a contract the following year (Peters & Turner, 2014). This is simply a practical concern before we even get into the issues of stress and morale associated with temporary employment (Courtois & O'Keefe, 2015; Loveday, 2018).

Another barrier to making change to aspects such as module assessment is the advance notice needed by the bureaucracies of a university system, which are often unfeasible and unreasonable. A bugbear of ours is when notification of changes to modules for the following year is required for sign-off *before* existing material or new changes have even been delivered in a current year. This is especially a problem for modules taught in the second semester (or equivalent). Such requirements mean that module updates are stuck in a two-year cycle, rather than one, which is only exacerbated when teaching teams are changed. It might seem like the quick turnover of staff on a module will revitalise it, but, counter-intuitively, in our experience it can lead to stagnation as no one has the impetus (or power) to drive wider change and innovation.

Finally, whilst we understand the desire for module comparability and standardisation, complex guidelines concerning what module assessment and contact time and format should look like within a module can seem rather daunting – especially to incoming early career staff. This is exacerbated when admin windows are short and contracts temporary. If the sector wishes to harness the enthusiasm of early career staff, it should look at parts of the wider bureaucracy that remove power from academic staff and place it in the hands of administrators. For instance, different types of modules have different needs, and in this discussion, we have made clear that some of these needs, those which are pertinent to teaching statistics, would be much less of an issue compared to, say, English Literature. It makes little sense that attempts at innovation can be thwarted by an administrative process that cannot account for differences in subject material and pedagogical approaches.

Conclusion

Through critical reflection and analysis of student engagement, in this paper we have discussed the benefits and pitfalls of using technology to enhance the teaching of statistical teaching. We point towards evidence for improvement and engagement, and qualitatively reflect on how students demonstrate greater understanding of methods, building up slowing through a scaffolding approach towards their dissertations and preparing them more for "real-world" use. We also reflected on key contextual issues, suggesting that these changes were facilitated by a technologically savvy team who were able to work together over numerous academic cycles. However, this was mainly by accident, rather than design. Significant stability, investment, and time is needed to innovative – something that isn't always provided in an increasingly casualised university context.

Disclosure statement

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References

Ataş, H. , & Delialioğlu, Ö. (2018). A question–answer system for mobile devices in lecture-based instruction: A qualitative analysis of student engagement and learning. *Interactive Learning Environments*, *26*(1), 75–90. Routledge. https://doi.org/10.1080/10494820.2017.1283331

Bälter, O., Enström, E., & Klingenberg, B. (2013). The effect of short formative diagnostic web quizzes with minimal feedback. *Computers & Education*, *60*(1), 234–242. Pergamon. https://doi.org/10.1016/j.compedu.2012.08.014

Beesley, A. D., Clark, T. F., Dempsey, K., & Tweed, A. (2018). Enhancing formative assessment practice and encouraging middle school mathematics engagement and persistence. *School Science and Mathematics*, *118*(1–2), 4–16. Wiley. https://doi.org/10.1111/ssm.12255

Boring, A. 2017, January. Gender biases in student evaluations of teaching. *Journal of Public Economics*, *145*, 27–41. Elsevier B.V. https://doi.org/10.1016/j.jpubeco.2016.11.006

Brian, C., Fournier, E. J., & David Hill, A. (2000). Geography teaching in higher education: quality, assessment, and accountability. *Journal of Geography in Higher Education*, 24, 238–245). Carfax Publishing Company. https://doi.org/10.1080/713677380

Chapman, L. (2010). Dealing with maths anxiety: How *do* you teach mathematics in a geography department? *Journal of Geography in Higher Education*, *34*(2), 205–213. https://doi.org/10.1080/03098260903208277

Cohen, D., & Sasson, I. (2016). Online quizzes in a virtual learning environment as a tool for formative assessment. *Journal of Technology and Science Education JOTSE*, *6*(3), 2016–2022. OmniaScience. https://doi.org/10.3926/jotse.217

Courtois, A., & O'Keefe, T. (2015). Precarity in the ivory cage: Neoliberalism and casualisation of work in the Irish higher education sector. *Journal for Critical Education Policy Studies*, *13*(1), 43–66.

Courts, B., & Tucker, J. (2012). Using technology to create a dynamic classroom experience. *Journal of College Teaching & Learning (TLC)*, *9*(2), 121–128. Clute Institute. https://doi.org/10.19030/tlc.v9i2.6907

Dallimore, E. J., Hertenstein, J. H., & Platt, M. B. (2004). Classroom participation and discussion effectiveness: student-generated strategies. In *Communication Education*. Routledge. https://doi.org/10.1080/0363452032000135805

Dobson, J. L. (2008). The use of formative online quizzes to enhance class preparation and scores on summative exams. *Advances in Physiology Education*, *32*(4), 297–302. American Physiological Society. https://doi.org/10.1152/advan.90162.2008

Duke, R. A., & Madsen, C. K. (1991). Proactive versus reactive teaching : focusing observation on specific aspects of instruction. *Bulletin of the Council for Research in Music Education*, *108* , 1–14.

Dunn, P. K., Richardson, A., McDonald, C., & Oprescu, F. (2012). Instructor perceptions of using a mobile-phone-based free classroom response system in first-year statistics undergraduate courses. *International Journal of Mathematical Education in Science and Technology*, *43*(8), 1041–1056. Taylor & Francis Group. https://doi.org/10.1080/0020739X.2012.678896

Edwards, M. R., & Clinton, M. E. (2019). A study exploring the impact of lecture capture availability and lecture capture usage on student attendance and attainment. *Higher Education*, *77*(3), 403–421. Springer Netherlands. https://doi.org/10.1007/s10734-018-0275-9

Gikandi, J. W., Morrow, D., & Davis, N. E. (2011). Online formative assessment in higher education: A review of the literature. *Computers & Education*, *57*(4), 2333–2351. Elsevier Ltd. https://doi.org/10.1016/j.compedu.2011.06.004

Graves, N. J. 1975. "Geography in education." Humanities Press, Inc, 07716 ($15.00 hardbound, $6.25 paperbound).

Gregory, S. (1978). Objectives and methods in our statistical teaching. *Journal of Geography in Higher Education*, *2*(1), 23–27. https://doi.org/10.1080/03098267808708644

Hatziapostolou, T., & Paraskakis, I. (2010). Enhancing the impact of formative feedback on student learning through an online feedback system, electronic journal of e-learning, 2010. *Electronic Journal of E-Learning*, *8*(2), 111–122. https://eric.ed.gov/?id=EJ895699

Heaslip, G., Donovan, P., & Cullen, J. G. (2014). Student response systems and learner engagement in large classes. *Active Learning in Higher Education*, *15*(1), 11–24. SAGE Publications Sage UK: London, England. https://doi.org/10.1177/1469787413514648

Hill, M. F., Ell, F., Grudnoff, L., Haigh, M., Cochran-Smith, M., Chang, W.-C., & Ludlow, L. (2017). Assessment for equity: Learning how to use evidence to scaffold learning and improve teaching. *Assessment in Education: Principles, Policy & Practice*, *24*(2), 185–204. Routledge. https://doi.org/10.1080/0969594X.2016.1253541

Johnson, V. (2018). Masking neoliberal ideology: Teleological framing and the 'reinvention' of higher education. *Journal for Critical Education Policy Studies*, *16*(3), 137–165.

Kalman, Y., & Leng, P. (2007). A distributed model for managing academic staff in an international online academic programme. *Interactive Learning Environments*, *15*(1), 47–60. https://doi.org/10.1080/10494820601011128

Kibble, J. (2007). Use of unsupervised online quizzes as formative assessment in a medical physiology course: Effects of incentives on student participation and performance. *American Journal of Physiology - Advances in Physiology Education*, *31*(3)), 253–260. American Physiological Society. https://doi.org/10.1152/advan.00027.2007

Kottasz, R. (2005). Reasons for student non-attendance at lectures and tutorials: An analysis. *Investigations in University Teaching and Learning* 2(2) , 5–16.

Kulamakan, K., & Rangachari, P. K. (2018). Beyond 'formative': Assessments to enrich student learning. *Advances in Physiology Education*, *42*(1), 5–14. American Physiological Society. https://doi.org/10.1152/advan.00122.2017

Leek, J. T., & Peng, R. D. (2015). Statistics: P values are just the tip of the iceberg. Nature. Nature Publishing Group. https://doi.org/10.1038/520612a

Loveday, V. (2018). The neurotic academic: Anxiety, casualisation, and governance in the neoliberalising university. *Journal of Cultural Economy*, *11*(2), 2. https://doi.org/10.1080/17530350.2018.1426032

Nagandla, K., Sulaiha, S., & Nalliah, S. (2018). Online formative assessments: Exploring their educational value. *Journal of Advances in Medical Education & Professionalism*, *6*(2), 51–57. Shiraz University of Medical Sciences.

Neville, B. (1982). Introductory statistics for geography students: A comment. *Journal of Geography in Higher Education*, *6*(1), 79–81. https://doi.org/10.1080/03098268208708839

Ogange, B., Ogange, B., Agak, J., Okelo, K., & Kiprotich, P. (2018). Student perceptions of the effectiveness of formative assessment in an online. *Open Praxis*, *10*(1), 29–39.

Onwuegbuzie, A. J., & Wilson, V. A. (2003). Statistics anxiety: Nature, etiology, antecedents, effects, and treatments–a comprehensive review of the literature. *Teaching in Higher Education*, *8*(2), 195–209. https://doi.org/10.1080/1356251032000052447

Peters, K., & Turner, J. (2014). Fixed-Term and Temporary: Teaching fellows, tactics, and the negotiation of contingent labour in the UK higher education system. *Environment & Planning A*, *46*(10), 10. https://doi.org/10.1068/a46294

Petrović, J., Pale, P., & Jeren, B. (2017). Online formative assessments in a digital signal processing course: Effects of feedback type and content difficulty on students learning achievements. *Education and Information Technologies*, *22*(6), 3047–3061. https://doi.org/10.1007/s10639-016-9571-0.

Priya, S., & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments*, *15*(1), 27–46. Routledge. https://doi.org/10.1080/10494820600996972

Schaffer, H. E., Young, K. R., Ligon, E. W., & Chapman, D. D. 2017, February. Automating individualized formative feedback in large classes based on a directed concept graph. *Frontiers in Psychology*, *8*, 260. Frontiers Research Foundation. https://doi.org/10.3389/fpsyg.2017.00260

Scheyvens, R., Griffin, A. L., Jocoy, C. L., Liu, Y., & Bradford, M. (2008). Experimenting with active learning in geography: dispelling the myths that perpetuate resistance. *Journal of Geography in Higher Education*, *32*(1), 51–69. https://doi.org/10.1080/03098260701731496

Silk, J. (1979). Use of classroom experiments and the computer to illustrate statistical concepts. *Journal of Geography in Higher Education*, *3*(1), 13–25. https://doi.org/10.1080/03098267908708691

Warwick, P., & Ottewill, R. (2004). How can 'problem subjects' be made less of a problem? *Teaching in Higher Education*, *9*(3), 337–347. https://doi.org/10.1080/1356251042000216651

Wasserstein, R. L., & Lazar, N. A. (2016). *The American Statistician the ASA's statement on p-values: context, process, and purpose*. https://doi.org/10.1080/00031305.2016.1154108

Webb, N. M., Franke, M. L., De, T., Chan, A. G., Freund, D., Shein, P., & Melkonian, D. K. (2009). 'Explain to your partner': Teachers' instructional practices and students' dialogue in small groups. *Cambridge Journal of Education*, *39*(1), 1. https://doi.org/10.1080/03057640802701986

Weng, C., Weng, A., & Tsai, K. (2014). Online teaching evaluation for higher quality education: strategies to increase university students' participation. *Turkish Online Journal of Educational Technology*, *13*(4), 105–114.

Williams, R. J. (2022). The effect of casual teaching on student satisfaction: Evidence from the UK. *Education Economics*, *30*(1), 1. https://doi.org/10.1080/09645292.2021.1958168

Zieffler, A., Garfield, J., Alt, S., Dupuis, D., Holleque, K., & Chang, B. (2008). What does research suggest about the teaching and learning of introductory statistics at the college level? A review of the literature. Journal of Statistics Education. American Statistical AssociationAmerican Statistical Association. https://doi.org/10.1080/10691898.2008.11889566