Driving Course Engagement Through Multimodal Strategic Technologies

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Keywords: Online learning, multimodal learning, STEM, lightboard

Abstract

This paper describes the development of a new second-year level undergraduate Physics course at the University of Newcastle, comprising three four-week modules (encompassing Special Relativity, Nuclear and Particle Physics) for a combined roster of both Newcastle and James Cook students. A series of multimodal digital learning technology platforms were employed to see if they could maximise student engagement. Specifically, a flipped classroom system was trialled whereby students were tasked with creating their own lecture notes from online videos (created using *Lightboard* and *PowerPoint*). This approach resulted in 90% of the class actively engaging with the lecture content. Weekly online tutorial workshops consistently achieved an attendance rate of approximately 85% and included an online quiz based on embedded questions within the lecture videos. In addition, innovative STEM laboratory workshops exploited active engagement strategies including purely online worksheets to blended and remote experiments. The inclusion of a *Slack*-based project management hub enabled students to work seamlessly under constantly changing COVID-19 restrictions while exposing them to planning, management and *Python* control coding, under the visage of "embracing technology and best practice to deliver the greatest possible student experience". A review of students' view of the *Lightboard* and *PowerPoint* lecture content was conducted with *Lightboard* being the student's outright preference.

Introduction

Flipped, blended, online and mixed-mode classroom structures are well established in current teaching practices across university education (Vo, Zhu & Diep, 2017; Dziuban, Hartman & Moskal, 2004). These techniques place more onus on student self-learning and are designed to provide a more engaging environment to facilitate the learning process. Academic performance has been measured in many courses using these techniques (Dziuban, Graham, Moskal, Norberg, & Sicilia, 2018; Vo et al., 2017), and a variety of positive and negative outcomes have been shown. For example, using the flipped classroom mode, some studies showed that students were reluctant to carry out the pre-assigned work if no grade was awarded (Arnold-Garza, 2014; Katz & Kim, 2016). It is clear from all studies that for any new modalities to be implemented, early and sustained course coordination is vital. This includes making sure all material is developed prior to going online, encouraging inter-student as well as student-instructor communication, and administering the efficient use of teaching tools.

In the past decade, technology has increasingly been evaluated on whether it assists learning rather than being the next tech-tool to thrill students (Kirkwood & Price, 2014). These include polling tools such as clickers (Han, 2014) and online apps (Jonas-Dwyer, Clark, Celenza, & Siddiqui, 2012), as well as lecture video equipment such as *PowerPoint* (Baker, Goodboy, Bowman, & Wright, 2018), *Whiteboard* and *Lightboard* recordings (Morris, Swinnerton, & Coop, 2019). The majority of these evaluations have concluded that while technology can bring positive outcomes, they do not replace simple lecturer enthusiasm for engagement (Farber, 2008).

Lecture recording methods

It is well known that instructional videos, if they are done well, improve understanding and student enjoyment (Ramírez, Hinojosa, & Rodríguez, 2014). In addition, online recordings can redistribute face-to-face (contact) time to more effective in-class modes such as active learning or teamwork (Khan, Egbue, Palkie, & Madden, 2017). The more common lecture recording methods are reviewed below.

- *PowerPoint* recordings offer instructors an easily generated video output from prepared slides within the *PowerPoint* product. The recording usually contains a 'talking head' of the instructor that is embedded into the recordings to make them more engaging. A feature of this method is that the lecture material is readily available on the slides for the teacher to use as prompts and can include simulations and animations. In addition, instructors can record in the comfort of their office or at home on PCs or tablets.
- Video recording using a *Whiteboard* allows the presenter to be fully observed while writing on a white board. This method delivers a more personal interaction with the viewer who can now observe mannerisms as well as content. However, the instructor is often not facing the viewer and/or partially obstructing the content being written on the whiteboard. Simulations and animations cannot easily be incorporated into this method.
- The *Lightboard* lecture recording method is one the latest technologies to be embraced by university lecturers (Hay & Wiren, 2019; Schweiker, Griggs, & Levonis, 2020). It incorporates a fully observed instructor always facing the viewer while writing on a glass panel with coloured fluorescent or liquid chalk markers. However, studio based light boards are expensive and can cost as much as $10,000 AUD (for example Revolution Lightboards; https://revolutionlightboards.com/collections/lightboards).
- *Zoom*, *Collaborate*, *iSee* or other specific apps with digital black or white boards are now commonplace and allow lecture recordings to be made effortlessly. In addition to these systems, phone cameras can be used to record a lecturer simply talking while not using any additional aids or slides. This is particularly useful for a quick introduction of the course at the beginning of semester. Of course, *Zoom* and the like do allow the incorporation of *PowerPoint* slides, embedded simulations and animations to enhance the online learning experience to produce a similar product to point one above.

While individual recording methods have limitations that may not allow complex STEM concepts, such as 3D schematics, to be transferred in the most optimal way, they have the common feature of allowing viewers to pause, rewind and replay as many times as needed. Videos exploiting any of these technologies must be well-choreographed and attention be given to body mannerisms and cues, if they are to maximise message transfer (Young, 2021). Whilst debate about the optimal video length for maximum engagement is ongoing, it is generally accepted that short lecturette style videos around 6-10 minutes long, achieve student retention, i.e. watching all the way through (Schweiker et al., 2020).

Online modes of interaction

Typically, Universities pay for a virtual course management system (CMS) such as *Blackboard*™, *CANVAS*, or *Moodle*, to provide an easy, reliable and safe portal for their course material. Also known as a virtual learning environment (VLE) or learning management system (LMS), they feature customisable open architectures that allow many features to be included, such as polling, discussion boards, and user statistics. These environments are largely responsible for enhancing or hindering student engagement, the degree of which is not clear (Coates, James, & Baldwin, 2005; Walker, Lindner, Murphrey, & Doole, 2016), especially given that the student experience can be platform-specific. The CMS has constrained instructors to build courses in a certain way, limited by the architecture and features available (Lane, 2009). An example is the static discussion board, with threads used in many CMS environments, and has progressed in only minor ways over the last 30 years. The discussion board was designed to provide a platform with student interaction and therefore engagement. However, this "engagement" has diminished over the years as more interactive social media platforms have emerged.

Systems for online communication in industry have changed dramatically. Communicating management systems and are now becoming paramount for more than just email. Project driven businesses rely on real-time workplace interaction to ensure fast and secure exchange across the globe. Platforms such as *Slack*, *Microsoft Teams*, *Google Chat* and *Discord*, are just a few of the current channel-based communication environments that connect workplace software tools and services for seamless sharing of documents or other assets. However, uptake of these sort of tools by universities into the most common CMS systems has been much slower.

The University of Newcastle has recently upgraded its Bachelor of Science program to focus more on soft skills such as report writing and communication, as well as industry-based projects. The Physics discipline used this opportunity to develop courses based on multimodal teaching approaches, while under increasing teaching workload requirements. Each second- and third-year course was reduced by one contact hour, six down to five per week. This paper describes the first and second iteration of a new Modern Physics (Modern Physics II) course designed in 2020 under COVID-19 restrictions, that utilises the best attributes of online, blended, and face-to-face modalities with both CMS and workplace platforms. The objective was to identify a combination of different teaching modes (while not identical for every course due to constraints in equipment) that utilise technology to maximise the learning and enable flexibility during COVID-19 restrictions.

Methodology

The Modern Physics II course developed in 2020 was a result of 2 years of rethinking how to better deliver content and enhance engagement for all the Physics courses at the University of Newcastle, whilst aligning with the revision of the Bachelor of Science program. In particular, the Modern Physics II course was developed for a combined roster of both University of Newcastle and James Cook University students. The matchup with universities was based on what each physics discipline could offer each other, to complete a full range of undergraduate courses. The Modern Physics II course comprised three, four-week modules: Special Relativity, Nuclear and Particle Physics. The first implementation of the course consisted of 21 active students. Throughout this paper, statistics will be quoted based on this number of participants. Figure 1 outlines the initial proposed multimodal strategy for Modern Physics II, which will become relevant as the discussion continues.

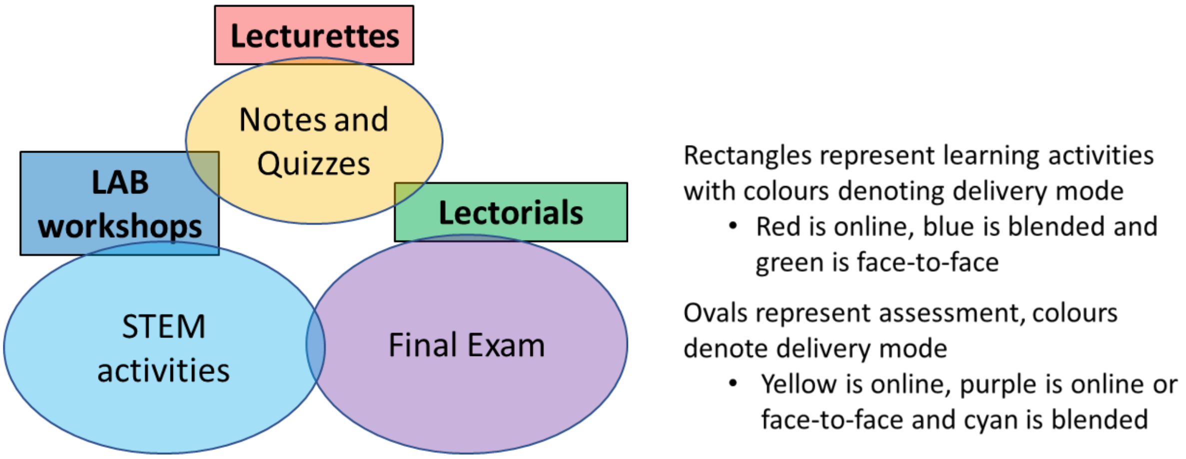

Figure 1. Proposed plan for Modern Physics II course multimodal approach to learning activities and assessment.

The rectangles in the figure represent the three modes used to interact with students under a multimodal education approach. The modes consists of online, face-to-face and blended, which were specifically chosen to maximise engagement with the students. Here we are defining engagement as a complete interaction with components of the course. For example, watching the majority of the lecture video recording, i.e. to the Newcastle logo at the end of the video, instead of just partially viewing or skipping sections. Other examples such as completing all quizzes, will be introduced in related sections below.

For the new Modern Physics II course, the assessment tasked to students (ovals in figure 1) were aimed at incentivising them to interact with the course materials in the most comprehensive way possible. The structure was designed such that students were assessed on recorded material prepared for both laboratory workshops and lectorials (a combination of guided example questions and problem-solving group work) in a variety of pedagogical forms (e.g., constructivist, collaborative and Inquiry Based Learning).

Students were polled using the online student evaluation of course survey organised by the University for each course. Feedback was also obtained through voluntary, brief (20 – 30 second) polling at the end of each module quiz, as part of their weekly assessment in weeks 4, 8 and 12. Only polling questions which showed a unimodal distribution without any outliers were included in analysis, thus providing a “large enough sample” for the statistics to be useful. This is important for low sample size (low student numbers) if evaluations are to have relevance (Statistics How To, n. d.). These polls had identifiers removed by a third party before being given to the course co-ordinator for evaluation. It should be noted that the 5-point Likert scale for small samples is limited, but still an adequate way of measuring personal attitudes (Willits, Theodori, & Luloff, 2016). The following sections will outline the multimodal approach taken for this course and the assessment of their outcomes.

Implementation and Outcomes

The initial delivery of the course in 2020 revealed that many aspects of this approach were well-received by the students and staff. For example, the majority of students appreciated making their own lecture summaries as an assessment task. Consequently, teaching the course with this model was more enjoyable as the students were well prepared for the lectorials. In addition, this flipped structure replaced the lost contact hour due to workload, however, higher than expected workload associated with the new course design generated some negative feedback from both students and academic staff. Students were required to study and submit multiple assessments each week, resulting in increased marking and course coordination duties. See next section.

Lecturettes

Online lecturettes (mini lectures) were designed for a flipped classroom scenario for the entire Modern Physics course using asynchronous learning so that students can learn on their own schedule. To ascertain which format engaged students more, this study was purposefully setup to have videos generated firstly using *Lightboard* for the first four-week module (Special Relativity), then *PowerPoint* for the second module (Nuclear Physics) and finally *Lightboard* returning for the last module (Particle Physics). Some of the videos used in all modules employed multiple people on screen to create a more conversational, Q&A-based lecturette (see figure 2a). Both *Lightboard* and *PowerPoint* videos incorporated the use of embedded images, animations, and simulations where appropriate. However, overlaying the external content on the *Lightboard* in a professional way required additional expertise, which was provided by the University multimedia support team (see figure 2b). All lecturettes also contained embedded questions with hints and solutions on the content, so that students can attempt these questions until they get them correct. These embedded questions from the lecturettes form the framework for the weekly online quizzes performed during the lectorial (see Lectorial section) The following example of an embedded question with optional hints was taken from the Special Relativity module.

> **Q: If the time interval measured at the same location on a moving frame is 100sec, and is observed to be 109 sec by someone in a non moving frame, how fast is the moving frame going? (ANS = 0.4C)**
>
> **Hint 1: Which frame is the proper time in?**
>
> **Hint 2: Calculate gamma and then v)**

No lecture notes or text, other than material in the videos, was provided to the students. Students were tasked with writing summary notes from the recordings. This assessment task made up 18 % of their final grade and was the main workload concern for both students and staff as commented below.

‘*While the note writing was good, it made the course have quite a heavy workload*.’

The increased marking workload of the lecture summaries substantially reduced by week 3, from 60 to 10 minutes, as nearly all students fully adhered to the rubric. Implementation of this assessment structure may be of workload concern for very large class sizes however the new CMS technology called *Gradescope* (http://www.Gradescope.com), provides automated grading of text-based submissions via Artificial Intelligence and are currently trialling at the University of Newcastle. The weekly online quizzes would impose no additional problems for large class sizes.

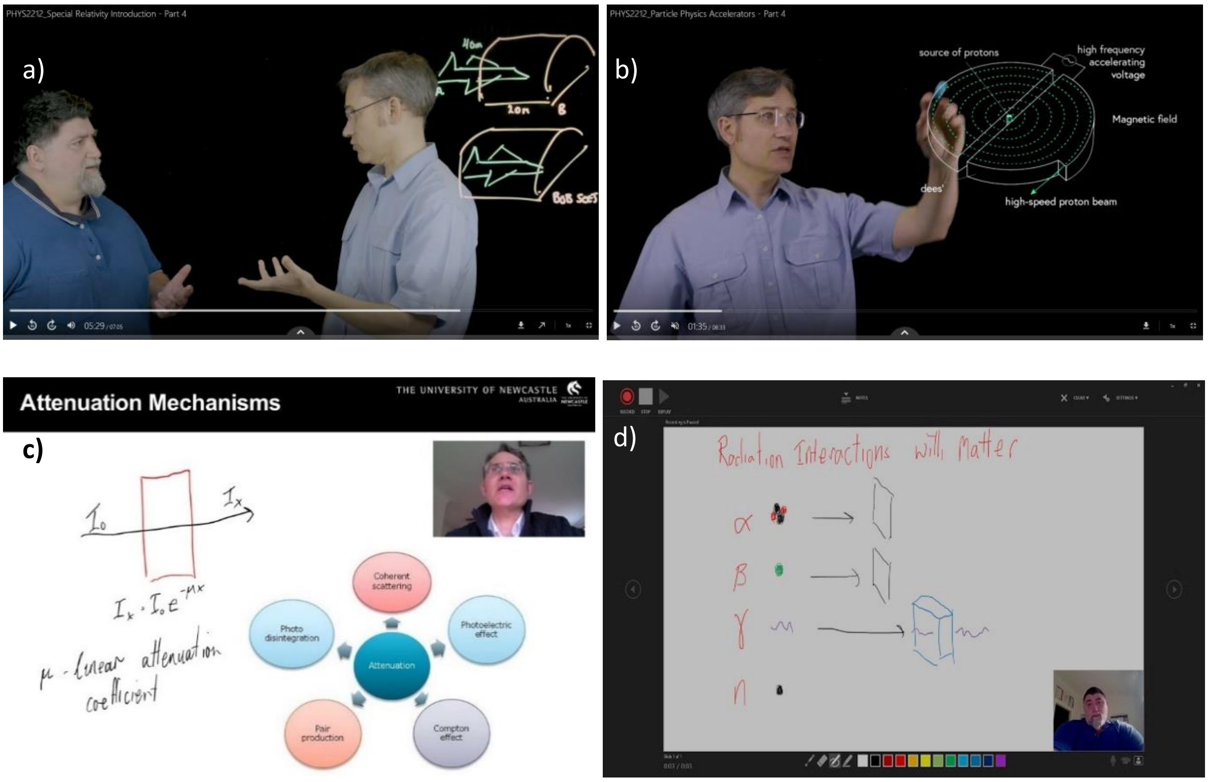

Figure 2. lightboard with a) multiple people and b) embedded material. PowerPoint with c) embedded academic head and text and images (predominately used) and d) recording studio with embedded academic head using writing tools.

Blackboard statistics showed 100% engagement with the lecture video content, including watching the <u>entire length</u> of the videos for every video in the entire course. The flipped classroom delivery mode was compared between *Lightboard* and *PowerPoint* video lecturette recordings over a two-year period. There was no statistical difference between the average scores of the submitted summary notes based on either *Lightboard* and *PowerPoint* recordings (*N*= 21, t=-2.1, 0.3 for 5% significance). Students were also polled through *Blackboard* as part of their lectorial quiz, with the following questions relating to the lecturettes videos.

> *'To what extent did the lightboard videos support your learning?' , which produced a score of 4.6 out of 5. (5 being very helpful and 0 being very unhelpful)*

> *'To what extent did the PowerPoint video recordings support your learning?', which produced an average score of 4.04 out of 5.*

The results for these two questions are in a histogram in Figure 3 and show that while both output modes provided positive outcomes, they also show a statistically significant difference in opinion based on a t-test comparison of the *Lightboard* and *PowerPoint* means in Table 1 (*N*= 28, t= -3.8, $p<1x10^{-3}$ for 5% significance). In particular, the students perceived that the *Lightboard* videos had a much greater positive impact on supporting their learning and engagement than the *PowerPoint* recordings. No difference was observed between University of Newcastle and James Cook University cohorts, although the sample sizes are too low for a real comparison at this stage.

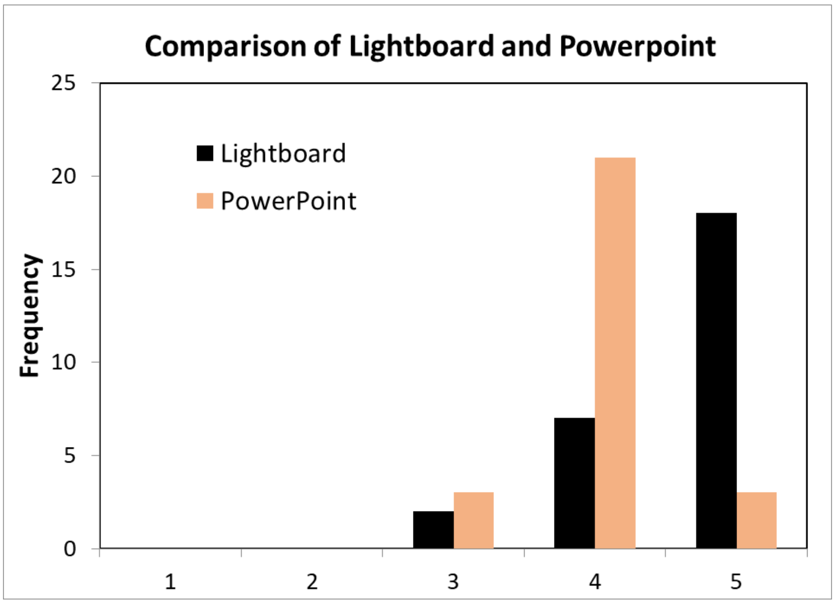

Figure 3. Comparison of *Lightboard* and *PowerPoint* for the learning support. A score of 5 corresponds to "very helpful" and 1 "not very helpful".

Table 1. Frequency responses for the polling questions for comparison of *Lightboard* and *PowerPoint* video recordings and subsequent lecture summaries.

Question	*N*	Very unhelpful	Unhelpful	Neutral	Helpful	Very Helpful	Mean
Score		**1**	**2**	**3**	**4**	**5**	
To what extent did the lightboard videos support your learning?	28	0	0	2	7	19	4.61
To what extent did the PowerPoint video recordings support your learning?	28	0	0	3	21	4	4.04
Lecture summaries helped make you engage in course	25	0	1	5	9	4	3.84

Students polled in the online course satisfaction survey commented the following about the lightboard and PowerPoint recordings.

> *'The pre-recorded video lectures were a really fantastic improvement on previous courses and helped with engagement. Very professional'*

> *'This course has been effectively run online quite well I think, the frequent assessments help to keep focus on the course, and the lecture videos are flat out the best and most informative pre-recorded lectures I have had in a course so far'*

> *'The lightboard videos were very engaging and to the point making the material easier to digest.'*

Students were also polled during occasional lectorials on the summaries they had to submit on the online lecture videos:

> *'Lecture summaries helped make you engage in course'* which produced a score of 3.8 out of 5.

Students polled in the online student feedback of course, also remarked on this assessment task.

> '*I do really enjoy the lecture videos, and having the lecture notes assessed is a great idea that all courses should be doing'*

> '*It is good making the notes each week as it builds a great set of notes*.'

Lectorials

Lectorials are so-named to emphasise to other academics at our University that these sessions are to be treated as a new format of delivery, and not just a tutorial or lecture but a synergy of the best parts of both. This delivery method was first used by the Royal Melbourne Institute of Technology (RMIT) in 2010 (Mahapatra, 2018). This new format consisted of 2-hours of designed active learning through problem solving which evolved throughout the course. Initially, the first part of each lectorial was instructor-led, however after the first two weeks, the first part of the lectorial ended up being driven by the students requesting time to ask questions relating to the online videos or embedded quizzes (15-20 minutes). The second part of the lectorial then became the academic stepping through the major topic for that week through an instructor-led, guided learning exercise which involved Q&A with the students (approximately 30 minutes). The third part consisted of the weekly quiz (5-10 minutes) while the fourth was guided problem-based teamwork learning, where most of the questions were set out for completion in a stepwise fashion to guide the students through answering the problems. Effective time management through a well-scripted set of lectorial notes was critical to maintaining engagement and keeping students on task. A small percentage of students would leave the lectorial if the quiz was placed within the first hour in the session, which correlates well with previous studies concluding students are incentivised to engage if an assessment is present (Arnold-Garza, 2014; Katz & Kim, 2016).

In the first year (2020), the lectorials were held in an online *Zoom* environment for all three modules due to COVID-19 restrictions. In the second year of running the course (2021), the *iSee* virtual environment was compared to *Zoom* in different modules, Special Relativity (module 1) in *iSee* and Nuclear and Particle physics sections in *Zoom*. In either environment, students were strongly encouraged to have their cameras on, which gave it a closer feel to a face-to-face session. Students would comply but had to be repeatedly encouraged at the beginning of each lectorial. The attendance was over 85% each week and stayed over 80% for the entirety of the term. This was the highest rate of attendance for any second year Physics course at the University of Newcastle and needs to be placed in the context of typical remote learning course attendance rates dropping to 30-50% within a few weeks, based on our previous experience.

Zoom provided a relatively low bandwidth option which all students found easy to use and avoided equity issues when video cameras were turned on. In addition, Zoom comes with a built-in white board that all students could interact with in real time with very little lag issues. In class polling was also utilised when the instructor had a preprogramed agenda, since polling required advance preparation for the current University licence. When the lectorial conversation deviated, there was no avenue to setup an ad hoc poll. As *Zoom* was embedded within the blackboard CMS, access links were effortlessly setup and made available to students in a designated area. In-class polling, Table 2, showed that *Zoom* was helpful to engage with the majority of students. The question:

> *"How helpful was using Zoom to engage with the course*?" produced an average response of 4.3 out of 5

Table 2. Polling questions for Lectorials

Question	*N*	Very unhelpful	Unhelpful	Neutral	Helpful	Very Helpful	Mean
Score		**1**	**2**	**3**	**4**	**5**	
How helpful was using Zoom to engage with the course?	28	0	1	2	7	9	4.26
How helpful was iSee to engage with the course	9	0	1	1	4	3	4.00

It was found that the *Zoom* environment was not too dissimilar to a face-to-face classroom where we could separate students into groups as well as ask individuals questions. Most discussions however ended up being dominated by the same roughly 30% of the class (based on a review of the recorded *Zoom* sessions). This outcome was reflected by the following course feedback

> '*still don't like online lectorial, feel very awkward to ask questions and discuss online. I felt I was constantly cutting off others speech unconsciously*.'

One of the difficulties with the *Zoom* breakout groups was that the instructor had to 'leave' one group to provide learning support to another. Even with multiple instructors it was found that under the initial licence agreement, the instructor who setup the *Zoom* session was the only one who could move. This issue was resolved during the second iteration of the course with a new licence agreement enacted.

The *iSee* virtual environment used in module 1 in the second iteration of the course in 2021, provided an immersive atmosphere that initially provided quite an exciting avenue for the online lectorials. This system included a virtual lecture theatre, tutorial rooms, and "hang out" spaces like outdoor areas and a coffee shop, that all try to mimic the real-world that students interact with at University, and includes a feature where the audio is distance relative mimicking real life. However, there were issues with this technology, including access since this environment was not fully integrated into the University CMS. Like *Zoom*, *iSee* provided an in-built white board, which was to be employed for the lectorials by splitting the students up into groups. Each group would have an interactive screen to solve problems where the instructor could also monitor their progress by simply moving or rotating their view to that board. Unfortunately, the in-built *iSee* white board had limited drawing tools and resolution, making writing effectively illegible. The authors tried a variety of alternatives, including *Microsoft OneNote* (however JCU students could not log in due to the access limitations) and a variety of online whiteboards, which all had CPU resource issues while in combination with the *iSee* environment. Table 2 shows that students did think the *iSee* environment was helpful in engagement, but not as well as *Zoom*.

Laboratory Workshops

The laboratory workshops were constructed to use a variety of active engagement techniques, from purely online worksheets to hands-on and remote experimental work. These assessments were developed to work seamlessly under changing COVID-19 restrictions by providing additional real-time online support through multiple avenues such as *Zoom*, *Collaborate* and *Slack*. Students were organised in groups and could choose to attend face-to-face or via *Zoom*, with an external monitor setup in the teaching laboratory. This flexibility circumvented many difficulties such as restricted laboratory numbers and illness, limited laboratory space capacity (ensuring recommended distancing), and alleviating student and staff anxiety associated with enclosed spaces under COVID-19.

As part of these workshops, multiple new activities were developed. The first was an innovative face-to-face learning activity designed to offer students a more realistic project-based workplace environment that they would be exposed to in a research-based company. This activity required students to assemble a robotic arm (*Arduino Tinkerkit Braccio Robotic Arm*), and then attach an Arduino controller to interface the arm with a computer and code the arm to move (see Figure 4a). In addition, students used their functioning robotic arm to conduct, design and perform an experiment using a radioactive source. The experiments students chose to investigate with radioactive sources varied depending on their coding and mathematical ability and ranged from simple linear intensity changes with distance to full 3D-intensity mapping using spherical coordinates. Students were able to upload progress to their supervisor in the *Slack* messaging application and get real-time feedback. In the process of completing this workshop, students were exposed to planning, management, and *Python* control coding where they had to provide both visual and written updates to their "workplace supervisor" (the demonstrator) via a *Slack* channel created for each team. During experimenting with picking up objects, students soon realised that the base plate accompanying the kit was not large enough to prevent the arm from falling over. As a consequence, students were also required to gain tool workshop training in our local Makerspace (University workshop where students can design and build projects through self-creative or self-directed learning) to create new base plates, as shown in Figure 4a. These robotic kits have also been made available to students to take home in circumstances preventing face-to-face contact.

Additional workshops were incorporated from previous courses as remote (off-site) access laboratories (Sharafutdinova et al., 2013). Firstly, a remotely linked large commercial grade robotic arm (*ST Robotics*) was employed for an experiment on nuclear spectra, using a highly radioactive material that students cannot be exposed to. This remote workshop involved a written report where they were required to submit a draft and get feedback via a letter, similar to how a journal editor would respond. The students had to write a response to this editor letter, and submit along with their changes to the submitted draft. As well as providing an authentic experience to scientific work practice, this encourages students to review their own work, improve scientific writing skills, and achieve better marks.

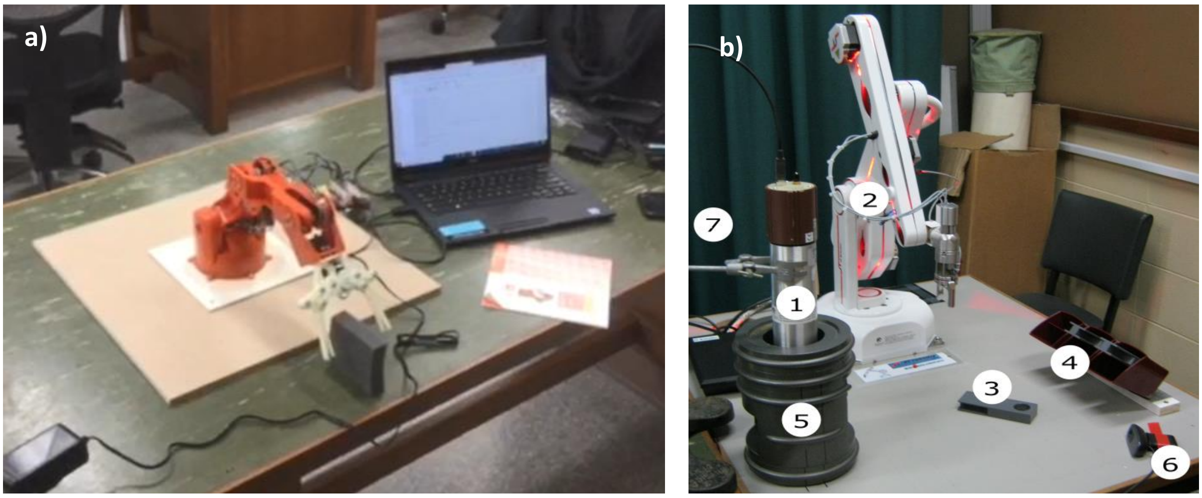

Figure 4. a) Robotic kit arm setup and testing its ability to pick up a radioactive source encased in foam, and b) Remote robotic arm setup with scintillation counter (1), robotic arm (2), radioactive source holders (3), housing for radioactive source holders (4), radiation lead shielding chamber (5), USB web camera for real time view of lab operation (6) and control computer (7)

The second remote laboratory involved remote access to equipment to measure sub-atomic particles (muons) created in the upper atmosphere, and tied in student knowledge from both the particle physics and special relativity modules. Students were required to submit a two-minute video report or "vlog" on their experiment and outcomes, and was an attempt to broaden the students' science communication skills. The submission of video reports however was a large strain on the submission portal in the learning environment system (*Blackboard*) and alternative submission methods such as via USB, were implemented during the first year (2020). In the second implementation of the course (2021), *Zoom* was more familiar to the students and provided a much easier way to record video in compressed mp4 format.

All these laboratory workshops had near 100% participation and were designed to align well with learning outcomes identified in the strategic plan associated with the Bachelor of Science redevelopment. Specifically, these activities targeted the "embracing technology and best practice to deliver the best possible student experience" and "producing life-ready graduates" goals. The laboratory workshops received overwhelmingly positive feedback in course evaluations. For example:

> '*Having a laboratory report that was then reviewed and a letter to review submitted was great opportunity to see how real papers are handled*.'
>
> '*The robotic arm lab was awesome'*

Final Exam

The final exam made up 40% of the overall marks. The exam was made up of a mixture of multiple choice, short answer, and essay questions based on the work done within the lectorials and laboratory workshops. Due to COVID-19 and the exam being open book, it was decided that all questions were to be new to the students. Consequently, a significant amount of time was spent on careful question development. This generated a much more difficult and longer exam than students would have been offered in pre-COVID-19 circumstances. No sample exam or other exam materials were given to the students. For quality assurance, after exam submission, some students were randomly chosen to carry out a ten-minute oral viva through *Zoom*. In this time, students responded about how certain questions were answered in the exam. For the two years running the course, the average mark for the exam was 61 % over both cohorts, with no statistical difference observed between the two cohorts.

Conclusion

The new multimodal pedagogical approach employed for our 2nd year Modern Physics course produced high student attendance and engagement. Professional lightboard lecturettes were demonstrated to be evidently more helpful and engaging for students than *PowerPoint* recordings (N= 28, t= -3.8, p<1x10^{-3}), but require in-house expertise to be readily available. Incentivising students to generate their own weekly summaries of the lecture videos with embedded questions as assessment task ensured high engagement with the course content and class activities. The use of *Zoom* to conduct the class activities was found to be very helpful by both students and academics. Utilising workplace channel-based communication platforms provided the necessary real-time monitoring and flexibility required in laboratory workshops for post-COVID-19 student-instructor interaction.

Acknowledgements

This work is under Quality Assurance (QA259), approved by the University of Newcastle Human Research Ethics Committee.

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