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Exploring student perceptions and use of face-to-face classes, technology-enhanced active learning, and online resources

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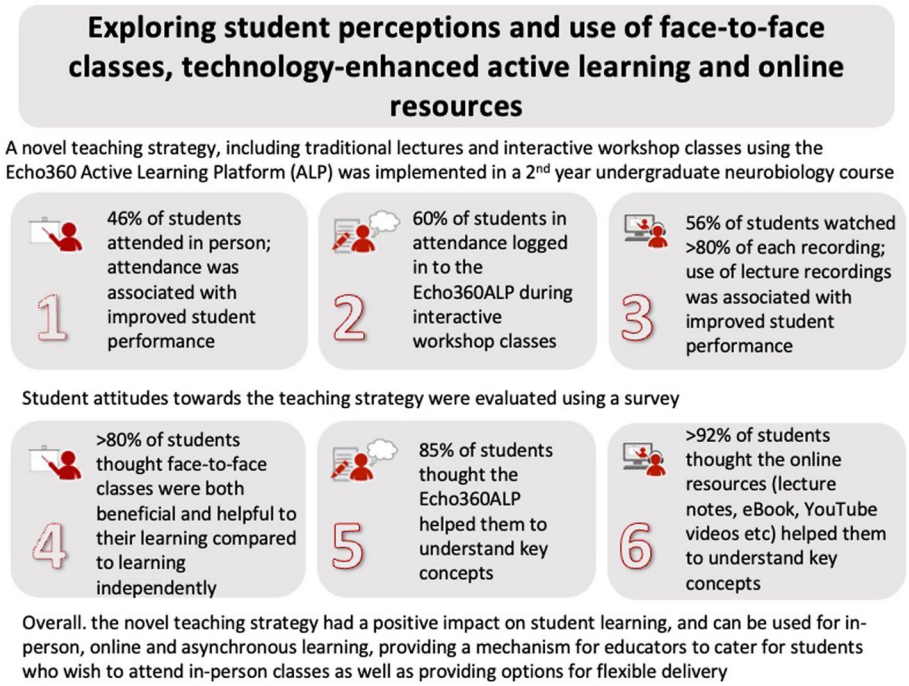
Abstract

The current cohort of undergraduate students is often said to value technology and is assumed to prefer immersive, interactive, and personalized learning experiences. In contrast, many educators recognise the value of face-to-face classes and believe that attending class positively impacts student performance. A novel teaching strategy, including traditional lectures and interactive workshops using an educational technology platform were implemented in an undergraduate neurobiology course. Attendance in class and use of lecture capture recording were associated with improved student performance. Further, student attitudes toward the teaching strategy were evaluated via a survey. The survey respondents included those that regularly attended class and those that did not. Overall, irrespective of attendance, students thought that face-to-face classes were beneficial to their learning and the use of active learning activities helped them to understand the course content. The most common reasons for non-attendance in class were attributed to factors such as the class schedule, work and family commitments and were not related to the availability of class recordings and other online resources. In contrast, the most common reasons for attendance in class included the perceived benefit, the standard of teaching and the level of interest in the course. The novel teaching strategy had a positive impact on student learning, and can be used for in-person, online and asynchronous learning, providing a mechanism for educators to cater for students who wish to attend in-person classes as well as providing options for flexible delivery.

Keywords: Asynchronous learning, Synchronous learning, Attitudinal survey, Lecture capture, Echo360ALP

Graphical Abstract



Introduction

Each new generation of students has characteristics, interests and learning preferences that set them apart from the previous generation, and understanding these differences is necessary for educators to create learning environments that are engaging, inspiring and productive (Poláková & Klímová, 2019). The current cohort of undergraduate students are often described as individuals who have grown up with technology as an integral part of their daily lives (Seemiller & Grace, 2016). They are thought to be highly adaptable to new technology and expect their learning experiences to be immersive, interactive, and personalized (Reviewed in (Shorey et al., 2021)). This cohort of students are also considered to be more independent learners, often relying on online resources to support their education, with a preference for and the ability to learn at their own pace (Chicca & Shellenbarger, 2018; Seemiller & Grace, 2016).

In 2020, the global coronavirus pandemic necessitated a rapid pivot to online and blended learning at universities in Australia and around the world, accelerating the trends that were already in process (Watermeyer et al., 2021). As a result, there has been a rapid expansion into the online learning space and an increasing reliance on the use of educational technology and virtual learning environments to deliver content and to facilitate online learning (Reviewed in (Arday, 2022)). As educators, we are entering an unprecedented era, one in which we are tasked with providing high quality instruction to engage students in their own learning despite the potential for ongoing educational disruption. There are many challenges in this changing landscape

including how to cater to students who want the flexibility of studying online or asynchronously with those that want to return to face-to-face delivery.

Prior to the pandemic, a common mode of instruction at university was the traditional didactic lecture, although technology-enhanced active learning, problem-based learning and flipped classroom strategies have also become popular (Kirkwood & Price, 2014). Educators often placed value on in-class attendance which was viewed as an important indicator of student success (Crede et al., 2010; Guleker & Keci, 2014). Indeed, a systematic review of the relationship between lecture attendance and academic achievement revealed that 75% of studies showed a significant positive association between class attendance and academic performance for undergraduate students in the biosciences (Doggrell, 2020b). However, there is an increasing trend at our Institution and others to provide lecture capture recordings and to develop online digital resources to facilitate student learning. The provision of these resources offers increased flexibility for students to engage with the course content, but a common concern is that this may negatively affect attendance and may not improve student outcomes (Gosper et al., 2010; Kinash et al., 2015; Preston et al., 2010). Specifically, the availability of captured lectures has been postulated to reduce student interaction in face-to-face classes (Mark et al., 2010). Attendance rates for students vary widely and the reasons for absenteeism often include student perception of the value of traditional lectures as well as the availability of class recordings and other online resources (Reviewed in (James & Seary, 2019)). There is also the potential for traditional modes of delivery to be at odds with the learning preferences of the current generation of students (Shorey et al., 2021).

Technology-enhanced learning is a broad term that can be used to describe any form of e-learning. Accordingly, technology-enhanced learning strategies can refer the use of technology to improve learning in face-to-face classes, the creation and use of digital resources for asynchronous learning or using social media (and other platforms) to encourage collaborative learning (Ansari & Khan, 2020; Voorn & Kommers, 2013). The impact of these strategies on student learning is reliant on the student's engagement with and usage of the specific technological platform that is implemented (Dunn & Kennedy, 2019). While the impact of in-class attendance on academic achievement has been extensively studied (Crede et al., 2010; Guleker & Keci, 2014), when technology-enhanced learning strategies are implemented, the relationship between student attendance and academic performance is more difficult to ascertain. Some studies have shown no correlation between class attendance and performance in courses where lectures are recorded and class materials are available online (Doggrell, 2020a; Kauffman et al., 2018). Other studies have shown that students who study independently, using online resources, can have similar academic outcomes and may even outperform those who attend class (Eisen et al., 2015; Lukkarinen et al., 2016).

Active learning is a key component to undergraduate science, technology, engineering, and mathematics (STEM) education (Freeman et al., 2014) however, lectures at higher degree institutions are often held in learning spaces that are not conducive to in-class participation (Büchele, 2021; Fadelelmoula, 2018; O'Keeffe et al., 2017). To overcome this challenge, educators often use technology to enhance the learning experiences for students (Wood et al., 2018). Echo360 is a platform that is commonly used for the automatic recording of classes. The newest iteration of this product, the Echo360

Active Learning Platform (Echo360ALP), is a technology-enhanced learning platform designed to facilitate active learning, promoting student engagement and participation (Shaw et al., 2015). The Echo360ALP has been available at Griffith University from 2018. Its functionality includes the ability for educators to embed polling questions at strategic points in their presentations and students can log in and answer these questions in real time. This active learning platform also includes the ability to directly embed multimedia into in-class presentations which is likely to appeal to learners who prefer to seek information through visual learning (Seemiller & Grace, 2016). Using a technology-enhanced active learning platform as a tool, it is possible to create novel and innovative learning experiences which may encourage students to attend class and engage with class material.

The present study

The learning preferences of the current cohort of students for immersive, interactive, and flexible learning experiences are at odds with the traditional didactic delivery of lectures at university. To address this issue, a novel teaching strategy was implemented in a second-year undergraduate neurobiology course incorporating a unique blend of traditional lectures, active and interactive learning strategies, and online learning resources. Specifically, face-to-face classes included traditional didactic lectures which were used to deliver course content, and workshop classes that used an active learning platform to facilitate student interaction and engagement during class (Freeman et al., 2014; Shaw et al., 2015). In addition, all classes, were recorded and made available to students asynchronously. The teaching strategy was designed to meet the diverse needs of students and was aimed at fostering student engagement and motivation to attend class and engage with the course materials (Dunn & Kennedy, 2019). Thus, a key objective of the current study was to investigate student attendance in face-to-face classes, their use of class recordings, and the impact of these on student performance in the course. Students were also surveyed to establish their views on the teaching strategy including the use of an active learning platform in the classroom, their use of the available resources as well as factors that influenced their decision to attend, or not attend classes in person.

Methods

Cohort characteristics

The study participants were second-year undergraduate neurobiology students who completed the course as part of their program of study at Griffith University. Ethical Clearance for this project was obtained from the Griffith University Human Ethics Committee (GU Ref No: 2018/651). The course is offered in one 12-week trimester each year with two distinct cohorts analysed in this study (2018 and 2019). The course is a requirement for students in the Bachelor of Biomedical Science program and an elective for students in other health programs. Many of the students in these programs have career trajectories that include medicine, medical research, or allied health professions. In 2018 the cohort consisted of 115 students; 85 (74%) were from the Biomedical Science program, and 21 (18.3%) were from the Health Science program. The remaining nine students were from other health-related programs. In 2019 the cohort consisted of 93 students; 63 (72%) were from the Biomedical Science program, 25 (26.9%) were from

the Health Science program, and the remaining student was from another health-related program. In the 2018 cohort there were 67 female students (58.3%) and 48 male students (41.7%). In the 2019 cohort there were 54 female students (58.1%) and 39 male students (41.9%). Data from both cohorts were combined in the analysis.

Educational context and course structure

The course was designed using a constructivist approach (Biggs, 2014) and consists of a series of scaffolded weekly topics starting with fundamental topics (e.g. neuroanatomy) and progressing to more complex integrated topics (e.g. dementia). The main objective of the course is to teach students about the function of the brain and specifically how damage to discrete areas of the brain results in the symptoms associated with various neurological and neuropathological conditions.

Each topic was designed and structured using Bloom's Taxonomy (Krathwohl, 2002). The theoretical content was taught in face-to-face lectures which were automatically recorded using the Echo360 lecture capture system and made available within a few hours of the scheduled class. Additional digital resources including detailed learning objectives, presentation slides, and review questions were available for each topic. Students also had access to an online interactive textbook hosted by a third-party vendor that was authored by the course instructor, free to access under specific conditions and directly aligned to the course outcomes. The online textbook included formative assessments in the form of quiz questions as well as embedded multimedia usually in the form of YouTube videos that were vetted for appropriateness and accuracy of content.

To encourage student engagement and facilitate deep learning, each topic also included clinical case studies to provide a real-world context for students (Meil, 2007; Mickley & Hoyt, 2010). Students were expected to engage with and acquire knowledge about each topic from one of the available resources (in-person lecture, recorded lecture, or interactive textbook), and then apply that knowledge to analyse case studies in the workshop classes. For some topics, the theory and applied components were combined in a single class. The workshops (14 in total) were designed to be interactive and used an active learning platform. Each workshop included at least one case study and included polling questions which the students could answer in real-time as well as multimedia (video) which was used to showcase patient symptoms. The workshop classes were also automatically recorded using the lecture capture system. Students had access to the recording itself as well as the presentation files which included the embedded polling questions.

The timetable, timing and form of assessment, venue and teaching staff were consistent for the course offering in both 2018 and 2019. All lectures and interactive workshop classes were delivered by a single instructor in both 2018 and 2019.

Student attainment measures

The final exam was worth 50% of the overall grade and was held during the exam period at the end of the trimester. This item of assessment was conducted in-person, under exam conditions and included case study questions like those presented in interactive workshop classes. The dependent measures used as measures of student performance were the final exam percentage (*Final Exam*) and final overall percentage (*Overall*

Percentage). Student grades for two pre-requisite anatomy and physiology courses were available for most students (83.5% of students in 2018 and 92.5% in 2019). The average pre-requisite grade was determined for each student individually and was used as a variable in the bivariate Pearson's correlation analysis. Students without grades for the first-year courses were external transfers who received credit for the course.

Class attendance & in-class participation

Attendance was recorded in 14 classes during the trimester. A list of student names was circulated during the class. Students could sign in on entry to the class or mark their name off as the clipboard circulated through the room. The sign-in sheets were also available during the 10-min break in the middle of the two-hour class and at the end of class for any student who had not marked off their name. Attendance, as expressed as a percentage of enrolled students, was determined for each individual class (*Class Attendance*). *Student Attendance* was calculated as the total number of classes attended by each individual student (0–14). In-class participation was defined as the number of students who logged in to the active learning platform during class expressed as a percentage of the number of students who attended in-person.

Lecture capture analytics

Lecture capture data was downloaded once for each cohort on the day of the final exam and therefore reflects the number of views during the trimester and in the review period on the lead-up to the final exam. For each individual student, the viewing data was extracted for each class recording and included the view duration, capture duration and percentage of video viewed. If a student accessed and watched more than 10% of a recording it was counted as a "*View*". If a student accessed and watched more than 80% of the recording it was counted as a "*Complete View*". If a student accessed and watched between 10 and 80% of the recording it was counted as a "*Partial View*".

Data analysis

The data was analysed using IBM SPSS Statistics 28 software (SPSS Inc. Chicago, IL, USA). The relationship between *Student Attendance* (total number of classes attended; 0 – 14), *Complete Views* (number of class recordings where > 80% of the recording was watched by the student; 0 – 14) and *Partial Views* (number of class recordings where 10 – 80% of the recording was watched by the student; 0–14) and performance in both the final exam and the course overall was investigated using bivariate Pearson's correlation analysis. To determine if performance in the pre-requisite courses influenced the relationship between these variables, a partial correlation analysis was performed. Analysis of Variance (ANOVA) and post hoc testing (Tukey HSD) was used to determine if differences in student performance measures reached statistical significance (using an α of 0.05).

Student attitudinal survey and data analysis

Data was collected by means of an attitudinal survey. The survey was adapted from previous studies assessing student perspectives to lecture attendance in undergraduate engineering (Fitzpatrick et al., 2011) and neuroscience courses (O'Keeffe et al., 2017).

Table 1 Opinions on lectures and workshops

Reason	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
I think the lectures were very beneficial to my learning	48.04	34.31	7.84	6.86	2.94
I think the workshops were very beneficial to my learning	72.82	20.39	5.83	0	0.97
Attending lectures and workshops helped me to understand the course material better than just reading through or watching the supplied resources	49.51	27.18	15.53	3.88	3.88
The use of in-class interactive tools helped me to understand key concepts in neurobiology	38.46	46.15	8.65	5.77	0.96
Since the lecture and workshop classes were recorded there was no real reason to attend class	10.58	13.46	14.42	47.12	14.42
The Instructor provided lecture notes, ebooks, YouTube videos and other resources which helped me to understand key concepts in neurobiology	60.00	32.38	5.71	0.95	0.95
I accessed and used the online interactive textbook (Neurobiology: A Case Study Approach) which helped me to understand key concepts in neurobiology	32.32	15.15	16.16	20.20	16.16
I think face-to-face lectures and workshops are an out-dated mode of education in the modern world of information technology, distance learning and self-directed learning	0.96	9.62	13.46	36.54	39.42

In 2018, the survey was administered in person in the final class of the year. In 2019, the survey was administered online. The survey included questions regarding demographic information, questions about their attendance in each type of class, their opinions about face-to-face classes and lecture capture as well as questions about the resources provided in the learning environment (Table 1). Students were also asked to indicate their reasons for attendance or non-attendance in face-to-face classes by completing a matrix of possible predetermined options. Students who identified as "*non-attenders*" were given a choice of 17 options and asked to indicate whether it was "never a reason", "sometimes a reason" or "definitely a reason" for their non-attendance (Table 2). Students who identified as "*attenders*" were asked to respond to 14 options with the same three possible responses (Table 3). The survey also included three open questions designed to solicit opinions about attending class and active learning strategies.

The data from each survey was exported to Excel and responses to each question were counted to determine the percentage of students with each response. For questions regarding student opinion of lectures and workshops, data was collected using a 5-point Likert scale. The 5-point Likert scale consisted of the following options: "strongly disagree", "disagree", "undecided", "agree" and "strongly agree". The responses were converted to ordinal data ranging from 1 to 5 with 1 = "strongly disagree" to 5 = "strongly agree". A positive response was indicated by selection of either the "strongly agree" or "agree" option, a negative response was indicated by selection of either the "strongly disagree" or disagree" option. The final option was "undecided" indicating no clear agreement or disagreement with the statement.

Table 2 Reasons for non-attendance

Reason	Never a reason	Sometimes a reason	Definitely a reason
The standard of teaching in the course is poor	97.37	0	2.63
The material covered in the course is not interesting to me	97.37	2.63	0
I did not gain much benefit from lectures	78.95	15.79	5.26
I did not gain much benefit from workshops	84.21	11.84	3.95
The lectures are boring and do not engage my attention	82.89	15.79	1.32
The workshops are boring and do not engage my attention	85.53	13.16	1.32
The classes are recorded so there is no reason to attend	29.87	38.96	31.17
Assessment, labs and tutorials for other courses take up a lot of time and I don't have time to attend class for this course	62.34	28.57	9.09
I prefer to use the time for self-directed study	57.33	26.67	16.00
The lecture notes and other resources supplied for the course are more than sufficient	60.00	29.33	10.67
I accessed and watched the YouTube video links supplied for Neurobiology so did not need to attend class	76.32	21.05	2.63
I accessed the interactive textbook Neurobiology: A Case Study Approach so did not need to attend class	85.53	7.89	6.58
The time of the lecture did not suit me	25.32	37.97	36.71
The time of the workshop did not suit me	64.47	18.42	17.11
Family commitments make it difficult to attend class	59.74	27.27	12.99
Part-time (or full-time) work commitments make it difficult to attend class	56.41	20.51	23.08
My social life makes it too difficult to attend class	81.58	17.11	1.32

Table 3 Reasons for attendance

Reason	Never a reason	Sometimes a reason	Definitely a reason
The standard of teaching in the course is high	5.81	16.12	79.07
Attending class helps me to understand the course material	5.75	14.94	79.31
The material covered in class is interesting to me	2.3	17.24	80.46
Lectures are interesting and engage my attention	16.47	29.41	54.12
Workshops are interesting and engage my attention	4.65	27.91	67.44
Attending class means I have to spend less time studying	32.18	34.48	33.33
The interactive in-class tools used in the course help me to gauge my understanding of key concepts	16.39	40.23	43.68
Listening and participating in class complements the course resources	12.94	28.24	58.82
The Lecturer gets the students involved in activities during class, thus we are actively involved during lectures and workshops	21.43	35.71	42.86
I accessed the YouTube video clips but attended class to improve my understanding of the course content	23.53	31.76	44.71
I accessed the interactive textbook Neurobiology: A Case Study Approach but attended class to improve my understanding of the course content	44.05	23.81	32.14
I think I will miss out on important information if I miss class	12.64	32.18	55.17
The lecturer keeps a record of attendance	58.62	20.69	20.69
I want to maintain a good impression with the Lecturer	44.71	28.24	27.06

The data was analysed using IBM SPSS Statistics 25 software (SPSS Inc. Chicago, IL, USA). For each statement, descriptive statistics including the mean score were calculated. Further, Pearson's Chi-squared tests were performed to determine whether the student's choice significantly deviated from chance where the expected outcome was defined as equal numbers of students selecting each option. Students were also asked to indicate their reasons for attendance or non-attendance in face-to-face classes by completing a matrix of possible (predetermined) options. However, students were able to contribute additional responses and reasons via open ended questions.

Results

What resources did the students use?

Attendance in lectures and workshops was not mandatory and students were able to choose whether to attend class in person, use the class recordings as a substitute or a combination of both according to their own preferences. The class materials, including the class recordings and online interactive textbook, were available to all students enrolled in the course and the variety and comprehensiveness of the resources allowed students the flexibility to study independently if they chose.

Workshop attendance varied from 25.8 to 73.1% throughout the trimester for an average of 46%. Individual student attendance ranged from 0 to 100%. While students were encouraged to bring a laptop or other mobile device for in-class polling activities using the active learning platform it was not mandatory. In both cohorts there was a mixture of students who logged in and those who did not. The average percentage of students who logged in to the active learning platform during class was 59.6% (range: 17.8–86.1%).

Lecture capture usage varied across classes, with the average number of views per recording ranging from 99 to 263 (average: 152 views/class). The percentage of students viewing the recorded lectures ranged from 38 to 74% (average: 53.5%). Further, the percentage of students watching more than 80% of the recording ranged from 22 to 60% (average: 56%). Of the 205 analyzed students, 14 attended class in-person but did not watch the recordings ("*Attenders*"), 26 watched more than 80% of each class recording but did not attend in-person ("*Viewers*"), 29 attended class and watched more than 80% of each recording ("*High Engagers*") and 15 neither attended class in person nor watched the recordings ("*Low Engagers*").

The online textbook, hosted by a third-party vendor, was accessible at no cost to students under specific circumstances. Approximately 45% of students in the cohort signed up to access the online textbook but since it was hosted externally, precise tracking data was not available.

How did the students perform in the course?

In terms of in-person attendance, a weak but significant positive relationship was found between *Student Attendance* and performance on the final exam ($R_{205} = 0.284$, $P < 0.001$) and in the overall course percentage ($R_{205} = 0.268$, $P < 0.001$). These relationships remained significant even after controlling for average pre-requisite grade (Final Exam Percentage: $R_{185} = 0.258$, $P < 0.001$; Final Overall Percentage: $R_{205} = 0.235$, $P = 0.001$).

Regarding the impact of watching class recordings, a weak but significant positive relationship was found between watching more than 80% of each recording (*Complete*

Views) and performance on both the final exam ($R_{203}=0.29$, $P<0.001$) and in the overall course percentage ($R_{203}=0.307$, $P<0.001$). These relationships remained significant even when controlling for average pre-requisite grade (Final Exam: $R_{182}=0.279$, $P<0.001$; Final Overall Percentage: $R_{183}=0.316$, $P=0.001$). However, no significant relationship was found between partial lecture capture views (*Partial Views*) and performance on the final exam ($R_{203}=0.02$, $P=0.774$) or in the overall course percentage ($R_{205}=0.004$, $P=0.955$).

To determine if watching more than 80% of each class recordings is equivalent to attending class in person, the performance of "*Attenders*" was compared with that of "*Viewers*". These two groups of students performed similarly in both the final exam (Tukey HSD; $P=0.965$) and overall course percentage ($P=0.975$) suggesting that watching the class recordings can serve as an adequate substitute for attending in person. Further, both "*Attenders*" and "*Viewers*" outperformed "*Low Engagers*" on the final exam ("*Attenders*" vs "*Low Engagers*", $P=0.004$; "*Viewers*" vs "*Low Engagers*", $P=0.032$) and in the course overall ("*Attenders*" vs "*Low Engagers*", $P=0.001$; "*Viewers*" vs "*Low Engagers*", $P=0.009$). "*High Engagers*" performed at a similar level to "*Attenders*" (Final Exam, $P=0.899$; Overall Percentage, $P=0.975$) and "*Viewers*" (Final Exam, $P=1.00$; Overall Percentage, $P=1.00$) on both the final exam and in the course overall.

Student perspectives on the relevance of face-to-face classes

In total, 105 students completed surveys: 68 students in 2018 (59.1%) and 37 students in 2019 (40.2%). Overall, 78.1% of the students were 15–20 years of age and a further 20% of students were 21–30 years of age. There was one student who as 31–40 years of age and one who was in the 41–50-year age bracket. There were more females (66.67%) than males (33.33%). The majority (86.67%) of students used English as their first language and 93.33% of the cohort were domestic students. Most of the respondents were students in the Bachelor of Biomedical Science program (76.2%) and a further 17.14% were in the Bachelor of Health Science program. The remaining students were enrolled in a variety of other programs in the Faculty of Health. Of the students who completed the survey, 62.9% attended more than 50% of lectures, 17.1% attended less than 50% of lectures and 20% did not attend any lectures. Of the students who completed the survey, 72.4% attended more than 50% of workshops, 19% attended less than 50% of workshops and 8.6% did not attend any workshops.

Students were asked to indicate their level of agreement with five statements related to their experience of the course (see Table 1 for details). Out of 105 surveyed students, the majority found lectures (82%) and workshops (93%) beneficial to their learning (mean Likert score, 4.18 and 4.64 respectively). Chi-squared analysis showed a significant deviation in student preference from chance for both statements (Lectures: $\chi^2=81.73$, df$=4$, $P<0.001$; Workshops: $\chi^2=134.01$, df$=4$, $P<0.001$). The majority of students (76.7%; mean Likert score, 4.15) agreed that "*Attending lectures and workshop classes helped me to understand the course material much better than just reading through or watching the supplied resources*". Chi-squared analysis showed a significant deviation in student preference from chance for this statement ($\chi^2=75.30$, df$=4$, $P<0.001$). The majority of students (85%; mean Likert score, 4.15) agreed that "*The use of in-class interactive tools helped me to understand key course concepts*". Chi-squared analysis showed a significant deviation in

student preference from chance for this statement ($\chi^2 = 89.37$, df = 4, $P < 0.001$). Most students (62%; mean Likert score 2.59) responded negatively to the statement "*Since the lecture and workshop classes were recorded there was no real reason to attend class*". Chi-squared analysis showed a significant deviation in student preference from chance for this statement ($\chi^2 = 48.31$, df = 4, $P < 0.001$).

To understand how the students felt about the online resources that were provided by the instructor, students were asked to respond to two statements. The majority of students (92.4%; mean Likert score, 4.5), agreed that "*The Instructor provided lecture notes, ebooks, YouTube videos and other resources which helped me to understand key concepts in neurobiology*". Further, 47.5% of students responded positively to the statement "*I accessed and used the online interactive textbook (Neurobiology: A Case Study Approach) which helped me to understand key concepts in neurobiology*" (mean Likert score, 3.27). Chi-squared analysis showed a significant deviation in student preference from chance for both statements (Resources: $\chi^2 = 140.86$, df = 4, $P < 0.001$; Online textbook: $\chi^2 = 10.14$, df = 4, $P < 0.038$).

The final statement was designed to assess the student's overall opinion about face-to-face classes. The majority of students (76%) responded negatively to the statement "*I think face-to-face lectures and workshop classes are an out-dated mode of education in the modern world of information technology, distance learning and self-directed learning*" (mean Likert score 1.96). Chi-squared analysis showed a significant deviation in student preference from chance for this statement ($\chi^2 = 60.52$, df = 4, $P < 0.001$).

Factors affecting attendance in lectures and workshops

To determine which factors affected the decision not to attend lectures, students were given a choice of 17 possible options and asked to indicate whether it was "never a reason", "sometimes a reason" or "definitely a reason" (Table 2). In a similar fashion, students were asked about the factors which affected their decision to attend lectures and workshops. For this question they were asked to respond to 14 options with the same three possible responses (Table 3).

Various factors influenced student attendance in class. The lecture schedule and the availability of class recordings were reported as the primary reasons for non-attendance. Interestingly, the schedule of the workshop classes was of less concern to students. Of note, work and family commitments were also given as reasons for non-attendance with some students choosing to use the scheduled time for self-directed study instead. Also, of note is that students' reasons for non-attendance were not related to the standard of teaching in the course, the perceived benefit of attending class, the student's interest in the content covered in the course, or the availability of online resources. The complete list of options and the distribution of responses can be found in Table 2.

The perceived benefit gained by attending class, the quality of teaching and the level of interest in the course content played significant roles in determining student attendance. Of note, students who attended class responded positively to the three options related to the active learning activities and participation in class. The complete list of options and the distribution of responses can be found in Table 3.

Discussion

Most undergraduate students currently studying at university use technology as an integral part of their daily lives (Seemiller & Grace, 2016). These students have a preference for and the ability to use online resources to learn independently and at their own pace (Chicca & Shellenbarger, 2018; Seemiller & Grace, 2016), are predominantly visual and kinaesthetic learners and tend to embrace gamified, active and interactive learning experiences (Roberts, 2015) (Shorey et al., 2021). Creating engaging learning experiences is dependent on understanding the needs, interests, and learning preferences of the students we teach.

The global coronavirus pandemic necessitated a rapid pivot to online and blended learning strategies to minimize disruption to student education (Arday, 2022). The experience of students during that time is likely to be highly variable and dependent on the individual skill and experience of the instructors in their courses as well as availability of educational technology and virtual learning environments (Koh & Daniel, 2022; Sum & Oancea, 2022). For some courses and institutions lectures may have been delivered live but online, for others the classes may have been delivered asynchronously with prerecorded lectures available for students to view in their own time. Thus, student attitudes toward and preferences for online *versus* face-to-face classes will likely be influenced by this recent experience. However, reflecting on and critically evaluating the factors that motivated students to attend classes before the pandemic can provide valuable insight to inform our decisions as educators whether to continue teaching in the online space or return to the classroom.

Are face-to-face classes an outdated mode of education?

Even before the pandemic, the decline in attendance in face-to-face lectures was well documented with many educators questioning the value of this mode of teaching (Golding, 2011; O'Keeffe et al., 2017). Many studies attributed the decline in lecture attendance to the increasing availability of digital recordings and other online resources (Edwards & Clinton, 2019; Johnston et al., 2013). While the provision of these resources offers increased flexibility for students, a common concern has been the potential negative impact this may have on attendance and ultimately student performance (Gosper et al., 2010; Kinash et al., 2015; Preston et al., 2010). A similar trend was observed in the undergraduate neurobiology course analyzed in this study following the university mandated digital recording of lecture and workshop classes from 2013 onwards. However, despite reduced attendance, one of the recurring themes in student feedback was a desire for more discussion and interactivity during class.

With a view to improving the student experience and to encourage students to attend class, an active learning platform was used to augment neurobiology workshop classes to include videos and in-class polling. Overall, student attendance fluctuated during the trimester for an average of 46% which is similar to or greater than other courses in the biosciences (Doggrell, 2019, 2020a). While it is not possible to correlate in-class attendance to the use of the active learning platform directly, the survey responses indicated that this mode of teaching was popular among the students. Similar to other studies, attending class was weakly associated with better performance (Doggrell, 2019). More importantly, students who chose to attend class did so because of the high standard of

teaching, their interest in the course material and thought the classes were beneficial to their learning. There is also a perception among the surveyed students that they will miss important information if they miss class, despite the availability of other resources including class recordings. In contrast, reasons for non-attendance were not related to the quality of teaching, interest in the course content or the perceived benefit of attending class. The main reason for non-attendance were factors outside of the control of the course instructor and included the time of the scheduled lectures (5 – 7 pm on a Monday evening), as well as part-time work and family commitments. An important finding of this study is that the availability of digital recordings and other online resources allowed students with external commitments and time constraints to continue their studies and perform as well as their peers.

Students who did not regularly attend class stated that the availability of digital recordings influenced their decision not to attend. However, a high proportion of students who attended class accessed and used the class recordings, with most indicating that the availability of these resources was not a factor in their decision to attend class. Interestingly, watching the digital recordings was associated with better performance in the course but only if more than 80% of the recording was viewed. Further, students who exclusively used the digital recordings to access the course content had similar academic outcomes to those who came to class. Studies investigating the correlation between lecture attendance and academic performance when lecture capture was available have reported mixed results. A systematic review published in 2020 showed that in the biosciences, 69% of studies show a weak but positive association between lecture attendance and academic performance when lecture capture was available (Doggrell, 2020b). However, whether students had access to digital recordings was only indicated in 11 of the 29 studies analysed, and no data on how the students used the recordings was presented.

It should be noted that the students in the course take three other courses, some of which have mandatory laboratory classes as well as assessments at varying times during the trimester. However, unlike previous studies, only 9% of students indicated that assessments and demands for other courses was a reason for their non-attendance. In prior studies using a similar survey, 47% of neuroscience students (O'Keeffe et al., 2017) and 38% of engineering students (Fitzpatrick et al., 2011) indicated that this was a reason for their non-attendance. Further, approximately 30% of students expressed that their decision to attend class was sometimes influenced by assessments in other courses. Throughout the trimester, class attendance fluctuated, and the classes with the lowest student turnout coincided with mid-trimester assessments in other courses.

Since attendance in class was not mandatory and students had access to a variety of digital resources in addition to the class recordings, they had the flexibility to study independently if they chose. However, very few students (~11%) stated that the availability of the digital resources was a reason for their non-attendance and only 16% of students stated that they used the time for self-directed study. A notable distinction between students who did not attend class and those that did was their perception of the sufficiency of the digital resources. Only a small percentage of *Non-attenders* stated that they accessed the YouTube videos (less than 3%) or the interactive textbook (less than 7%) and therefore did not need to attend class. In contrast, approximately 45% of *Attenders* accessed the

YouTube video links, and around 32% of *Attenders* used the interactive textbook. Interestingly, *Attenders* viewed these resources as valuable supplements to their learning but still attended class to enhance their overall understanding of the course material.

Do active learning strategies improve the face-to-face learning experience?

One of the strategies that appealed to students the most was the use of an active learning platform during class. The platform was used to facilitate active learning, and to promote student engagement and participation (Shaw et al., 2015). Presentation files for each interactive class were uploaded to the platform directly, and multimedia and polling questions were embedded. At appropriate times during the class, the students were polled and given a few minutes to contribute their answers. All answers were anonymous, and students could change their answer if they chose. Multiple choice, short answer and click-on-target style questions were deliberately chosen to clarify key points and to prompt discussion. After a few minutes, the instructor switched to the "live" view of the responses and discussed the correct answers and reasoning with the class. Students could ask questions or seek further clarification and the polling questions commonly prompted detailed discussion of key concepts. While all students were encouraged to log in to the active learning platform during class, it was not compulsory to do so. The classes were automatically recorded and these recording captured the class in its entirety including the in-class polling, answers and resulting discussion. Overall, the interactive workshop classes were very popular with students as the system allowed them to actively participate in class, even though the classes were held in a lecture theatre that was not conducive to active learning (Büchele, 2021; Fadelelmoula, 2018). Students who attended class indicated that the active learning activities complemented the course resources, helped them to gauge their understanding of key course concepts and factored into their decision to attend class in person. Despite the availability of class recordings, students found greater benefit in attending class than working through the class materials by themselves. Students who did not attend class did not directly experience the benefits of the active learning strategy. Moreover, since their non-attendance was primarily due to external commitments, it is unlikely that the utilization of the platform, or any other teaching strategy, would encourage in-class attendance.

It is interesting to note that the impact of the active learning strategy was not limited to those students who logged in to the platform during class. Students who attended class but did not log in as well as those students who used the class recordings as a substitute for in-person attendance, performed well in the course. One explanation is that the students are learning vicariously by observing their peers' responses to questions and were thus able to gauge their understanding of key concepts without contributing answers themselves (Mayes, 2015; Roberts, 2015).

One of the potential limitations of using an active learning platform during class is that encouraging the use of laptops and other devices may be distracting to not just the students using the device but also their peers (Aagaard, 2015; Dontre, 2021; Fried, 2008; Sana et al., 2013; Wood et al., 2018). A proportion of students (~14%) attended class in person and watched more than 80% of each recording. The academic achievement of these students was comparable to those students who either attended class or watched the complete recording. One possible explanation is that despite coming to class in-person, these

students were either distracted during class or otherwise disengaged and felt the need to make up the class by watching the recording. However, informal feedback from students suggested that students who came to class used the recordings for review purposes.

Conclusion

In this paper we have examined the impact of a novel teaching strategy designed to improve student engagement in a second-year neurobiology course. This strategy was developed with the preferences of students in mind and included a combination of lectures, technology-enhanced interactive workshops, and online learning resources. Historically, educators have placed emphasis on the value of in-class attendance viewing it as an important indicator for student success (Crede et al., 2010; Guleker & Keci, 2014). In this study, in line with this belief, students who attended class found the experience to be beneficial to their learning. These students performed well overall, and better than those who did not attend class. However, one of the key outcomes is that students who had to depend on class recordings due to scheduling conflicts or other issues, achieved comparable results to their peers who attended class in person. Consequently, the availability of class recordings and other digital resources enhances flexibility without detrimentally affecting student performance. Students could choose how to access the course content based on their own personal preferences and circumstances and this likely lead to increased engagement and satisfaction with the learning experience. Although the study was limited to a single course, the outcome may be broadly applicable across other disciplines.

Lectures at tertiary institutions are often held in learning spaces that are not conducive to in-class participation (Büchele, 2021; Fadelelmoula, 2018; O'Keeffe et al., 2017). However, leveraging technology to enhance the in-class experience of students has been shown to improve student learning (Wood et al., 2018) but the impact is dependent on the students' engagement with and usage of the specific platform that is implemented (Dunn & Kennedy, 2019). In this study, an active learning platform was used to embed in-class polling questions and multimedia at strategic points during workshop classes. The questions and videos were chosen to showcase specific learning outcomes and provide opportunities for students to gauge their understanding of key concepts. Overall, student perception of the interactive workshops was positive, with most students stating that the classes were beneficial to their learning experience. Further, students felt that the in-class experience was enhanced by using the active learning platform and that this mode of teaching helped them to understand and apply the course concepts. The benefits of using this teaching approach is that it can be adapted for use in any discipline that involves both the acquisition and application of knowledge, it is readily scalable to accommodate large classes and can be used for both online and hybrid learning environments. This strategy can also be implemented using various platforms since there are several different in-class polling tools available.

The current generation of students, known for their adaptability to technology and inclination toward independent learning, highly value and often use digital resources (Chicca & Shellenbarger, 2018; Seemiller & Grace, 2016). Nevertheless, this study reveals that attending face-to-face classes still holds significant value, as students reported greater benefits from in-person interactions compared to relying on independent study. In summary, this research underscores the efficacy of a student-centred teaching

approach, leveraging technology and providing flexible access to course materials. By recognizing the evolving preferences and learning styles of students, educators can optimize engagement and learning outcomes in a variety of educational settings.

Abbreviations

STEM	Science, technology, engineering, and mathematics
Echo360	Echo360 Active Learning Platform
GU	Griffith University
SPSS	IBM SPSS Statistics 28 software Incorporated
ANOVA	Analysis of Variance
Tukey HSD	Tukey Highest Significant Difference

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Declarations

Competing interests
The author declares no competing interests.

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