Heliyon 9 (2023) e15873

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Does active participation via integrated questions in large lectures matter?

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ARTICLE INFO

Keywords:
Large lectures
Collaborative learning
Interactivity
Student motivation

ABSTRACT

This paper investigates whether the intensity of participation in large lecture quizzes in a tertiary education context, facilitated and monitored by an online platform, is associated with better examination performance. The platform mirrors lecture slides onto student devices and uses integrated "clicker" style questions within the lecture to quiz students on concepts learned. Using regression, we find that the intensity of quiz participation is positively related to students' performance. Student study perceptions, based on study and career plans, moderate the results. These findings are relevant to educators, especially in a post-COVID-19 learning environment, where the online quiz function could be used to foster participation.

1. Introduction

This study aims to understand whether participation in large lectures is associated with better examination performance when using a newly developed interactive approach, providing all students with the opportunity to participate. Given the introductory course context and the importance of ensuring students develop a solid foundation of knowledge in such a course, we focus on understanding the impact on students' examination performance. While students place importance on lectures as providing a topic overview and core information required [1], and literature indicates lectures can provide insight into how to understand concepts beyond what students comprehend via written resources [2,3], this study is motivated to address the objective of making large lectures a better learning experience. Lectures, seating hundreds of students, are widely acknowledged as ineffectual approaches to learning, where students are expected to receive and store knowledge in the absence of interaction and dialogue with academic staff [4]. Despite this, many institutions used large lectures for courses with high enrollment numbers. During the COVID-19 pandemic, classes largely moved online; as institutions move back to face-to-face teaching, many are directing academic staff to replace large on-campus lectures that lack interaction and dialogue with pre-recorded online equivalents. However, there are undoubtedly more participative ways to teach large groups of students – face-to-face or online – using "flipped" learning approaches [5] and other interactive approaches [6]. Participative and engaging approaches are regarded as particularly important when part of the cohort lacks intrinsic interest in the course, particularly introductory core mandatory courses [7–11].

Many audience response technologies have been designed to facilitate more active and participative styles of learning in large lectures [12,13], including the use of "clicker" based systems [14–16]. While these are nothing new and help facilitate a degree of participation, such systems can be limited by the need to enter activity codes for individual exercises, slowing the progress and even becoming a distraction. This is particularly problematic in mandatory first-year courses, where students often exhibit different interest

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https://doi.org/10.1016/j.heliyon.2023.e15873
Received 28 June 2022; Received in revised form 19 April 2023; Accepted 24 April 2023
Available online 2 May 2023

levels relating to program study plans and preferences [7–11].

To overcome limitations of clicker style systems (and address calls to improve the quality and effectiveness of tertiary education [17,18] while recognising the importance students attribute to their classroom experience, deeper learning approaches [19], and the efficacy of interactive student-centred learning within such contexts [20,21]), this study trials and evaluates a platform that mirrors presentations delivered on the lecture room screen onto student electronic devices (laptops, tablets and smartphones). The platform allows the lecturer to include questions in the presentation slides, which are automatically mirrored on students' devices, providing students with the opportunity to respond. Given the integration of questions into the presentation, there is no need to enter code(s) or open another window to access questions. Cumulative responses to questions can be displayed by the lecturer for all students to see.

This study builds on prior research demonstrating that blended learning models incorporating audience response systems enhance student engagement. Still, it is unclear what the impacts are on student performance and how this can vary in a large cohort [22]. Accordingly, this study contributes by examining whether students who participate in the learning experience facilitated by such a technology achieve higher levels of examination performance than might otherwise be expected. Our contribution is focused on addressing the value relevance of participative learning approaches for face-to-face learning post-pandemic, which, if not relevant, is another reason calling for the end of lectures. We find that the mirroring platform we use is associated with higher student performance when controlling for overall student ability; however, this is moderated by students' study and career plans, highlighting the importance of considering student characteristics and the related differing needs of students [20].

This paper is structured as follows. First, we present the theory development and, second, the intervention. Third, the research method is described, relating to the survey and largely the regression analysis. Fourth, we present the results, followed by the discussion section. Finally, we offer our conclusions and identify limitations and opportunities for future research.

2. Theory development

There has been much criticism of large lecture formats, often associated with less optimal learning experiences [4]. Reasons for this include the inability to tailor the learning to the needs of individual students, which can be incredibly diverse [23,24]. Large lectures can be intimidating, with those requiring assistance often feeling uncomfortable seeking support in front of so many others [25,26]. Students often feel invisible to the lecturer; consequently, they believe time off-task goes unnoticed [27]. Most, if not all, students bring their electronic devices to lectures, providing easy access to course materials but also to unrelated content (like social media), causing distraction [28–30]. In mandatory core courses, the issues with large lectures are exacerbated when students have different motivations and interests in learning [31]. In mandatory core courses, students range from those intrinsically motivated, those completing it for employability, to those who could not think of anything worse but must complete the course as a compulsory component of their degree [23].

Constructive alignment theory argues that there should be alignment across the learning objectives (and outcomes), coursework and assessment [32]. The passive nature of large traditional dialectic lectures is counter to this [33]. If participative classes are not feasible, one-way lecturer-to-student communication via learning management systems is an option, as evidenced during the pandemic; however, this non-participative approach is counter to constructive alignment theory. The "constructivism" element of constructive alignment theory argues that students should construct their own meaning through a process of actively selecting and then cumulatively constructing their own knowledge [32]. Simply lecturing to students, whether in person or online, provides students with little opportunity to select and cumulatively construct their knowledge to make sense of new and unfamiliar concepts. Such an approach is particularly problematic for students who are less interested in doing the course and, therefore, far less likely to take the initiative to construct meaning through reference to course resources [31].

The importance of understanding concepts, rather than memorising answers, can be demonstrated in large lectures by using technology; for example, asking multiple-choice questions relating to applying a concept, such as recording an accounting transaction in a different context to the example explained by the lecturer. This allows students to selectively draw on information just acquired and construct meaning from this information to answer such multiple-choice questions. The "alignment" element of constructive alignment theory comes in through formatively assessing students' multiple-choice (and other) responses and providing students with feedback relating to relevant accounting processes, such that they are more likely to align their understanding of different concepts consistent with the course learning objectives [34]. Research demonstrates students value formative assessments facilitated by clicker type technologies, which provide them first the opportunity to draw on their constructed knowledge and then subsequently receive feedback, where they are then more likely to correctly understand concepts as course learning objectives specify [14,32,35].

Expecting students to assimilate concepts in large lectures has always been challenging; the challenge is now further compounded by students' ready access to potentially distracting technology. While online classes are constraining in many ways, students may engage in off-task activities and behaviours [36,37]. Rather than fighting attachment to technology when back on campus, one that has likely grown considerably since 2020 [37], devices can be harnessed to improve learning. Some research indicates that online clickers facilitate greater student participation and focus, reducing the likelihood of student distraction and leading to better learning outcomes [38,39]. However, the benefits of using clickers on student performance are mixed [40,41]. This suggests that the implementation of the technology needs to be better considered, as demonstrated through an action research study by Frick et al. [7]. Further, the mixed effects on student performance may also be due to course content, cohort interests, and other motivations [7–11].

It was important to recognise the growing concerns around pedagogical justification regarding teaching interventions. Specifically, these concerns first relate to academic staff members applying the same teaching styles to small classes and large lectures without appropriate consideration [42]. Incongruent teaching methods retrofitted to unsuitable contexts are likely to lead to less optimal learning outcomes [42]. Second, there appears to be a willingness to adopt new technologies into teaching without justification for or the best means of realising their potential advantages [43,44], a problem perpetuated by necessity surrounding the pandemic [45]. This is concerning, as introducing new platforms to the learning environment can cause distraction and lower performance. For example, instructors, in some cases, have experimented with social media in courses that counter to intentions, gives students an outlet to avoid constructing their knowledge and succumb to the distractive forces of social media [28–30].

Given the concerns above, we anticipate addressing two factors will be advantageous to student learning as part of an intervention design. First, we know student distraction and off-task activity are more likely in mandatory core introductory courses [37]. The presence of electronic devices means distraction is more likely [28–30]. Therefore duplicating content and interactive questions, as controlled by the lecturer, on student devices encourages focus on the lecture as it progresses, reducing the likelihood of off-task activity. While prior literature indicates that in some contexts, self-paced content viewing can be desirable [46], the benefits of encouraging focus and also, if students are distracted, rejoining the lecture at the right place when they come back to task, outweighs the benefits self-paced viewing. This is particularly the case when students have low interest and motivation [47]. Second, we anticipate minimising long periods of passive lecture delivery and facilitating a more active and participative approach to be advantageous to student learning [33]. Introducing questions strategically and via duplication on students' devices at different points during class helps students realise the benefits of frequent participation [48,49], encouraging students to listen carefully and apply what they learn immediately. Encouraging active participation, thereby increasing the chance that students can successfully demonstrate their learning at an early stage, is also understood to improve students' self-efficacy and motivation [50] and success more broadly.

Encouraging students to focus via duplication on their device and encouraging frequent participation is consistent with that advocated by constructive alignment theory [32], in which students need to use the knowledge gained up to that point in the lecture to think, apply and respond, and then receive feedback. Accordingly, based on the above, we propose the following hypothesis.

H1. The intensity of lecture participation, using a duplicative and participative approach, is positively related to exam performance.

Given the diversity of students who study introductory accounting, we expect the intensity of lecture participation not to be consistently related to exam performance; this is consistent with mixed findings in the literature concerning student response systems [7]. As introductory accounting is often a mandatory first-year course in business/commence programs (the case at the institution where this study was conducted), students may have different reasons to undertake the course (for example, voluntary or mandated). Consequently, we expect variation in students' interest and study efforts when completing the course. The literature notes that some students indicate low interest in mandatory core introductory courses, perceiving such courses as boring and irrelevant to their future studies and careers [7–11]. Given such views, these students are likely to have a preference to not engage with the course, meaning passive rather than active learning within a constructively aligned approach is particularly problematic for such students [32]. Other students are interested in the course, perceiving it as an important foundation for their future studies and/or relevant to career plans [51,52]. Students interested in the course before commencement are more likely to exert study effort; this group will likely achieve performance outcomes regardless of the participative teaching intervention we apply. In contrast, students who do not see the relevance of the course to their future are more likely to lack motivation and exert less effort [53]. Accordingly, the duplicative and participative approach should encourage these students to participate in the learning experience and achieve higher performance than they would have otherwise achieved. We therefore hypothesise.

H2. Student course perceptions, related to future studies and/or career plans, moderate the implications of intensity of lecture participation on exam performance.

3. Intervention

Prior to the intervention, lectures were delivered using a slide-based PowerPoint presentation model. Students could download the slide set from the learning management system to view during and outside the lectures. In this study, during the duplicative and participative intervention approach, we used a platform that provided students with free access to online lecture slides that incorporated clicker-style questions. The platform was trialled at the institution this study was undertaken, specifically in the undergraduate introductory accounting course, an applied course where students need to demonstrate and understand the application of concepts, not simply memorise and relate facts. The platform is not available to other institutions on a commercial or non-commercial basis. Accordingly, we describe both the attributes of the platform to allow comparisons to be made with other products on the market.

Students could access the platform and answer the questions using either a laptop, tablet or smartphone. While nearly all students attended the lectures with laptops to address concerns related to digital poverty [54,55], ease of access through multiple devices was possible, addressing situations where students do not have the financial means of bringing their own laptop to university. Further, students could borrow a laptop from the library should they not have access to a device. The theatres where lectures were delivered had powerful free Wi-Fi networks, allowing all students to connect, negating the need for students to use their own data plans.

The platform allows students to access and review lecture slides at their own pace online, pre- and post-lecture; however, within lectures, the platform mirrors the lecturer's display on the students' devices. Students' devices were not locked to the lecture display and associated clicker-style questions; students could open other applications on their devices but could not change the presentation slide selection while the lecture was in progress. While students may be keen to go back and look at previous slides covered during the lecture, they may miss a more critical point, thus making the remainder of the lecture less coherent. This is a unique aspect of this platform and, therefore, the nature of the intervention in this study. Such an approach is intended to encourage students to focus in class, particularly for those less interested in the mandatory course. Clicker-style questions automatically and simultaneously appear on students' devices as the lecturer displays them, and students respond on their devices. The platform does not require a different

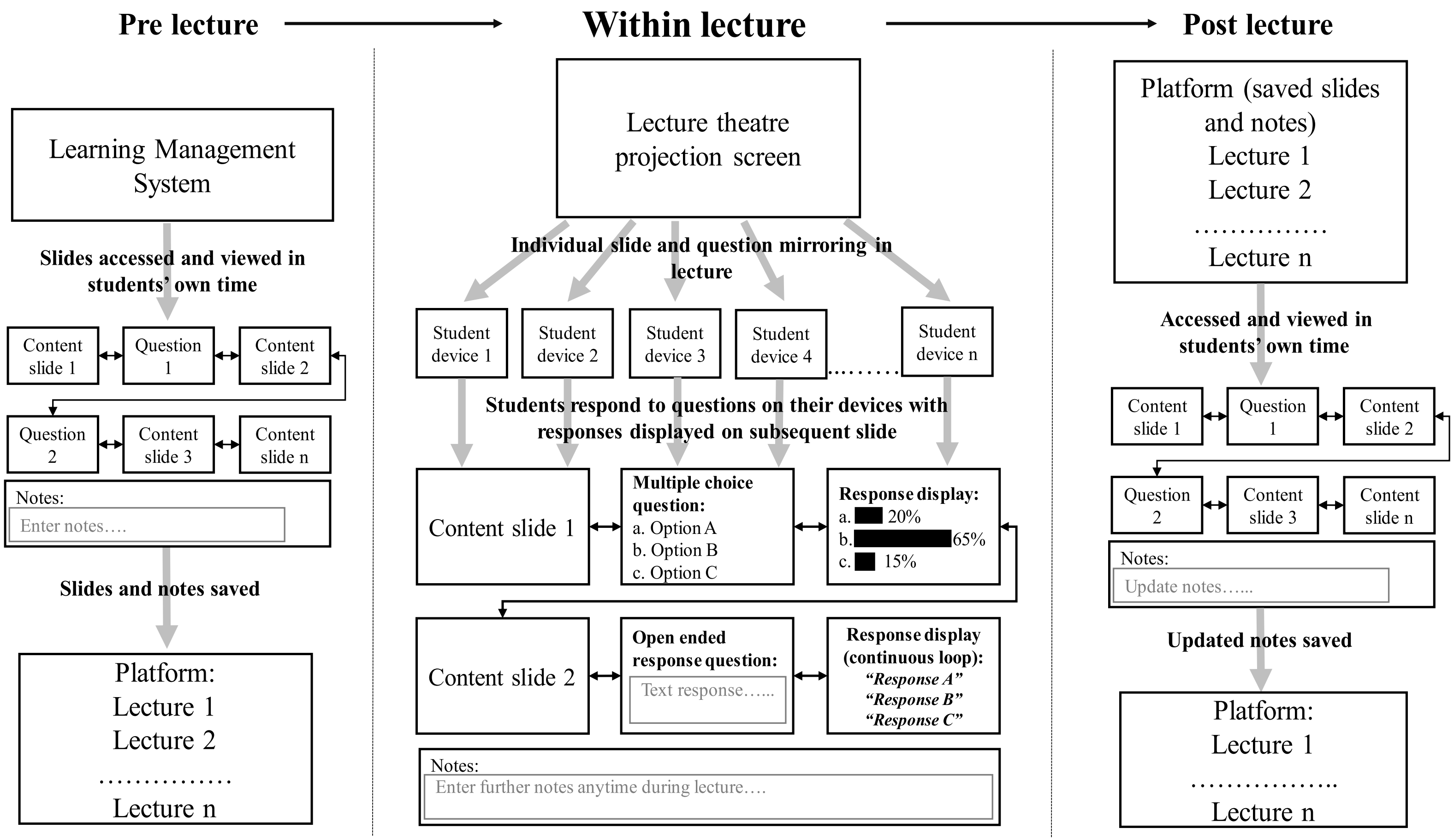

Fig. 1. Pre, post and within lecture platform use.

webpage and access code for each question, which is often the case with other platforms.

Students were encouraged to discuss their thought processes with their fellow students beside them in the lecture room while answering the questions, enabling a collaborative learning approach. The lecturer typically allowed a few minutes for students to think through their answer and discuss with their fellow students, although sometimes longer was allowed depending on the complexity of the question assigned. Such discussion and collaboration encouraged students to think through what content is relevant to each question rather than simply taking a guess and not constructing their knowledge in collaboration with peers.

The platform allows different styles of questions, including Likert scale agreement/disagreement, multiple-choice, option ranking, and open-ended questions. As shown in Appendix A, Screenshot 1, from the students' perspective, they can see how collectively all other students responded, but not individual's responses. This allowed the lecturer to encourage each student to respond independently by drawing on their own learning rather than selecting the most popular response of the student cohort, believing that answer to be true. This was useful because while responding to questions was strongly encouraged in our study, it was still optional and did not form part of the summative assessment of the course. From the lecturer's perspective, the number of responses and the cumulative responses can be viewed continuously as submitted, including a breakdown of the options students have selected, for example, how many responses to each multiple-choice option. If and when the lecturer desired, students' cumulative responses, with a breakdown of the responses as applicable to the question, could be displayed to students, as shown in Appendix A, Screenshot 2, usually, after students had finished responding. Showing students their cumulative responses provides a logical next stage in the lectures to justify whether the concept covered in the question should be revised. If a notable proportion of students answered incorrectly, this provided a logical segue to revise the concept and discuss the reason for the correct answer before progressing to the next stage of the content (as opposed to asking if anyone does not understand or equally as bad asking if everyone understands). Detailed analytics were generated at the end of the presentation; this data is used for this study. An illustration of the platform used both synchronously and asynchronously is provided in Fig. 1.

4. Research method

The research method presented in this paper received UTS Human Research Ethics Committee (HREC) approval and complied with informed consent requirements relating to all participants (ethics application: ETH21-5752). This study was undertaken in a large introductory accounting course at a metropolitan university in Australia before the pandemic. This allows us to examine the effectiveness of the intervention, in terms of student performance, based on an on-campus participative experience where all students had the opportunity to partake. Therefore, the results we present are representative of a large cohort of students who were encouraged but had the option not to participate in quizzes during large lecture-format classes.

4.1. Student survey

The platform was first piloted in a small introductory accounting class (33 students) in an accelerated teaching term in early 2017. This pilot allowed us to gain confidence that the platform could be used reliably in lectures. Subsequently, the platform was introduced into large lectures in the two main teaching terms in 2017, providing a total student cohort of 1662. Students were invited to complete an anonymous online survey at the end of the final lecture. Of the 585 students who attended the final lecture, 45.5% completed the survey, providing a total of 266 completed surveys. We hoped all students would have completed the survey, however, the survey was optional, and such a response rate is relatively high compared with satisfaction-based surveys in extant literature. The anonymity of the responses prevented non-response bias testing. However, the strong response rates, and the variety of students with different interests attending the final lecture (from those less diligent with their attendance, looking for the "examination hints" in the last lecture, to those attending consistently), provide confidence that non-response bias was mitigated.

Consistent with research calling for an examination of student perceptions (Han and Ellis 2019), students were asked about their level of agreement with nine statements on a 1–5 Likert scale, with 1 indicating strongly disagree and 5 indicating strongly agree.

Table 1
Student survey questions.

Panel A – Likert scale question. Students were asked to indicate level of agreement with the following questions (five-point Likert scale from strongly disagree to strongly agree):
1. Overall, I am satisfied with the use of the platform used in this subject
2. I feel that lectures are more engaging when the platform is used
3. Using the platform facilitated a more interactive learning experience
4. I felt more comfortable participating in lectures through the platform compared with discussing my answers in the lectures
5. Using the platform is time consuming and a waste of time
6. I liked comparing my responses with those of other students
7. I feel that my participation is more restricted when using the platform
8. The platform is easy to use on my electronic device
9. Overall, I feel the use of the platform enhanced my learning experience in the subject
Panel B – Open-ended questions
1. What were the positive aspects of the platform?
2. What were the negative aspects or things that could be improved with the platform?

Given the logic of using the platform to improve student learning through addressing issues including those related to student engagement, interactivity, collaboration, comfort when participating and distraction [27,33,36–39], the statements relate to addressing such issues for the purpose of the Likert scale questions. Students were also asked to provide open-ended comments on the positive and negative aspects of the platform. Table 1, below, provides the list of the Likert scale (Panel A) and open-ended questions (Panel B) students were asked in the survey. All 266 responses are used when analysing the survey data, as reported in the results section below.

4.2. Regression analysis

An ordinary least squares (OLS) regression approach is used to test Hypothesis 1 to measure whether the intensity of lecture participation (when using the platform) is positively related to examination performance. Using examination results, the percentage of questions attempted (data available in the platform analytics), and control data (from student records) allows us to overcome the limitations of self-reported data [56]. The control variables in our model proxy for student motivation and interest in their studies, thereby addressing potential concerns that more motivated and interested students participated in lectures, thereby driving higher performance (we also undertake a propensity score matching approach, detailed after the main results below). The data used to run the regression analysis, based on Model 1 below, consists of all 1662 students enrolled in the introductory accounting course at the time of intervention use. All data used for the regression analysis is gathered from the course and university records rather than self-reported student data, thereby allowing the full population of data to be used with no missing data. The OLS regression, Model 1, is used:

$$\text{Exam\_performance}_i = \beta_0 + \beta_1\text{Questions\_attempted}_i + \beta_2\text{Age}_i + \beta_3\text{Gender\_dummy}_i + \beta_4\text{WAM}_i + \beta_5\text{Year\_study}_i + \varepsilon_i \tag{1}$$

where the variables are measured as follows:

Exam_performance$_i$: The mid-session and final exam results and sections from these exams (as follows) are used to measure exam performance. These dependent variables are matched with the corresponding independent variables in the regression models run, as detailed below.

Final exam total score
Financial accounting (final exam section)
Earnings management (final exam section)
Cost volume profit analysis (final exam section)
Activity-based costing (final exam section)
Decision making (final exam section)
Mid-session exam total score
Practical component (mid-session exam section)
Theory component (mid-session exam section)

Questions_attempted (during lectures): This variable measure the percentage of questions students attempt in lectures. Consistent with Hypothesis 1, we examine whether the students' active participation in the learning experience through the platform is positively related to final examination performance by measuring the percentage of lecture questions attempted (lecture participation). We have

Table 2
Descriptive statistics and frequencies (n = 1662).[11]

Descriptive statistics (/possible marks)– continuous variables	Min.	Max.	Mean	Median	Std. Dev.
Final examination total score (/100)	5.000	96.000	48.155	46.000	18.113
Financial accounting (final exam section) (/24)	0.000	24.000	12.368	12.500	5.625
Earnings management (final exam section) (/22)	0.000	22.000	9.495	9.500	5.572
Cost volume profit analysis (final exam section) (/15)	0.000	15.000	4.319	4.000	3.338
Activity-based costing (final exam section) (/13)	0.000	13.000	4.212	2.000	4.447
Decision making (final exam section) (/10)	0.000	10.000	3.668	3.000	3.259
Mid-session exam total score (/40)	1.000	40.000	20.898	21.250	9.478
Practical component (mid-session exam section) (/20)	0.000	20.000	11.690	12.000	5.430
Theory component (mid-session exam section) (/20)	0.000	20.000	9.210	9.000	5.371
Whole session question attempts (percentage)	0.000	100.000	19.083	7.692	22.926
Financial accounting lecture question attempts (percentage)	0.000	100.000	30.505	28.571	28.910
Cost volume profit lecture question attempts (percentage)	0.000	100.000	18.863	0.000	35.205
Activity-based costing lecture question attempts (percentage)	0.000	100.000	16.667	0.000	32.292
Decision making lecture question attempts (percentage)	0.000	100.000	10.800	0.000	26.297
Pre-mid-session exam attempts (percentage)	0.000	100.000	31.699	33.333	29.875
Age	16.012	47.270	19.646	18.694	2.553
WAM	17.000	97.000	67.273	68.000	10.977
Year of study	0.000	6.000	0.362	0.000	0.773
Frequencies – dummy variables	**Binary codes**				
	1		**0**		
Gender (female 1, male = 0)	827		835		

Table 3
Spearman's correlations ($n = 1662$).

	Final examination total score (/100)	Financial accounting (final exam section) (/24)	Earnings management (final exam section) (/22)	Cost volume profit analysis (final exam section) (/15)	Activity-based costing (final exam section) (/13)	Decision making (final exam section) (/10)	Mid-session exam total score (/40)	Practical component (mid-session exam section) (/20)	Theory component (mid-session exam section) (/20)
Financial accounting (final exam section) (/24)	.764***								
Earnings management (final exam section) (/22)	.666***	.360***							
Cost volume profit analysis (final exam section) (/15)	.723***	.432***	.341***						
Activity-based costing (final exam section) (/13)	.632***	.397***	.224***	.433***					
Decision making (final exam section) (/10)	.689***	.400***	.349***	.584***	.403***				
Mid-session exam total score (/40)	.641***	.619***	.397***	.416***	.358***	.374***			
Practical component (mid-session exam section) (/20)	.607***	.605***	.309***	.418***	.376***	.369***	.877***		
Theory component (mid-session exam section) (/20)	.522***	.486***	.391***	.314***	.257***	.291***	.874***	.543***	
Whole session question attempts (percentage)	.268***	.242***	.179***	.155***	.171***	.184***	.267***	.244***	.220***
Financial accounting lecture question attempts (percentage)	.247***	.245***	.176***	.123***	.144***	.172***	.255***	.228***	.216***
Cost volume profit lecture question attempts (percentage)	.187***	.149***	.121***	.132***	.127***	.137***	.185***	.174***	.148***
Activity-based costing lecture question attempts (percentage)	.186***	.137***	.114***	.151***	.139***	.145***	.155***	.156***	.113***
Decision making lecture question attempts (percentage)	.196***	.140***	.090***	.170***	.160***	.165***	.145***	.151***	.102***
Pre-mid-session exam attempts (percentage)	.232***	.236***	.167***	.110***	.130***	.159***	.244***	.215***	.209***

(*continued on next page*)

Table 3 (*continued*)

	Final examination total score (/100)	Financial accounting (final exam section) (/24)	Earnings management (final exam section) (/22)	Cost volume profit analysis (final exam section) (/15)	Activity-based costing (final exam section) (/13)	Decision making (final exam section) (/10)	Mid-session exam total score (/40)	Practical component (mid-session exam section) (/20)	Theory component (mid-session exam section) (/20)
Age	−.154***	−.144***	−.200***	−.068***	0.017	−.057**	−.188***	−.051**	−.284***
WAM	.639***	.561***	.438***	.414***	.349***	.396***	.638***	.560***	.564***
Year of Study	−.120***	−.125***	−.098***	−.054**	−0.026	−.066***	−.214***	−.147***	−.229***
Gender (female 1, male = 0)	.121***	.064***	.048*	.167***	.059**	.110***	.002	.027	−.024

	Whole session question attempts (percentage)	Financial accounting lecture question attempts (percentage)	Cost volume profit lecture question attempts (percentage)	Activity-based costing lecture question attempts (percentage)	Decision making lecture question attempts (percentage)	Pre-mid-session exam attempts (percentage)
Financial accounting lecture question attempts (percentage)	.879***					
Cost volume profit lecture question attempts (percentage)	.702***	.463***				
Activity-based costing lecture question attempts (percentage)	.675***	.451***	.608***			
Decision making lecture question attempts (percentage)	.597***	.393***	.586***	.554***		
Pre-mid-session exam attempts (percentage)	.844***	.986***	.416***	.409***	.345***	
Age	−.176***	−.168***	−.055**	−.078***	−.059**	−.168***
WAM	.328***	.325***	.184***	.184***	.194***	.313***
Year of Study	−.248***	−.233***	−.134***	−.107***	−.095***	−.229***
Gender (female 1, male = 0)	.012	.001	.040	.047*	.065***	−.002

***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level (2-tailed).

a series of "questions attempted" independent variables that are matched to the corresponding dependent performance variables (in brackets below) across the regression model run. These are as follows.

Whole session question attempts (matched to final exam score model)
Financial accounting lecture question attempts (matched to financial accounting and earnings management final exam sections)
Cost volume profit lecture question attempts (matched to cost volume profit analysis final exam section)
Activity-based costing lecture question attempts (matched to activity-based costing final exam section)
Decision making lecture question attempts (matched to decision matching final exam section)
Pre-mid-session exam attempts (matched to mid-session exam total score, practical and theory mid-session exam components)

Age_i: Age of student at the time they participated in the study. Prior research finds that student maturity, proxied by age, significantly predicts examination performance [57].

$Gender\_dummy_i$: Gender measure, that is assigned 1 for female, 0 for male. While findings are mixed, some studies find females outperforming males [58,59].

WAM_i: The weighted average mark (WAM) is based on the final results in all university courses students have studied, up to but excluding introductory accounting. This variable controls for students' ability and efforts concerning their studies overall, which is expected to predict future performance [60,61].

$Year\_study_i$: Measures what year of study a student is in at the time of their participation in this study (for example, first year, second year, etc). The further a student progresses in their degree, the higher their metacognition is likely to be [62], and the more likely they are to adopt different learning approaches [63], leading to better performance.

The descriptive statistics[1] and frequencies of the full sample of variables are reported in Table 2 below, indicating sufficient variation for regression analysis.

The correlations are reported in Table 3 below. There are high correlations between performance variables and between question attempt variables, as expected. However, the performance and question attempt variables are included in the regression model on a one-by-one basis. The correlations do not raise any concerns for the purpose of the regression analysis reported in this paper. Further, multi-collinearity analysis was undertaken based on all the regression results reported, and no instances of multi-collinearity were identified.

Our measures of *Questions_attempted* (during lectures) are based on the percentage of questions in lectures students attempted, as explained above. Given that the measures of this variable are essentially a summation of attempts of questions in lectures related to the scope of each measure, assessing the consistency of such attempts is of interest. In order to do so, we report Cronbach's alpha in Table 4 below. Cronbach's alpha for all questions attempted variables exceeds 0.7, which indicates acceptable internal consistency and reliability [64]. This means that student participation and attempts are generally consistent throughout the teaching session.

4.3. Moderating effects

To test Hypothesis 2, to identify whether student perceptions of the course, related to motivation to complete the course, moderate the implications of the intensity of lecture participation on exam performance, we split our sample based on two factors. First, we create two sub-samples of students who are only enrolled in the business degree program, and the two sub-samples are based on whether students choose to enrol in an accounting major as part of the business degree program. While all students enrolled in the business degree program are required to complete the introductory accounting course, those enrolling in an accounting major as part of the business degree program are expected to understand that the introductory accounting course is an important foundation for their studies. In contrast, students not enrolled in an accounting major may not perceive the introductory accounting course as an important part of their studies. Second, we create two sub-samples based on students' program choice, either a business degree program or a non-business program. Students in the business program must complete the introductory accounting course. In contrast, those from other programs take the course as an elective and are likely to be motivated to complete it to broaden the scope of their studies and/or future career plans. Students often take the introductory accounting course as an elective, contributing to programs outside the business school, including those focusing on design, engineering, information technology and science.

4.4. Self-selection bias

Testing is warranted to confirm whether higher-performing students are not the substantial majority engaging in lectures via the platform, hence driving the performance effects observed. We apply the propensity score matching technique [65] and estimate the propensity scores using logistic regression (Model 2 below). We use the *$Interactive\_Engagement_i$* binary variable as the dependent variable, based on whether students answer any interactive questions during the session (assigned a binary variable 1). The independent variables are related to student motivation and performance and, accordingly, are valid predictors of students' choice of whether they engage in lectures using the platform.

[1] The descriptive statistics reported in Table 2 are based on the non-normalised variables. For ease of interpreting correlations and regression results, non-normalised variables are used. Regression results based on normalised variables, available upon request, are consistent with the results we report in this paper.

TABLE 4
Internal consistency.

Variable	Cronbach's alpha
Whole session question attempts	0.931
Financial accounting lecture question attempts	0.759
Cost volume profit lecture question attempts	0.923
Activity-based costing lecture question attempts	0.897
Decision making lecture question attempts	0.873
Pre-mid-session exam attempts	0.735

Table 5
Paired T-test comparisons.

	Panel A		Panel B	
	2016 (Pre-intervention)	2017 (Intervention)	2016 (Pre-intervention)	2017 (Intervention)
Mean (final exam score/100)	45.671	43.496	53.311	55.526
Observation number (matched)	388.000	388.000	352.000	352.000
Significance	0.016**		0.043**	

***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level (2-tailed).

$$Interactive\_Engagement_i = \beta_0 + \beta_1 RAcct\_major\_dummy_i + \beta_2 Age_i + \beta_3 Gender\_dummy_i + \beta_4 WAM_i + \beta_5 Year\_study_i + \varepsilon_i \quad (2)$$

The propensity scores of students in the intervention period (2017) are matched with students in the year before the intervention (2016) using the nearest neighbour matching method without replacement [65]. Based on propensity score-matched intervention and pre-intervention students, we conducted a paired *T*-test; the results are reported in Table 5, Panel A, below. These tests indicate a significant *decrease* in students' final exam scores for students in the intervention group relative to propensity score-matched students studying the course before the intervention. However, once we remove students who engaged in less than one-third of the interactive lectures during the 2017 period from a sample used to run the paired *T*-test, we find a significantly *higher* final exam score (Table 5, Panel B)[2]. We deem that students who engage in less than a third of lectures are not likely to realise a material impact on their final exam performance, hence the significant result when we remove these students from the sample. For clarity, the observation number in our paired *t*-test comparisons analysis drops from 388 to 352, indicating that 36 students in the 2017 matched sample of 388 attended lectures less than one-third of the time.

It should be noted that the final exam for the course, while examining the same course content, was significantly revised and marginally more difficult for the intervention cohort. Other than this more difficult final exam and the duplicative and interactive approach, no other changes are made in the course from the pre-invention period (2016) to the intervention period (2017). There are two implications of this more complex 2017 final exam for the purpose of this study. First, we show that students who engage in the interactive lectures in a meaningful manner, answering a third or more of the interactive questions, achieve significantly higher final exam marks despite the exam being more difficult. This supports the efficacy of the intervention. Importantly and consistent with the purpose of propensity score matching, our results indicate that student self-selection bias, higher-performing students self-selecting into lectures, is not a concern. Second, based on the lack of concern regarding self-selection bias, the OLS regression results we report below are most appropriate to examine the variation in performance implications across different topics. It should be noted that as with any comparison across different cohort years, as we present in this section, there may be changes across the cohorts that we can't control, and therefore caution should be exercised when interpreting these results.

5. Results

5.1. Survey

Students' level of agreement based on the average of the 1–5 Likert scales with the nine statements relating to the platform are summarised in Table 6, Panel A. Overall satisfaction is 3.70, thus, students, on average, indicate agreement that they are satisfied with the platform use. The remaining eight items of the Likert scale items (2–9) similarity show averages in the high threes, with the exception of items 5 and 7, indicating agreement relating to the positive aspects of the platform. Two negative items are included relating to the platform being a waste of time and restricting participation (items 5 and 7), with students indicating average agreement in the twos in both cases, indicating average disagreement with these items. The contrast in the average agreement between the positive and negative aspects across items 2–9 indicates validity in student responses, rather than students simply indicating the same agreement regardless of the indicator. Further to the averages for each Likert scale indicator, we also provide a representative selection

[2] As the breakdown of the mid-session and final exam marks varied cross the pre- and during-intervention period, we focus only on the overall final exam score comparison for the purpose of this test.

Table 6
Student survey feedback ($n = 266$).

Panel A – Likert scale responses. Survey question	Response (average on Likert scale 1–5)
1. Overall, I am satisfied with the use of the platform used in this subject	3.70
2. I feel that lectures are more engaging when the platform is used	3.92
3. Using the platform facilitated a more interactive learning experience	3.99
4. I felt more comfortable participating in lectures through the platform compared with discussing my answers in the lectures	3.95
5. Using the platform is time consuming and a waste of time	2.40
6. I liked comparing my responses with those of other students	3.92
7. I feel that my participation is more restricted when using the platform	2.46
8. The platform is easy to use on my electronic device	4.03
9. Overall, I feel the use of the platform enhanced my learning experience in the subject	3.62
Panel B – Representative selection of open-ended responses for the positive and negative aspects of the system	
1.I really enjoyed the discussion that is facilitated through the interactive questions – it really helped clarify issues and provided help with subsequent homework questions. Having already discussed major issues meant I could immediately choose the correct methodologies.	
2.Very fun and interactive! Forces me to continually follow along in the lectures, and I like seeing what other students are thinking and what answers they get to questions.	
3.Encourages me to participate and answer questions without feeling like I'll look like an idiot.	
4.Its interactive, everyone can join in anonymously which is a big positive aspect considering the fact that a lot of people don't answer simply because they are shy.	
5.The interactive quiz questions are great to test knowledge and compare with other students without the pressure of being singled out.	
6.Lectures are more engaging. I am not getting side-tracked by scrolling through the slides.	
7.It's very interactive and it's interesting to answer questions on screen and compare them to what other people answer. Also, the slides are always synchronised with what the lecturer is talking about.	
8.I think being able to go back on slide is important. The platform does not have this feature.	
9.Not being able to go back to the slide when the lecturer moves on.	

of student comments in Table 6, Panel B, which will be elaborated on in the discussion section below.

5.2. Regression results

The main results are presented in Table 7, Panels A and B below. All regression models are significant, as confirmed by the *F*-statistic, and explain considerable variation in the dependent variables, ranging from 16.7 to 42.7%, as confirmed by the *R* square value. Further effect sizes are also quite substantial across many of the regression results, with Cohen's f^2 ranging from 0.078 to 0.835. All coefficients for the *Percentage of questions attempted* independent variable of interest are significant at the one percent level across all nine regressions relating to the final and mid-session dependent performance variables in Table A and B, respectively. The only exception is the theory component of the mid-session exam, which is significant at the 10% level (*t*-statistic: 1.683). Overall, these results provide strong support for hypothesis one. More generally, we find the control variables, particularly *Gender* and *WAM*, are significant across the models indicating they are important controls for student motivation and interest in their studies.

The moderation results based on the sample split as to whether the student is taking an accounting major are reported in Tables 8 and 9 (with Panels A and B reporting the results relating to final and mid-session exam dependent performance variables respectively). Table 8 presents the results relating to students enrolled in the business program who have enrolled in an accounting major as the basis of their future study plans. The results largely indicate lecture participation via the platform is related to neither mid-session exam nor final exam performance, with one exception; there is a positive and significant result at the five percent level for the *Percentage of questions attempted* coefficient in the *Activity-based costing* dependent variable model (coefficient: 0.186, *t*-statistic: 2.388). This also appears to drive a significant coefficient (coefficient: 0.140, *t*-statistic: 2.135) related to questions attempted in the *Total score* (final exam) dependent variable model. The results in Table 9 report the effects of lecture participation for students enrolled in the business program who had the option to choose an accounting major but chose not to. The results (Table 9) are consistent in terms of both the coefficients and significance level, with the results based on the complete sample (Table 7). In the context of the accounting major choice, these results support hypothesis two.

The moderation results are presented in Tables 10 and 11 (with Panels A and B reporting the results relating to final and mid-session exam dependent performance variables, respectively), based on the sample split according to whether students are enrolled in the business degree or other programs. The results for students enrolled in the business degree program (Table 10) are largely consistent with the main results (Table 7) in terms of coefficients and significance levels. The results for students enrolled in other degree programs (Table 11) are largely insignificant, except for the effects on financial accounting performance in the final exam, where the coefficient is positive and significant at the five percent level (coefficient: 0.169, *t*-statistic: 2.099). These results indicate that for students who voluntarily enrol in introductory accounting as an elective course as part of their non-business degrees, the use of the platform does not have a significant effect on their exam results. Therefore, hypothesis two is also supported in the context of students' program of choice, either business or non-business.

6. Discussion

The survey responses suggest that students' positive perceptions (associated with higher engagement, interaction, comfort when

Table 7
Main regression resultsPanel A: Final exam performance.

	Total score		Financial accounting		Earnings management		Cost volume profit analysis		Activity-based costing		Decision making	
Independent variables	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Percentage of questions attempted	0.109	5.573***	0.090	4.240***	0.051	2.178**	0.053	2.363**	0.075	3.199***	0.096	4.198***
Age	0.032	1.596	0.018	0.832	–0.052	–2.175**	0.032	1.337	0.119	4.815***	0.053	2.169**
Gender dummy	0.099	5.310***	0.053	2.652***	0.044**	2.007	0.151	6.817***	0.057	2.503**	0.098	4.376***
WAM	0.624	30.948***	0.547	24.838***	0.419***	17.397	0.408	17.351***	0.346	14.183**	0.378	15.867***
Year of study	0.048	2.324**	0.034	1.533	0.042*	1.722	0.034	1.404	0.014	0.553	0.012	0.625
Adjusted R^2	0.427		0.325		0.193		0.190		0.132		0.167	
Cohen's f^2	0.745		0.481		0.239		0.235		0.152		0.200	
F-stat (*p*-value)	248.570*** (0.000)		160.651*** (0.000)		80.234*** (0.000)		79.052*** (0.000)		51.483*** (0.000)		67.706*** (0.000)	

Panel B: Mid-session exam performance	Total score		Practical		Theory	
Independent variables	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Percentage of questions attempted	0.053	2.604***	0.056	2.611***	0.036	1.683*
Age	0.021	0.991	0.116	5.241***	–0.081	–3.692***
Gender dummy	–0.016	0.811	0.008	0.401	–0.036	–1.763*
WAM	0.613	29.305***	0.550	24.634***	0.526	23.778***
Year of study	0.008	0.379	0.020	0.868	–0.006	–0.253
Adjusted R^2	0.387		0.302		0.314	
Cohen's f^2	0.631		0.433		0.458	
F-stat (*p*-value)	210.393*** (0.000)		144.678*** (0.000)		153.291*** (0.000)	

Table 8
Accounting major moderated regression results ($n = 163$)Panel A: Final exam performance.

	Total score		Financial accounting		Earnings management		Cost volume profit analysis		Activity-based costing		Decision making	
Independent variables	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
Percentage of questions attempted	0.140	2.135**	0.087	1.215	0.044	0.586	0.024	0.324	0.186	2.388**	0.137	1.842*
Age	0.029	0.423	−0.032	−0.426	0.043	0.558	−0.027	−0.349	0.179	2.212**	−0.049	−0.623
Gender dummy	0.064	0.985	0.016	0.219	0.112	1.524	0.122	1.642	−0.073	−0.949	0.011	0.154
WAM	0.600	8.435***	0.470	6.024***	0.427	5.298***	0.397	4.908***	0.218	2.951**	0.363	4.498***
Year of study	0.188	2.745***	0.133	1.758*	0.077	0.991	0.127	1.621	0.122	1.511	0.096	1.234
Adjusted R^2	0.337		0.202		0.147		0.135		0.072		0.134	
Cohen's f^2	0.508		0.253		0.172		0.156		0.078		0.155	
F-stat (*p*-value)	17.607*** (0.000)		9.227*** (0.000)		6.626*** (0.000)		6.076*** (0.000)		3.519*** (0.005)		6.039*** (0.000)	

Panel B: Mid-session exam performance	Total score		Practical		Theory	
Independent variables	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
Percentage of questions attempted	0.013	0.199	0.030	0.413	−0.008	−0.116
Age	0.083	1.195	0.184	2.440**	−0.047	−0.655
Gender dummy	0.023	0.348	−0.051	−0.714	0.091	1.340
WAM	0.616	8.533***	0.499	6.384***	0.532	7.192***
Year of study	0.076	1.086	0.103	1.364	0.023	0.322
Adjusted R^2	0.312		0.193		0.278	
Cohen's f^2	0.453		0.239		0.385	
F-stat (*p*-value)	15.759*** (0.000)		8.790*** (0.000)		13.523*** (0.000)	

***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level (2-tailed).

Table 9
Non-accounting major moderated regression results ($n = 1355$)Panel A: Final exam performance.

	Total score		Financial accounting		Earnings management		Cost volume profit analysis		Activity-based costing		Decision making	
Independent variables	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
Percentage of questions attempted	0.109	5.157***	0.086	3.719***	0.053	2.063**	0.055	2.223**	0.079	3.117***	0.107	4.217***
Age	0.035	1.626	0.035	1.519	−0.059	−2.277**	0.029	1.142	0.116	4.363***	0.049	1.855*
Gender dummy	0.091	4.524***	0.051	2.310**	0.024	0.975	0.147	6.073***	0.054	2.153**	0.106	4.308***
WAM	0.654	29.864***	0.570	23.661***	0.437	16.406***	0.437	16.874***	0.383	14.308***	0.393	14.846***
Year of study	0.075	3.399***	0.027	1.102	0.072	2.702***	0.069	2.615***	0.037	1.338	0.045	1.681*
Adjusted R^2	0.455		0.348		0.202		0.208		0.155		0.179	
Cohen's f^2	0.835		0.534		0.253		0.263		0.183		0.218	
F-stat (*p*-value)	227.437*** (0.000)		145.663*** (0.000)		69.773*** (0.000)		72.132*** (0.000)		50.671*** (0.000)		60.192*** (0.000)	

Panel B: Mid-session exam performance	Total score		Practical		Theory	
Independent variables	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
Percentage of questions attempted	0.056	2.553**	0.058	2.494**	0.040	1.704*
Age	0.011	0.504	0.100	4.230***	−0.082	−3.473***
Gender dummy	−0.021	−1.031	0.0008	0.370	−0.046	−2.092**
WAM	0.639	28.086***	0.578	23.736***	0.548	22.523***
Year of study	0.029	1.272	0.069	1.588	0.012	0.497
Adjusted R^2	0.416		0.330		0.334	
Cohen's f^2	0.712		0.493		0.502	
F-stat (*p*-value)	194.198*** (0.000)		134.773*** (0.000)		136.795*** (0.000)	

***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level (2-tailed).

participating, and the ability to compare responses) outweigh negative perceptions, consistent with students' overall satisfaction. While higher average satisfaction would have been desirable, these survey indications are not unsurprising; there is a high proportion of students studying the course as part of their mandatory foundation degree courses (only 8.4% of students intending to major in accounting), and this may reflect negative views of the course overall. Perhaps students would have preferred a more traditional class delivery, where they are provided with the answers, rather than going to the effort to construct their understanding, discussing this

Table 10
Business degree moderated regression results ($n = 1519$)Panel A: Final exam performance.

	Total score		Financial accounting		Earnings management		Cost volume profit analysis		Activity-based costing		Decision making	
Independent variables	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
Percentage of questions attempted	0.111	5.555***	0.087	3.937***	0.051	2.099**	0.051	2.178**	0.088	3.607***	0.111	4.676***
Age	0.035	1.702*	0.031	1.404	−0.051	−2.101**	0.025	1.040	0.125	4.928***	0.040	1.626
Gender dummy	0.087	4.554***	0.047	2.256**	0.031	1.362	0.145	6.298***	0.040	1.685*	0.097	4.144***
WAM	0.648	30.951***	0.559	24.219***	0.436	17.296***	0.433	17.589***	0.364	14.268***	0.389	15.496***
Year of study	0.086	4.089***	0.038	1.653*	0.070	2.781***	0.076	3.029***	0.045	1.718*	0.053	2.090**
Adjusted R^2	0.443		0.330		0.200		0.201		0.141		0.174	
Cohen's f^2	0.795		0.493		0.250		0.252		0.164		0.211	
F-stat (*p*-value)	242.597*** (0.000)		150.655*** (0.000)		76.829*** (0.000)		77.509*** (0.000)		50.962*** (0.000)		64.807*** (0.000)	

Panel B: Mid-session exam performance	Total score		Practical		Theory	
Independent variables	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
Percentage of questions attempted	0.051	2.447**	0.055**	2.454**	0.034	1.545
Age	0.018	0.861	0.111	4.898***	−0.080	−3.600***
Gender dummy	−0.018	−0.923	0.000	0.983	−0.033	−1.555
WAM	0.637	29.416***	0.569	24.469***	0.546	23.742***
Year of study	0.031	1.451	0.044	1.882*	0.011	0.478
Adjusted R^2	0.407		0.315		0.330	
Cohen's f^2	0.686		0.460		0.493	
F-stat (*p*-value)	209.679*** (0.000)		140.467*** (0.000)		150.669*** (0.000)	

***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level (2-tailed).

with peers and providing their response, although our regression results do not support such a traditional approach.

Consistent with suggestions in the literature [66], students' open-ended survey responses indicate they like the interactive and participative nature of the platform, particularly in contrast to other large lecture formats where they perceived they don't normally have the opportunity to participate. These positive responses are consistent with the literature noting the importance students place on class experience and deeper learning approaches [19]. Lecturers also observed that the integrated questions throughout the lecture appeared to break the lesson up into segments that were "bearable" for student attention spans, without distractions caused by switching platforms, as is the case for other clicker technology previously used by the lecturers, which requires separate URLs and access codes. Lecturers noted that students appeared less distracted when using the platform. Further, it was unnecessary to ask students to stop talking towards the end of the lecture compared to prior sessions.

Open-ended survey responses suggest students' greatest dislike was the inability to go back and view previous slides covered while the lecture was in progress, consistent with ad hoc student feedback provided to lecturers. Some students saw this as an advantage, motivating them to keep up with the lecture and avoid distraction. Consistent with this, in ad hoc discussions with lecturers, students openly admitted the inability to revert encouraged them to focus more on the material rather than assume if they engaged in off-task activities – in this case, going over previous slides – they could "catch up". Accordingly, instead of being a distraction, using the platform on devices kept and encouraged student focus, addressing concerns noted in the literature relating to device distraction [28–30]. Such encouragement is particularly valuable for students who are less interested in the course, completing it only as a mandatory requirement and finding it more challenging to focus [31].

Related to minimising distraction, immediate access to lecture content and associated questions created less time pressure and provided more opportunities to actively and synchronously engage students while formatively examining knowledge of different concepts, which students found valuable [14,35]. This allowed the class to be better tailored to students' needs, more time spent on areas less understood and provided students with a high degree of perceived academic control, which students find desirable [67]. Before using the mirroring platform, the lecture delivery commenced with an explanation of the core concepts, followed by a series of different application-based examples. Subsequently, with the introduction of the platform, integrated questions replaced some of the application-based examples, allowing students to work through these applications using their devices rather than passively following extensive examples.

Consistent with students' survey responses and lecturer observations, the main results provide strong support for the efficacy of the platform. The only exception in the main results is the marginally significant effect on theory question performance in the mid-session exam. However, interestingly, the theoretical component of the final exam, once again focusing on earnings management, is significantly related to lecture participation. The results suggest that further exposure to theoretical-based accounting topics post-mid-session exam and more time for students to consolidate their knowledge was an important component of realising the benefits of our participative approach. More generally, most control variables are significant across the models indicating they are important controls for student motivation and interest in their studies.

Table 11

Non-business degree moderated regression results ($n = 141$)Panel A: Final exam performance.

	Total score		Financial accounting		Earnings management		Cost volume profit analysis		Activity-based costing		Decision making	
Independent variables	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Percentage of questions attempted	0.083	1.089	0.169	2.099**	0.054	0.622	0.094	1.156	−0.047	−0.534	−0.069	−0.853
Age	0.024	0.305	−0.117	−1.419	−0.025	−0.280	0.089	1.030	0.089	0.963	0.123	1.441
Gender dummy	0.241	3.415***	0.120	1.651	0.198	2.521**	0.224	2.818***	0.230	2.837***	0.135	1.706*
WAM	0.437	5.555***	0.433	5.202***	0.315	3.505***	0.178	2.038**	0.212	2.346**	0.282	3.300***
Year of study	−0.123	−1.474	0.061	0.705	−0.044	−0.471	−0.204	−2.195**	−0.152	−1.580	−0.248	−2.685***
Adjusted R^2	0.322		0.266		0.147		0.135		0.094		0.152	
Cohen's f^2	0.497		0.362		0.172		0.156		0.104		0.179	
F-stat (*p*-value)	14.421*** (0.000)		11.244*** (0.000)		5.852*** (0.000)		5.398*** (0.000)		3.917*** (0.002)		6.046*** (0.000)	

Panel B: Mid-session exam performance	Total score		Practical		Theory	
Independent variables	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
Percentage of questions attempted	0.080	0.965	0.080	0.955	0.063	0.740
Age	0.092	1.083	0.182	2.111**	−0.017	−0.192
Gender dummy	0.052	0.680	0.116	1.510	−0.024	−0.302
WAM	0.449	5.203***	0.388	4.450***	0.417	4.679***
Year of study	−0.005	0.055	−0.064	−0.702	0.055	0.594
Adjusted R^2	0.201		0.185		0.149	
Cohen's f^2	0.252		0.227		0.175	
F-stat (*p*-value)	8.085*** (0.000)		7.420*** (0.000)		5.956*** (0.000)	

***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level (2-tailed).

Our results strongly indicate that student perceptions of the course, relating to future studies and/or career plans, moderate the results. We expected students who voluntarily select the course do so to broaden the scope of their studies and/or future career opportunities and are thereby motivated to engage with the course anyway [51,52] and, therefore the use of the platform does not lead to significantly higher performance for these students. Our results confirm this is the case. This does not mean these students don't benefit in other ways. For example, with much student isolation, particularly during the pandemic, the approach provides the opportunity for students to interact, contributing in some way to their feeling of belonging at university, a very important aspect of student experience [68]. The one exception to these results was the significant and positive effect on activity-based costing final exam performance for accounting major students. Activity-based costing is often cited as a relatively more difficult (introductory) accounting topic, therefore active participation in activity-based costing lectures is expected to have a significant and positive impact on student performance, especially for those who see introductory accounting as an important foundation of their studies [53].

In contrast, students who are required to complete the course as part of the business program and often have a mixed view of the course, including a lack of interest and low initial motivation (Danowitz, 2016; Frick et al., 2020; Gasiewski et al., 2012; Gibbens, 2019; Gomes & Mendes, 2014), achieve significantly higher exam marks where they participate in lectures using the platform. This suggests, as discussed earlier, the platform encourages these students to focus, minimising distraction and promoting a more productive learning environment, effectively targeting the learning needs of these students.

Beyond the independent variables of interest, percentage of questions attempted, we find the gender dummy is an important control variable, and in particular, females achieve higher grades. This is consistent with accounting literature which indicates that females are more interested in accounting studies, with higher intrinsic and extrinsic motivation, and tend to work harder than males [69]. Unsurprisingly, weighted average marks are also a very important control variable, consistent with indications in the literature [60,61].

7. Conclusion

This study shows that lecture participation when using a platform facilitating lecture slide mirroring with integrated questions is positively and significantly related to exam performance. However, this positive and significant result only applies to specific groups of students, helping address the mixed findings reported in the literature concerning audience response systems [7]. It appears students who are studying the course as a foundation to further studies and/or voluntarily for their own interest or career aspirations are motivated to complete the course, undertake an effort, in any case, to construct their understanding of the course through the various resources and feedback available in the learning management system. This aligns with the course learning objectives, and thereby, these students perform well in summative assessment as predicted by constructive alignment theory [32], regardless of whether they attend participative lectures.

Students not planning to specialise in accounting via an accounting major (i.e. completing the course due to program requirements only) benefit most from the intervention from an examination performance perspective. These students, who have mixed views of the course [7–11], may only actively construct their knowledge when essentially forced to do so through the participative approach in lectures and thereby receive feedback that is relevant to improving and aligning their understanding with the course learning objectives. This indicates that placing pre-recorded lectures online, with no consideration for how students will actively participate in the learning process, is a very dangerous approach. This suggests that many institutions need to carefully consider appropriate teaching models moving forward, consistent with the importance of considering student characteristics and their different learning needs [20]. In the context of this study, this means students completing the subject on a mandatory basis should be required to focus and actively participate in an interactive manner using the intervention proposed.

Based on our findings, the platform appeared to be a valuable means of facilitating a participative approach, allowing the move away from one-way transmissive teaching approaches universities are often requiring with the return to campus of students post-pandemic. Student distraction due to devices in the classroom is a long-debated issue [28–30]. Recognising we cannot get away from students having devices in the classroom, rather than being a distraction, this intervention shows how the devices can be harnessed to not just engage the student in class but also, due to mirroring and frequent interaction, minimise the opportunity for students to be distracted by them. Accordingly, it appears that the mirroring and fixed movements of slides and questions are particularly valuable in return to campus modes of learning to encourage students to focus, participate in class and also improve their sense of belonging.

As with any study, there are limitations and research opportunities warranting further consideration. First, while our study shows student motivation and interest are important moderators of intervention effectiveness on exam results, other factors such as student age and background also warrant further theoretical development and testing. We focused on moderating values related to accounting studies and associated future plans; however, other moderating factors also warrant consideration when implementing and tailoring new teaching interventions [70] to ensure students receive the greatest benefit, for example, language background and international student status [20]. Second, we focus our analysis on a platform facilitating slide mirroring with integrated questions, which is not available on a commercial or non-commercial basis. All platforms vary, and the associated learning experience each platform facilitates in sum also varies; therefore, the implications on student performance identified in this study may not be replicated in the context of other platforms. Testing is warranted to confirm whether this is the case, considering the attributes of each platform, similar to what we report in this paper. Third, while this study was conducted in a face-to-face learning environment, it would be interesting to examine how the technology could extend to an online class environment, given the impact of students attending large face-to-face lectures during pandemics and the likely continuation of online classes to some degree post-pandemic.

Author contribution statement

James Wakefield, Jonathan Tyler: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

The authors do not have permission to share data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank Raechel Wight, colleagues, the participants at the 2017 International Teachers Programme (ITP), the 2018 UTS Teaching and Learning Forum, the 2018 RMIT Accounting Educators Conference, the 2018 AFAANZ Conference, and the Heliyon journal reviewers for their feedback on this paper. Thank you to Madison Reynolds for her research assistance.

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