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Adoption and use of smart devices as clickers in classrooms in higher education

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Abstract

The availability of students' smartphones, tablets, and laptops, known as bring your own devices (BYOD), used as clickers rather than the custom devices provided by institutions is increasing. Introducing BYOD as clickers and the level of adoption by students is not explored in the literature. Another element that is not reported in the literature is students' negative perception of the use of clickers. This paper reports on the factors of the adoption of BYOD and the impact of the use of BYOD for engagement and active learning. The study used mixed-method data analysis. A questionnaire was used to collect qualitative and quantitative data from 78 students. The technology acceptance model (TAM3) was used to develop a partial least square-structural equation modeling (PLS-SEM) model to test hypotheses on the factors affecting the adoption of BYOD by students as clickers. PLS-SEM was used to test the proposed hypotheses based on TAM3 factors. The qualitative data analysis indicates that BYOD has a role as a facilitator of active learning and engagement. Job relevance has a weak positive relationship with output quality; result demonstrability has a negative weak relationship with resistance to adoption. Incompatibility of BYOD as a clicker acts as a factor for the nonadoption of the technology. This research suggested the inclusion of the BYOD technology compatibility factor for analyzing the perception of usefulness. The findings have particular implications for curriculum planners and educators.

KEYWORDS

active learning, BYOD, clickers, PLS-SEM, TAM, technology adoption

1 | INTRODUCTION

Lecturing has a history dating back 900 years, starting when universities were founded in Western Europe [16]. With the introduction of new technology in teaching and learning processes, traditional face-to-face lecturing has been replaced with online teaching. Universities have adopted significant technology for teaching and learning processes due to the COVID-19 pandemic, using tools such as Zoom, WebEx, and Teams. This sudden and forced shift to online teaching is changing the 900-year-old practice. New platforms and applications, such as

TurningPoint and Menti, create interactive sessions. However, according to students' perceptions, the level of interactivity and positive impact have limited results. In addition, students' participation is impacted by the nonadoption of bring your own devices (BYOD) as a clicker.

Technology is used to facilitate lectures; clickers are used to create engagement and active learning in higher education. Students use their own smartphones, laptops, and tablets to participate in activities integrated into the slides. Clickers change the teaching strategy from a lecturer-centered (traditional) to a student-centered learning paradigm [28]. Literature reports students' positive perceptions of the use of clickers in class for engagement and active participation. While some agreement can be found about students' positive perception of the use of clickers in class, this agreement is not universal. When students were asked about their colleagues' use of clickers, the results were less certain. The data from this research shows a 29% (see Table 7) difference between students' self-reported positive impact and their colleagues' perceptions.

The major findings of this research are that students' perception of the use of clickers in large group teaching improves the students' learning experience and subject interest. It increases engagement and encourages active learning. Students reported good discussions of concepts and ideas conducted with their peers and lecturers. However, students' perception of their colleagues' positive impact of the use of clickers is significantly lower than their own perception of the positive impact on their learning. These data show a low level of students' adoption of BYOD when used as clickers. The data from this research showed that, on average, only 60% (see Table 5) of students use their BYOD as clickers. The partial least square-structural equation modeling (PLS-SEM) analysis indicates a weak association between job relevance and output quality, and a weak negative association between result demonstrability and resistance to adoption.

In this paper, the exploration of students' perceptions of the use of voting systems in a classroom is reported. This paper fills the gaps in understanding: (1) students' perception of the use of their devices as clickers to improve their examination scores and learning; (2) the comparison of the self-reported and peer-reported impact of clickers on learning; and (3) the factors for adoption/nonadoption of the use of BYOD as clickers to participate in active learning. The paper is organized as follows: first, the literature review is presented, followed by the method used for data collection, and finally, the findings, discussions, and conclusion sections are presented.

2 | LITERATURE REVIEW

The technology used for active participation is called by different names: audience response system (ARS) [19], clickers [22], and student response system (SRS) [10]. The term "clicker" is used to refer to the technology used in classroom participation. The history of clickers started in the 1960s with custom-made clickers connected to networks that enable students to respond to questions raised in the classroom. These are custom-made hardware and software systems that provide interconnectivity that enables students to respond to questions posed by lecturers during class time [25].

Emerging technologies are enhancing students' engagement and creating an active learning environment [7]. The TurningPoint system enables students to use their own devices to participate in classroom activity. In previous years, the technology required students to use a bespoke clicker to participate. Hence, the development of new technology and the use of mobile phones, tablets, and laptops enable instructors to implement the technology as clickers.

2.1 | BYODs as clickers

The abundance and affordability of smartphones, tablets, and laptops that are connected to various services and platforms facilitate the integration of these devices as clickers. BYOD is cost-effective [24] for institutions to implement the technology. The presentation of slides built with the audience response software system displaying the contents of the slide, including questions, onto the BYOD with multiple answers or short answers in real-time, facilitates engagement. The web-based clicker system facilitates the use of any BYOD as a clicker. This reduces the configuration and maintenance of custom-made clickers for institutions.

These BYOD devices enable participating students to answer questions and further instruction, prompting discussion between students. This creates active learning and a high level of engagement in the learning activity. Active learning includes students actively participating in group discussions about concepts or ideas or answering questions using clicker systems [16] BYOD helps lecturers to engage students with what [9,14] called a "digital classroom."

The advantage of students owning these BYOD devices is that they can customize them to their preferences. The customization helps to satisfy individual needs by changing the font, font size, background, and contrast, which removes some barriers to participation. Students' familiarity with their own devices helps facilitate ease of use when devices are used as clickers. The use of BYOD increases student productivity, as they are familiar with their devices [30]. The knowledge of the devices by the students makes it easy to find applications that can be used as clickers. Another advantage is the ease of use of the devices by students when operated as clickers. Unlike custom-made devices, BYOD requires little or no training to operate by their owners. Students have a personal preference for which apps to load and use; for example, some may prefer not to use location-tracking applications. These different choices of applications arise from concerns about the security and tracking implications of some software. For example, some students may prefer the Firefox browser to Google Chrome because they perceive the Firefox browser as being more secure and not tracking users.

2.2 | Engagement and active learning

In traditional lectures, responses to the lecturers' questions are answered by one student raising their hand, while all other students remain passive. Clickers enable all students to answer the question anonymously [19]. This enables students to see what their peers' responses are to the question. Those who did not choose the correct answer realize they are not the only ones. In a typical lecture situation, such students are often inhibited from asking a question by the belief that "everyone knows except me." As responses are anonymous, no one has to worry about the humiliation of giving a wrong answer, which encourages students to respond to the questions. The technology helps to a better level of engagement and facilitates active learning. This also helps the lecturer to gauge the different levels of knowledge in the classes based on the answers and discuss further the concepts and ideas with examples. This can be followed up by the lecturer by putting forward questions to see if the additional examples and discussions have facilitated an understanding of the discussed concepts and ideas.

Using clickers increases learning activity and changes the social environment experienced by students when compared to traditional lecture-based instruction [22]. Buil et al. [4], argue that the clicker system generates concentration in activities that enhance the learning experience of students. Voting systems such as clickers in a classroom help in several ways: Cline et al. [11], argue that voting systems can help in designing discussion questions and measure if students have mastered a particular concept. The responses from students provide real-time feedback for lecturers to improve the teaching delivery by providing examples to further explain the underlying concepts under discussion.

The TurningPoint clicker system is seamlessly integrated with PowerPoint and allows educators to pose questions in real-time, collect anonymous responses, and facilitate discussion. The clicker system removes barriers to participation in responding to questions and removes self-censorship in participating in sensitive topics; it also displays aggregate responses to prompt active participation [17]. The anonymity of the clicker system facilitates active participation and allows students to learn from each other by knowing what others think about the subject [17]. One reason for student disengagement is the anxiety of being judged by their teacher and peers. The anonymity of the system helps students to communicate their thoughts and misunderstandings without being judged and learn from active discussion [15].

One challenge of teaching large classes is the lack of engagement of students with the subject [31]. Technology is recognized for its ability to create an environment that facilitates different modalities of engagement. Research by Cheung et al. [10], showed that educators agree that clickers are instrumental in engaging students in learning.

The traditional lecture is still the main method of teaching in higher education. There is evidence that shows the use of clicker systems increases engagement and active learning and consequently improves exam results. For example, Freeman et al. [16] conducted a meta-analysis of 225 studies showing that the average examination scores improved by 6% in active learning when compared to traditional lecturing. Similar results were found by Hussain and Wilby [26], who found that students who were part of a class that used a clicker system received better final grades compared to students who were taught without a clicker system. The recent study by Anderson et al. [2], indicates that the impact of clickers on results depends on students' characteristics (weak, average, or strong) and the difficulty of the course. Clickers improve grades for weak students in more challenging quantitative courses. However, the participation of many students leads to active discussions of the concepts presented in the classroom, which motivates students to take more responsibility for their own learning [27].

Another challenge of teaching large classes is maintaining students' concentration for a reasonable amount of time [5]. A similar study by Burns [6], found that students' attention wanes and recall diminishes after 20 min of lecture time. Other research also shows that students' level of concentration decreases after 20–30 min of lecture [4]. Burke and Ray [5] suggest engaging students with activities at predetermined intervals to maintain their concentration. Clickers can be used to generate activities to involve students and break up the lecture at a prespecified time to maintain students' concentration. The study by Buil et al. [4] shows that the use of clicker systems increases students' absorption and concentration. The clicker activities provide breaks that engage students in different activities, which reset their attention span and increase their retention period. The clicker activities, linked to breaking up 2-h lectures by providing activities in 20-to-30-min intervals, increase students' attention span and help them understand and recall concepts.

2.3 | Technology adoption and education

The technological development of mobile phones, such as the fourth and fifth generations, facilitates the integration of services using these new smart devices. The development of these new technologies enables the integration of technology into teaching and learning activities in classrooms. For example, the increased reliability of network connectivity and availability of applications on the cloud make TurningPoint software enable the provision of clickers on BYODs. The application of TurningPoint is not without problems; the system is not working on some browsers and on some devices.

The TurningPoint application supports devices such as smartphones, tablets, and laptops using different browsers to provide clicker activities in classrooms, and this decreases the barrier to participation. The TurningPoint application is simple to use through BYOD with no training requirements. This further reduces the barrier. TurningPoint's ability to collect detailed data about class activity, and its availability for further analysis, provide the opportunity for lecturers to reflect and adjust their teaching approach to increase participation and engagement in the learning and teaching processes.

Students had positive perceptions regarding the use of clickers in the classroom for participation, engagement, and attention to the presented content [26]. However, perceptions may not reflect the impact of the use of clickers. For example, Batchelor [3] shows that clickers had positive students' perceptions but did not help reduce Maths anxiety, but rather helped increase engagement. Other researchers reported that students had positive perceptions of clickers, which helped increase participation, engagement, and retention of educational concepts [34, 35]. However, there is disagreement on the length or extent of the retention of concepts when using clickers in the classroom. Freeman et al. [16] systematically analyzed 225 studies and concluded that the use of clickers in the classroom increased pass rates and retention. However, the study by Robson et al. [34] indicates that there is no significant increase in short-term knowledge retention when using clickers in the classroom compared to traditional lectures. These different studies agree that clickers increase active learning and engagement. The current evidence indicates that clickers create student-centered teaching and learning modalities, facilitating better engagement, and understanding of the subject matter, and implying the attainment of better marks [28].

The adoption of teaching and learning technologies by teachers has been researched using the TAM3 model by Scherer et al. [38] and Prieto et al. [32]. TAM3 provides the factors that facilitate the adoption of technology by users. The two significant factors that affect the behavioral intention to adopt technology are the perception of ease of use and the perceived usefulness of the technology by users, see Figure 1 [41].

The characteristics of the two main factors are explained by constructs, as shown in Figure 1. The constructs for perceived usefulness are the subjective norm, image, job relevance, output quality, and result demonstrability. Perceived ease of use is expressed by the following constructs: computer self-efficacy, perception of external control, computer anxiety, computer playfulness, perceived enjoyment, and objective usability.

The application of these constructs is dependent on the characteristics of users who adopt or reject the technology. The study population for this study is third-year computing students who extensively use mobile phones and laptops for their social and study activities. Some of the students develop applications that are used on mobile phones and laptops. One of the main factors of TAM3, perception of ease of use, is not used for the following reasons: (1) computing students have well-established practical experience, including developing apps to be used on these devices; (2) the technology is adopted and used by students who participate in this research.

This study explores to what extent TAM3's perception of usefulness factor constructs affects the adoption of BYODs as clickers. The reason for the selection of these factors is to see if students are willing to use their BYODs as clickers to participate in class activities.

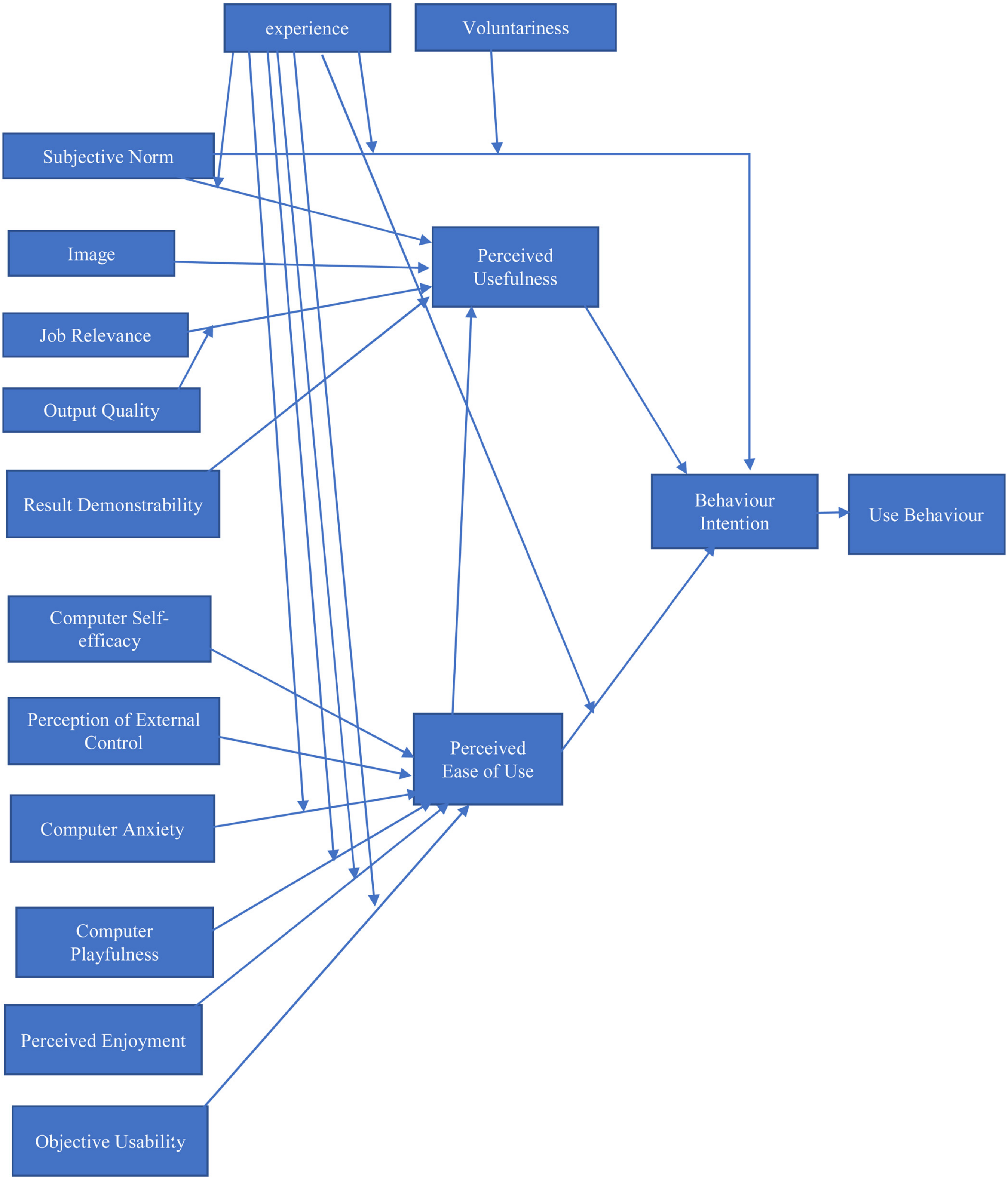

FIGURE 1 Technology acceptance model, technology acceptance model 3 constructs [41].

The hypotheses are aimed at testing the perception of the usefulness of BYODs for engagement and improving their average grade mark. Furthermore, the study by Venkatesh and Bala [41], indicates that the perception of usefulness is a significant factor in determining adoption when compared to the perception of ease of use. The definitions of the constructs are presented as shown in Table 1.

TABLE 1 Perception of usefulness factor of TAM3 adopted from Venkatesh and Bala [41].

Factor	Determinants identified by Venkatesh and Bala [41]	Definition of determinants by quoted by Venkatesh and Bala [41]
Perception of usefulness	Subjective norm	The degree to which an individual perceives that most people who are important to him think he should or should not use the system
	Image	The degree to which an individual perceives that use of innovation will enhance his or her status in his or her social system
	Job relevance	The degree to which an individual believes that the target system is applicable to his or her job
	Output quality	The degree to which an individual believes that the system performs his or her job tasks well
	Result demonstrability	The degree to which an individual believes that the results of using a system are tangible, observable, and communicable

Abbreviation: TAM3, technology acceptance model.

TABLE 2 Perception of usefulness adopted from Venkatesh and Bala [41].

Code	Observed items	Latent variable (perception of usefulness)
CP	Clickers influences on colleagues' participation	Subjective norm
PE	Previous experience of using Voting system	
SP	Smartphone	Adoption
IT	Clickers influences on building interest on the topic	Job relevance
LE	Clickers influences on learning	
AT	Clickers influences on attention	Output quality
PA	Clickers influences on participation	
DY	When using clickers lectures were dynamic	
AP	When using clickers in lectures allow more active participation	
NV	I prefer voting without clickers	Resistance to adoption
RE	Using Clickers improve examination marks	Result demonstrability

The TAM3 model in Figure 1 shows constructs for perceived usefulness. The constructs of subjective norm and image are self-explanatory.

- Job relevance: The final goal of learning is a critical engagement with concepts and ideas and securing better marks. The construct tests whether the use of BYODs can provide better average marks, which is a test of the efficacy of BYODs.
- Output quality: This construct measures the effectiveness of the use of BYODs, to determine to what extent average marks would be improved as a result of the use of BYODs.
- Result demonstrability: This construct measures students' belief that the use of BYODs will result in an improved average mark.

The latent variable "resistance to adoption" is not included in the TAM3 model but is introduced to see if "result demonstrability" reduces resistance to adoption. This latent variable was tested using both hypothesis (H5) and research question (RQ4), as shown in the "Research Questions/Hypotheses" section below. The data collecting tool in Appendix A3 was used to test the hypotheses, and Appendix A4 was used to answer research question 4.

In Table 2, the three latent variables (Adoption, Resistance to Adoption, and Result Demonstrability) are observed through single-item measures. Diamantopoulos et al. [13], recommended avoiding the use of single-item measurement and suggested that its use should be limited to special circumstances, though the circumstances were not defined. Sarstedt et al. [36] also generally argued against using single-item measures. Diamantopoulos et al. [13] call for further research on the use of single-item scales, and Cheah et al. [8] responded to this call by finding that, in the context of hospitality management, single-item measures yield higher degrees of convergent validity for small samples. As this research has a small sample size, it justifies the use of single-item measures for the above latent variables.

2.4 | Research questions/hypotheses

Research questions (RQ1–RQ3) were designed to explore the impact created on those students that adopt and use BYODs on the teaching and learning processes.

- RQ1: Explore students' perceptions of the effect of BYODs on students' engagement and understanding of the topic presented in classes.
- RQ2: Examine students' perceptions of the impact of BYODs on active learning and resulting in better average examination scores.
- RQ3: Examine students' perception of their colleagues' participation increasing as a result of using BYODs in the classroom.

The reasons for designing the research question (RQ4) and the hypotheses were to explore the factors of adoption using thematic analysis and PLS-SEM, respectively. The hypotheses explore the possible factors, based on TAM3, that influence the adoption of BYODs.

- RQ4: Explores the factors students' perception of the nonadoption of the use of BYODs in the classroom. Qualitative data was collected to answer RQ4, see Appendix A, Table A4.

The following research questions and hypotheses were developed from the literature review and the context of the case study under research. They aim to answer the research questions and test the proposed hypotheses.

The study attempts to answer the following research questions:

RQ1: To what extent do students perceive the use of clickers generates engagement and a better understanding of the topic presented in classes?

RQ2: To what extent do students perceive that participation using clickers can facilitate active learning, resulting in better average examination scores?

RQ3: To what extent do students perceive their colleagues' participation increases because of the use of clickers?

RQ4: What are the main factors that affect BYOD adoption as clickers?

To explore the possible factors for the adoption/nonadoption of BYODs as clickers, the following hypotheses were formulated based on TAM3 [41], focusing on the perception of usefulness factors, see Figure 1 for details. Perception of usefulness has five latent variables: subjective norm, image, job relevance, output quality, and result demonstrability. The proposed hypotheses test how these latent variables influence the adoption of BYODs as clickers.

- H1: Hypothesis formulated that "job relevance" predicts the adoption of BYODs as clickers. The assumption here is that the use of BYODs will result in securing better grade marks, which will encourage students to adopt the technology. "Job relevance" is an indicator of BYOD use efficacy as a system outcome for better grades for students.
- H2: Hypothesis formulated that "job relevance" as a system that its efficacy produced better grades and "output quality" latent variable measures to what extent the efficacy is effective in getting better grades. The system, BYOD use in the classroom enables students to do their tasks well, in this case, secure better grades. The assumption is that "job relevance" predicts "output quality," the logic being that once students know that "job relevance," the use of BYODs improves students' marks, then "job relevance" predicts "output quality."
- H3, H4, and H6: Are presented as predictors of adoption, as stated in the TAM3 model.
- H5: "Resistance to adoption" is not part of TAM3, but here the hypothesis is proposed to see if "result demonstrability," if students perceive that the use of BYODs improves their grade marks, then the hypothesis is that "resistance to adoption" will reduce.

The model presented in Figure 2 indicates the hypotheses to be tested. The hypotheses were tested using the PLS-SEM method.

H1: Job relevance predicts the adoption of BYOD as a clicker

H2: Job relevance predicts output quality

H3: Output quality predicts BYOD adoption as clickers

H4: Result demonstrability predicts the adoption of BYOD

H5: Result demonstrability predicts the level of resistance to adoption

H6: Subjective norm predicts adoption

The structural model shows the link between the constructs identified by TAM3. This is a reflective model. The latent constructs with the respective measuring factors are presented in Table 2.

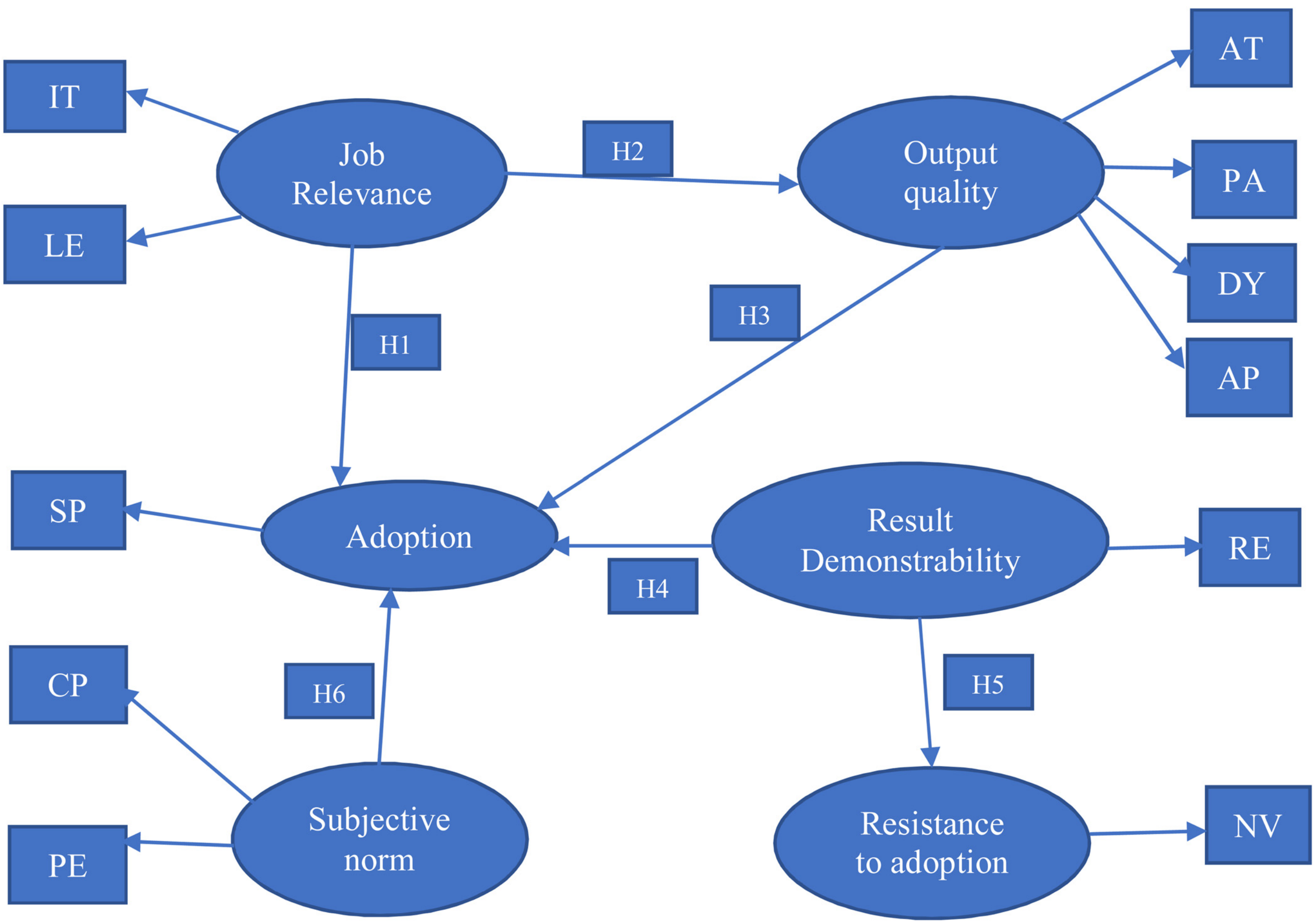

FIGURE 2 Structural model.

2.5 | Methodology

The aim of this research was to identify the factors that influence the adoption of BYOD as clickers and to explore the impact of using BYOD as clickers on teaching and learning. Mixed methods research was used to achieve this aim, collecting both qualitative and quantitative data. A convergent mixed method design was used, in which both types of data were collected and analyzed separately, then compared to see if the findings confirmed or contradicted each other. Creswell and Creswell [12, p. 217], describe this method as “a researcher collects both quantitative and qualitative data, analyses them separately, and then compares the results to see if the findings confirm or dis-confirm each other.” The timing, data collection tool, analysis, and merged results are shown in Table 3.

2.6 | Study design and procedure

A questionnaire was used to collect students' perceptions of the effect of clickers on the learning and teaching activities in their classes. To reduce bias regarding the self-reported level of participation and impact, students were asked to complete the questionnaire about the use and the impact of clickers on their peers. The data collected were analyzed using descriptive statistics, thematic analysis, and multivariate analysis using PLS-SEM to test the proposed hypotheses. These data were collected using open-ended survey questionnaires (see Appendix A) and analyzed using the thematic method [37]. The data collected using closed-ended questionnaires were analyzed using descriptive statistics and PLS-SEM methods.

2.7 | Sample

The research participants were computing students in a third-year core module of a 4-year undergraduate program at a Scottish university. The total number of students taking the module was 258. Every lecture included multiple questions, and students participated using their own devices as clickers. Participation was

TABLE 3 Convergent mixed method.

Data collecting method	Data collecting timing	Data	Analysis	Adoption of BYOD (merged result)	Results of effect of BYOD use	Interpret results to compare
Questionnaire	The same time	Qualitative	Thematic analysis	RQ4	RQ1–RQ3	New finding or insight
	The same time	Quantitative	SPSS, v21, and PLS-SEM	Hypotheses		

Abbreviations: BYOD, bring your own devices; PLS-SEM, partial least square-structural equation modeling.

voluntary and not associated with grades. Students were encouraged to participate using their personal devices. The survey was conducted in the last week of the semester, and 127 students attended it. This is a low number of attendees as students were completing coursework for other modules. Eighty-two responses were received from students, and four responses were rejected for incomplete data. A total of 78 responses were used to analyze the data.

The level of adoption of clickers by students was calculated using the difference between the number of students attending a session and the number of responses on the TurningPoint system. The use of smartphones as clickers was explored using PLS-SEM. Smartphones were used more than tablets or laptops. Table 2 shows the latent and observed items based on Venkatesh and Bala [41]. The observed items are presented using descriptive statistics, as shown in Tables 3–9.

2.8 | Data collecting instrument

These data were collected using questionnaires, presented in Appendix A. The questionnaire had four parts, as shown in Appendix A, Tables A1 through A4.

- Appendix A1 was aimed at collecting demographic data and students' past experience with using clickers.
- Appendices A2 and A4 were aimed at collecting data to answer the proposed research questions.
- Appendix A3 was used to collect data to test the proposed hypotheses.

2.9 | Data analysis

The data collected using the instruments in Appendix A, Table A1 was analyzed using SPSS V21. The data collected using the instrument in Appendix A, Tables A2–4 were analyzed using the thematic method [37]. Hsieh and Shannon [23] point out three approaches to interpreting meaning from the content of text data: the conventional method, the direct content analysis method, and the summative content analysis method. The conventional method derives codes from data, while the direct content analysis method uses theory to define code before and during data analysis. The summative content analysis method uses keyword identification before and during data analysis. This research uses the conventional method, which provides a richer understanding of the phenomenon under investigation [23].

PLS-SEM was used to analyze the data collected using the instrument in Appendix A, Table A3 to test the proposed hypotheses. The PLS-SEM method was used to explore and find the factors that affect the adoption of technology, BYOD devices, such as clickers. SmartPLS (software used to calculate PLS-SEM, from https://www.smartpls.com/, version 3.3.7.) was used to estimate the structural equation model. PLS-SEM is used in many disciplines, such as marketing [21], tourism [40], and hospitality [1], to test hypotheses. The use of PLS-SEM to test hypotheses and scrutinize internal consistency, reliability, and validity enables researchers to demonstrate rigor and enables replicability of research [20].

2.10 | Survey results

The module is taught to all computing students in their third year of a 4-year program. There were 78 survey participants (see Table 4). A significant number of participants were male (87.2%), while female participants made up 12.8%. This also shows the low number of female enrollments in computing education, with only 12.8% of the participants being female.

The total number of students registered on the module was 258 (see Table 5). The total attendance number for 12 weeks of teaching was 2800. The data from the TurningPoint software shows that 1680 participants used BYOD during the 12 weeks of teaching. The voting system selected on the TurningPoint system was anonymous, so it was not possible to link individual students to their activities on the TurningPoint system. However, these data show that BYOD was adopted by 60% of the students.

TABLE 4 Research participants.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Female	10	12.8	12.8	12.8
	Male	68	87.2	87.2	100.0
	Total	78	100.0	100.0	

TABLE 5 Bring your own devices (BYOD) adoption.

	Students no	Total attendance no	Total number of BYOD use as clickers	Percentage of BYOD use compared to attendance
Devices used	258	2800	1680	60

TABLE 6 BYOD used by students.

		Multiple responses		Percent of cases
		Frequency	Percent	
Devices used	Smartphone	71	67.6	91.0
	Laptop	28	26.7	35.9
	Tablet	6	5.7	7.7
Total		105	100.0	134.6

Abbreviation: BYOD, bring your own devices.

Students used multiple devices to respond to activities during the class lecture (see Table 6). The smartphone was the main device used as a clicker to participate in class activities at 67.6%, followed by laptops at 26.7% and tablets at 5.7%.

Table 7 shows that 81.1% of students report a positive influence on their attention as a result of participating in using BYOD as clickers, while 13% of students perceive that clickers do not influence their attention when participating in activities using clickers. Using clickers in class has increased the level of participation by students by 88.3%. A small minority of students (3.9%) perceived that the use of clickers had a negative influence on participation. Students' perceptions of the impact of clickers on their peers' participation are much lower than their own reported level of participation. These data show that 58.4% of students indicate that there is a positive influence on the participation during lectures by their peers. The self-reported positive influence of participation is higher by 29.9 percentage points (see Table 7, $88.3 - 59 = 29.3\%$) compared to the data reported by students about their peers' level of participation. Most students (52%) perceive that the use of clickers did not influence an improvement on average examination marks.

As shown in Table 8, these data show that 94.9% of students agree or strongly agree that when clickers are used in lectures accompanied by activities, it generates active participation. The activities help students to discuss and understand the subject better, leading to the attainment of the learning outcomes of the module and higher marks.

Table 9 shows that students who anonymously participate using clickers increase participation in class activities. These data show that 79.5% of students agree or strongly agree that anonymity increases participation. The clicker allows anonymity, so students do not feel judged by the teacher or their peers.

Table 10 shows that 10.3% of students prefer the traditional lecture style without the use of clickers, while 67.9% of students prefer lectures with clickers.

2.11 | Technology adoption analysis using PLS-SEM

The level of adoption of clickers by students using their own devices is 60%. The analysis of the identified perception of usefulness factors for the adoption of BYOD using PLS-SEM to explain the 40% of nonadoption did not associate any of the perceptions of usefulness factors. The qualitative data analysis results suggested that factors such as noncompatible devices and browsers and students' negative perception of usefulness might explain the nonadoption of BYOD for clicker use.

Table 11 shows the results of the PLS-SEM internal consistency and reliability test using average variance extracted (AVE) and composite reliability (CR). Crobach's α is not used, as it may over- or underestimate scale reliability when used for reflective models [18]. The measured items show good levels of loading for the respective constructs. The measured

TABLE 7 Students' perceptions in the percentage of the effect of the use of clickers on attention, participation of self and peers, interest in the topic, and level of facilitation of learning.

	Attention (%)	My participation (%)	My colleague's participation (%)	Increase of interest on the topic (%)	Facilitate learning (%)	Increase examination marks. (%)
Positive influence	81.1	88.3	59.0	51.9	50.0	40
Negative influence	1.3	3.9	1.3	1.3	3.8	3.4
Did not influence	13	6.5	11.5	36.4	20.5	54
Not sure	3.9	1.3	28.2	9.1	25.6	2.6

TABLE 8 When using clickers in lectures, it allows for more active participation.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly agree	38	48.7	48.7	48.7
	Agree	36	46.2	46.2	94.9
	Neutral	2	2.6	2.6	97.4
	Disagree	1	1.3	1.3	98.7
	Strongly disagree	1	1.3	1.3	100.0
	Total	78	100.0	100.0	

TABLE 9 Anonymously participating using clickers increases participation.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly agree	36	46.2	46.2	46.2
	Agree	26	33.3	33.3	79.5
	Neutral	12	15.4	15.4	94.9
	Disagree	3	3.8	3.8	98.7
	Strongly disagree	1	1.3	1.3	100.0
	Total	78	100.0	100.0	

items "my participation," "anonymous voting increase participation," and "prefer lectures with clickers" had loading levels lower than 0.4 and were excluded from the analysis.

The discriminant validity using the Fornell–Larcker criterion is satisfied, as shown in Table 12. All the diagonal values are greater than the values below the diagonal.

The discriminant validity using the heterotrait-monotrait ratio (HTMT) (see Table 13) for the job relevance and output quality constructs shows that there is a high level of correlation between output quality and job relevance, as shown by the HTMT value of 0.914. The value should not exceed 0.9, and the result is slightly higher than the recommended cut-off point by 0.014. This shows that the observed elements for the two latent variables have a high level of correlation.

As shown in Table 14, job relevance and output quality have a weak positive association, while result demonstrability has a weak negative relationship with resistance to adoption. The logical argument is that if the results of using clickers demonstrate better examination

TABLE 10 I prefer lectures when clickers are used.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly agree	20	25.6	25.6	25.6
	Agree	33	42.3	42.3	67.9
	Neutral	17	21.8	21.8	89.7
	Disagree	3	3.8	3.8	94.5
	Strongly disagree	5	6.4	6.4	100.0
	Total	78	100.0	100.0	

TABLE 11 Internal consistency and reliability.

Constructs	Item (code)	Loading	AVE	CR
Output quality	AT	0.7560	0.5140	0.8080
	DY	0.7480		
	AP	0.7340		
	PA	0.6210		
Adoption	SP	1.0000	1.0000	1.0000
Resistance to adoption	RE	1.0000	1.0000	1.0000
Job relevance	IT	0.5210	0.5640	0.7090
	LE	0.9220		
Result demonstrability	RE	1.0000	1.0000	1.0000
Subjective norm	CP	0.7960	0.5510	0.7100
	PE	0.6850		

Abbreviations: AVE, average variance extracted; CR, composite reliability.

marks, then resistance to adopting BYOD as a clicker reduces.

3 | THEMATIC ANALYSIS

The collected qualitative data were analyzed to create the following themes: attention, participation, active learning, adoption, and resistance to the use of clickers. The thematic results on attention by students indicate that they focus more on the subject as a result of using clickers. The qualitative data also show a high level of participation and active learning because of the use of clickers. However, students' perception of the level of their colleagues' participation is lower than their own, and the data also show that there are students who will not participate using clickers.

3.1 | Adoption and use of BYOD

Integrating smartphones, laptops, and tablets by companies such as TurningPoint to be used as clickers reduces the cost of buying customized devices for institutions. This helps to increase the adoption of the technology. BYOD helps to minimize the adoption barrier and facilitates student participation. However, the data show that there is a high level of nonadoption by students (40%) to use their devices for clicker use. The literature did not discuss adoption issues regarding the BYOD devices to be used as clickers. There is an implication for pedagogy designers and practitioners to be aware of this issue and devise a mitigating measure to reduce adoption barriers.

3.2 | Participation

Students have positive perceptions of the level of attention and participation when clickers are used in lectures. A study by Hussain and Wilby [26] confirms these results. However, when students were asked about their colleagues' level of participation, they had a lower rate of perception at 51.9% compared to their own level of participation at 88.3%. When students were asked about general participation (see Table 8), 94.9% of students perceived an increase in active participation because of the use of clickers.

One theme developed from the qualitative data analysis on the effect of the use of clickers in lectures is the level of participation by students. One of the research participants explains the result as follows:

> It is a good idea. It gives us a view of what people think and different opinions. It is also enhancing participation and interest in the lecture.

TABLE 12 Discriminant validity results using the Fornell–Larcker criterion.

	Adoption	Job relevance	Output quality	Resistance to adoption	Result demonstrability	Subjective norm
Adoption	**1.0000**					
Job relevance	0.1490	**0.7510**				
Output quality	0.1300	0.4040	**0.7170**			
Resistance to adoption	−0.1410	0.1030	0.1780	**1.0000**		
Result demonstrability	0.0740	−0.2960	−0.2700	−0.3050	**1.0000**	
Subjective norm	0.0670	0.0650	0.2430	0.1470	0.0410	**0.7430**

Note: Bold values show the square root of AVE of evey multi-item constract is shown on the main diagonal.

TABLE 13 Discriminant validity using HTMT.

	Adoption	Job relevance	Output quality	Resistance to adoption	Result demonstrability	Subjective norm
Adoption						
Job relevance	0.283					
Output quality	0.142	**0.914**				
Resistance to adoption	0.141	0.301	0.201			
Result demonstrability	0.074	0.665	0.32	0.305		
Subjective norm	0.153	0.642	0.664	0.316	0.675	

Abbreviation: HTMT, heterotrait-monotrait ratio.

TABLE 14 Path coefficients and significance values.

	Original	*T* Statistics	*p* Values	2.50%	97.50%	Decision
Job relevance » Adoption	0.1490	1.2770	0.2020	−0.1500	0.3370	
Job relevance » Output quality	0.4040	4.5980	**0.0000**	0.2140	0.5410	Weak positive relationship*
Output quality » Adoption	0.1020	1.1940	0.2330	−0.0660	0.2540	
Result demonstrability » Adoption	0.1450	1.2700	0.2040	−0.0910	0.3660	
Result demonstrability » Resistance to adoption	−0.3050	2.9210	**0.0040**	−0.4940	−0.0950	Weak negative relationship**
Subjective norm » Adoption	0.0260	0.2140	0.3310	−0.3020	0.1770	

Note: Bold values indicate relationship between the constracts statistical significant at $p < 0.05$.
*$R^2 = 0.163$.
**$R^2 = 0.093$.

Other similar research reports similar results. Using clickers in classrooms improves the participation of students. A study by Rana et al. [33] surveyed 33 journal papers, and the review indicates a link between interactivity, engagement, and participation. Some argue that the increase in interactivity, engagement, and participation depends on the technology and the pedagogy used to engage students. If one assumes well-designed pedagogy and applied using clicker technology, it increases interactivity, engagement, and participation. Another research participant expressed the level of participation as follows:

> It helps people to learn more, because they are more focused on the lecture as well as participation.

3.3 | Attention

One theme that arises from the qualitative data is positive attention generated because of the use of clickers. Two of the respondents explain the effect of clicker use in the lecture:

> I enjoy the voting system as it breaks up the two-hour lecture and gives us some time for discussion between peers.

> It is engaging for the students and really breaks up 2 h of the lecturer talking. It is hard to pay attention to any lecturer for that long if it is just talking.

Other participant expresses the positive impact of clickers on attention as follows:

> It made me pay more attention to the topic being discussed!

> It made the topic feel more connected. It forced me to examine my view on the topic.

3.4 | Active learning

The qualitative data indicates that there are students who are aware of the impact of Clicker on improving learning. For example, research participants state the followings:

> It gives a better way to learn, more interesting.

> It helps me learn and understand the subject more.

> It is great, and I learn a lot from it.

> It helps people to learn more, because they are more focused on the lecture as well as participation.

One participant suggested other lecturers should adopt the Clicker system.

> I feel the voting system helps with the learning activities and that more lecturers should use them to engage the class.

The Clicker facilitates active learning through discussion on the selected topic. Students are encouraged to engage with their peers to discuss and exchange views, creating active and interesting discussions and this increases engagement. The following sentiments were expressed by research participants on the level of discussions generated using Clicker:

> It helps engage in conversation about the subject at hand.

> Fun, inspires discussion.

> It makes the lectures livelier as they are followed by a discussion.

Creating awareness in the classroom at the beginning of the use of clicker, explaining that participating in the clicker improves students' mark, can encourage students to adopt the clicker.

4 | DISCUSSION

The discussion is organized on the combined results from the quantitative data analyzed using descriptive statistics, and PLS-SEM. The qualitative data result was discussed to answer the research questions.

4.1 | Hypotheses testing

The PLS-SEM analysis of the TAM3 latent construct indicates that the hypotheses H1, H3, H4, and H6, *p* values exceed the .05 value cut-off point, indicating no association between these latent variables. The latent variables "job relevance," "output quality," "result demonstrability," and "subjective norm" did not predict BYOD adoption as clickers.

The *p* value for H5 and H2 is less than .05, (see Table 14), which indicates there is an association between the latent variables. The R^2 value for H5 is less than .25, indicating negative weak association between the "result demonstrability" and "resistance to adoption" latent variables. The result indicates that if students perceive that the use of BYOD is likely to increase their average grade then they will adopt the technology or adoption resistance to the technology decreases.

Similarly, the R^2 value for H2 is less than .25, indicating that there is a weak association between "job relevance" and "output quality" constructs (see Table 14). The result indicates that the use of BYOD increases students' average marks. This shows the system's efficacy to achieve the intended aim of getting higher marks. The extent the intended aim is achieved, the level of increase in the average students' marks measures how the system works well, indicating the association of "job relevance" to output quality (see the definitions in Table 2).

4.2 | Participation and engagement (RQ1: Students' perception of the use of BYOD to increase engagement and a better understanding of the topic presented in the classroom)

One mode of operation of clickers is the ability for anonymous participation, which helps increase participation. These data show that, as seen in Table 8, 94.6% of respondents strongly agree or agree that anonymous voting increases participation. 21.8% of students show no preference between traditional lectures and lectures that incorporate the use of clickers, as seen in Table 10. The PLS-SEM analysis indicates that anonymous participation does not seem to have an impact on the output quality of the latent variable, as its loading is below 0.4.

Other similar research reports indicate similar results. Using clickers in classrooms improves the participation of students. The study by Rana et al. [33], surveyed 33 journal papers, and the review indicates the link between interactivity, engagement, and participation. Some argue that an increase in interactivity, engagement, and participation depends on the technology and the pedagogy used to engage students. If one assumes well-designed pedagogy and its application using clicker technology, it increases interactivity, engagement, and participation. Another research participant expressed the level of participation as follows:

> It helps people to learn more, because they are more focused on the lecture as well as participation.

In a traditional lecture, students' attention and recall diminish after 20 min of lecture [6]. The data in Table 7 show that the use of clickers in lectures has a positive influence on students' attention, with 81.1% of respondents agreeing. The qualitative data analysis indicates that the use of clickers in lectures provides an opportunity to discuss key concepts among students and provides pauses from the lecture. This resets the attention span of students and helps to increase engagement, allowing students to attend the lecture with full attention and use their time effectively.

4.3 | Active learning (RQ2: Can the use of BYOD increase active participation and increase better average examination score?)

Active learning increases engagement and participation and improves exam scores. According to Freeman et al. [16], active learning increases exam pass marks by 6%. There is evidence to support the use of clickers in classrooms to facilitate active learning [25, 29]. The data in Table 7 indicate that students' perceptions about their learning improvement when using the clicker system are 50%, while 25.6% of students are not sure if it impacts learning. The other 20.5% of students think that the use of clickers has no influence on their learning. The data in Table 7 indicate that only 40% of students perceive that the use of BYOD increases examination marks, but more than half (54%) did not perceive that it has no impact on the examination marks. This is the main factor in the nonadoption of the BYOD system using clickers.

4.4 | Colleagues' participation (RQ3: To what extent does BYOD facilitate positive influence for their colleagues)

The data indicate that students' colleagues' positive influence as a result of the use of BYOD was much lower, at 29.1%, when compared to the self-reported positive influence of 88.3%. This is a clear indication that BYOD has a positive influence on students' learning and engagement. The environment it generates for discussions and participation enables students to increase their learning. Students' perception may indicate that the use of BYOD may not have any impact on the increase of their average mark, but the logical conclusion is that students learn better, engage, and participate, and this likely increases their average mark as indicated by other research [16, 28].

4.5 | Nonadoption of BYOD as clickers (RQ4: Factors that affect the adoption of BYOD as clickers)

Two significant reasons identified for the nonadoption from the qualitative study are the incompatibility of BYODs to students' devices and chosen browsers and students' preference for traditional lectures. The study by Stowell [39], indicates that 31% of mobile devices lose internet connection sometimes or most of the time during clicker use. However, during the use of clickers for this research, there were no reports of network connectivity problems when using mobile devices. There are still adoption barriers arising from the incompatibility of different systems.

The TAM3 model does not include compatibility as a factor for the adoption of technology by individuals. Systems like BYODs used as clickers should be compatible with other systems used by users. In this case, the use of BYODs as clickers should be compatible with students' devices and preferred applications such as browsers. The TAM3 perceived ease of use factor could include the degree of compatibility of the new device to the existing system as an additional construct to explain the adoption or nonadoption of technology.

The second reason is that students perceive that technology has no influence on increasing interest in the topic, facilitating learning, or increasing examination marks. For example, Table 7 shows that there is no influence on increasing interest in the topic at 36.4% and facilitation of learning at 20.5%, and an increase in examination marks at 54%. Furthermore, the PLS-SEM analysis did not imply a strong association between result demonstrability and adoption.

There are students who are reluctant to use clickers during lectures. The data presented in Table 10 indicates that 10.3% of students strongly agree or prefer not to use clickers. The main factors include software incompatibility and students' preference for different clicker systems. Two research participants stated:

> I could never participate because voting wasn't available for the Mozilla browser.

> There are better solutions used (Menti), which may cut down on audience confusion.

Sometimes the technology may not work, or students may be unable to access the platform. But the technology has improved and is available on various browsers. When students cannot participate, the impact is disruptive to the learning and teaching processes.

The traditional lecture does not create an environment for participating in activities that engage large classes. The data in Table 6 show that students prefer lectures with integrated activities that involve them. The advancement of technology facilitates lectures to include activities that engage students in the learning process. As shown in Table 6, smartphones are used most of the time (67.6%) to participate in clicker activities. These data show that mobile devices provide convenience and simplicity when used as clickers by students.

4.6 | Limitations of the research and future works

The present study sample was collected from university undergraduate students in the school of computing, limiting the findings as it did not include students' experience from other disciplines. As a result, the findings may not be generalized to the general university student population.

Many students did not participate in the research as there were many groups of students with different coursework and examination timetables who focus on the job at hand rather than participating in the research. The timing of data collection must be carefully selected to increase participation and must not be aligned with when students are busy with coursework or examination preparations.

Third, the study focused on five latent variables. There may be other influential latent variables that affect students' adoption behavior of BYODs as clickers. The findings of this research suggested the inclusion of the degree of compatibility as a construct in the TAM3 model. Future work could include the suggested degree of compatibility construct as one of the factors for the perceived ease of use of the technology to explain the level of adoption.

The design of the measured variables (observed items, see Table 2) and their association with latent variables is always an approximation. The latent variables may be expressed in many different measured variables, and the association of these variables' strengths and weaknesses can limit the interpretation of the outcome of the analysis.

Data were collected anonymously from the students during the use of BYOD activities to increase participation. As a result, students' GPA was not triangulated with students' BYOD level of participation. It was not possible to find if participation in the use of BYOD in the classroom can increase students' GPA.

5 | CONCLUSION

The nonadoption of BYOD used as a clicker has not been discussed in the literature. The main reasons for the nonadoption of BYOD as clickers are students' low perception of the use of clickers to improve their marks and noncompatible technical issues. The proposed hypotheses H1, H3, H4, and H6 are not supported. However, H2 and H5 are supported. H2 indicates that "job relevance" predicts "output quality"; implying that BYOD improves attention and active participation.

The PLS-SEM analysis (H5) indicates that the "result demonstrability" latent factor has a negative weak association with the "resistance to adopt." Creating awareness of the importance of the use of BYOD to increase average students' marks in the classroom will reduce the resistance to adoption.

The findings of this research show that students perceive that the use of clickers increases attention, participation, engagement, and active learning. The study confirms what the literature indicates: the use of BYOD as clickers increases engagement, promotes active participation in learning activities, and improves understanding. The result also shows that the system generates discussion and increases the attention span of students.

The barriers to the adoption of BYOD are the incompatibility of the technology with the preferences of students' devices and choices of browsers. Students choose to use specific devices and browsers for a variety of reasons, such as concern about security. Educators and system designers have to pay attention to reducing system incompatibility to increase the adoption and use of BYOD in the classroom. Further development of technology will reduce the number of incompatible devices and browsers. However, the TAM3 model should include the compatibility construct to explain the adoption of technology. The findings of this research have particular implications for educators and system designers for to put mitigating measures to reduce the nonadoption of BYOD for clicker use.

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

DATA AVAILABILITY STATEMENT

Data will be supplied on request.

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APPENDIX A

TABLE A1 Questions used to find demography and previous experience with the use of clickers.

Questions	Choice
1. Gender	Male, female, prefer not to say
2. Have you had previous experience of using clickers	A = Smartphone, B = laptop, c = tablet
3. I have used the following device(s) as a clicker	A = Smartphone, B = laptop, c = tablet

TABLE A2 Questions on Students' perception on the use of BYOD's.

Questions	Choice
1. The use of BYOD's in lectures help me to focus my attention	A. Positive influence B. Negative influence C. Did not influence D. Not sure
2. The use of BYOD's in lectures help me to increase my participation in the class	Ditto
3. The use of BYOD's in lectures help to increase my colleagues' participation	Ditto
4. The use of BYOD's in lectures help to increase my interest on the topic	Ditto
5. The use of BYOD's in lectures help to increase the facilitation of learning	Ditto
6. The use of BYOD's in lectures help to increase my examination marks	Ditto

Abbreviation: BYOD, bring your own devices.

TABLE A3 The questions are designed with five Likert scale, strongly agree, agree, neutral, disagree, and strongly disagree.

Observed items	Latent variables
1. Clickers influences on colleagues' participation	Subjective norm
2. Previous experience of using voting system	
3. Smartphone	Adoption
4. Clickers influences on building interest on the topic	Job relevance
5. Clickers influences on learning	
6. Clickers influences on attention	Output quality
7. Clickers influences on participation	
8. When using clickers lectures were dynamic	
9. When using clickers in lectures allow more active participation	
10. I prefer voting without clickers	Resistance to adoption
11. Using Clickers improve examination marks	Result demonstrability

TABLE A4 Open-ended questions.

1.	How do you describe the use of BYOD in your learning activities?
2.	How do you explain the use of BYOD on your participation, attention, and understanding of the subject?
3.	Please provide your reasons if you have not used BYOD in the classroom.

Abbreviation: BYOD, bring your own devices.

AUTHOR BIOGRAPHY

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