The Impact of Live Polling Quizzes on Student Engagement and Performance in Computer Science Lectures: A Post-COVID19 Study

Xingyu Zhao[a]
WMG, University of Warwick, Coventry, U.K.
Department of Computer Science, University of Liverpool, Liverpool, U.K.

Keywords: Active Learning, Live Polling Quiz, Formative Assessment, Classroom Interactivity, Post COVID19 Education, Real-Time Feedback, Survey Analysis in Education, Behavioural Shift in Learning.

Abstract: Before COVID19, live polling and real-time feedback tools gained popularity in higher education for enhancing student engagement, boosting attention, participation, and understanding of course materials. However, recent changes in learning behaviours due to the pandemic necessitate a reevaluation of these active learning technologies. In this context, our study focuses on the Computer Science (CS) domain, investigating the impact of Live Polling Quizzes (LPQs) in undergraduate CS lectures. These quizzes comprise fact-based, formally defined questions with clear answers, aiming to enhance engagement, learning outcomes, and overall perceptions of the course module. A survey was conducted among 70 undergraduate CS students, attending CS modules with and without LPQs. The results revealed that, while LPQs contribute to lecture attendance, additional factors likely play a larger role in attendance rates. Students generally find LPQs beneficial for understanding content, maintaining attention, and fostering motivation, but also viewing them as essential for re-establishing peer and instructor connections post-pandemic. Students prefer a balanced LPQ frequency and clear, accessible instructions, reflecting a reliance on digital tools and self-paced engagement habits developed during remote learning.

1 INTRODUCTION

Before the COVID19, live polling and real-time feedback tools were popular in higher education classrooms as a way to boost student engagement and performance in learning (Lim, 2017; Serrano et al., 2019; Voelkel and Bennett, 2014; Lantz and Stawiski, 2014; DeSouza and Fleming, 2003; Salas-Morera et al., 2012; Hennig et al., 2019). However, state-of-the-art research works on the impact of using live polling systems in in-person lectures were mostly performed based on data collected *before* the COVID19. Arguably, students' learning behaviours may have changed after the pandemic, following nearly 3 years without in-person teaching (Rapanta et al., 2021). The shift to remote learning during COVID19 may have already altered student engagement and expectations (Cicha et al., 2021). For instance, changes and new trends regarding the learning environment are identified in (Al Ansi and Al-Ansi, 2020), the new engagement behaviours in hybrid-classrooms is discussed in (Hjersman et al., 2022), and technology used in blended learning will likely play a critical role (Imran et al., 2023). In this regard, there is a need to re-examine student perceptions of active learning technologies, like live polling and real-time feedback tools, in light of these changes (Phelps and Moro, 2022; Reimers, 2021), which motivates this work.

Focusing on the Computer Science (CS) domain, we have undertaken a survey-based investigation to reevaluate the effects of integrating Live Polling Quizzes (LPQs) into undergraduate (UG) CS lectures, where the questions are all based on factual information and are formally defined, having clear answers, as opposed to open-ended or opinion-based questions that lack definitive answers. Our study revolves around several research questions that delve into aspects such as student engagement, learning outcomes, ideal frequency and usability, as well as potential correlations with overall perceptions of the course module. More specifically, a survey of 14 questions (12 multiple choices with Likert scale answers and 2 fill-in-the-blank questions) was distributed to 70 UG students who have been attending UG CS modules

[a] https://orcid.org/0000-0002-3474-349X

Zhao, X.
The Impact of Live Polling Quizzes on Student Engagement and Performance in Computer Science Lectures: A Post-COVID19 Study.
DOI: 10.5220/0013218700003932
In *Proceedings of the 17th International Conference on Computer Supported Education (CSEDU 2025) - Volume 1*, pages 291-298
ISBN: 978-989-758-746-7; ISSN: 2184-5026

with and without using LPQs. 30 responses (in which 28 are valid) were collected and analysed both quantitatively and qualitatively. Finally, the threats to validity are discussed.

The new data shows some insights as follows:

i) Although LPQs may have contributed to higher attendance, they alone do not completely account for the higher lecture attendance rates. Other factors may have contributed more than LPQs.

ii) LPQs were broadly viewed as beneficial for comprehending lecture content, effective at keeping students' attention, motivation and participation.

iii) Post-pandemic, students view LPQs as critical for rebuilding social connections with peers and instructors, filling a gap left by remote learning. LPQs help students readjust to live, in-person engagement and sustained focus, challenging the passive habits developed during remote, self-paced learning.

iv) Students after COVID19 prioritize clear, accessible instructions and intuitive technology interfaces, reflecting their reliance on digital tools during remote learning.

v) Students prefer a balanced LPQ frequency, finding overly frequent quizzes disruptive rather than engaging—likely influenced by their autonomy in remote learning during the pandemic.

2 METHOD

Aim. The aim of this study is to assess student perceptions and self-reported behaviours related to the use of LPQs during CS lectures. Specifically, the study seeks to understand if the inclusion of LPQs increases student motivation, engagement, and sense of understanding and connection in the classroom. Additionally, we aim to examine if attendance and participation in lectures with LPQs is associated with students reporting more positive benefits compared to traditional lectures without these interactive features.

Context. The University of Liverpool (for double-blind review) is a public research university located in Liverpool, UK. It is a member of the Russell Group of leading research-intensive universities in the UK. Students in their third year of an UG CS programme at the University of Liverpool are typically working towards a Bachelor of Science (BSc) degree in CS. The programme provides students with core computer science knowledge and skills such as programming, algorithms, data structures, databases, operating systems, and more. In their third year, students take advanced courses like formal methods, machine learning, and often work on a final year project where they apply what they've learned to develop a computing system or conduct research. The programme prepares students for careers in software engineering, data science, and other technology fields upon graduation.

Design. A survey with 14 questions (12 multiple-choice questions and 2 fill-in-the-blank questions), about 10 minutes in length, was designed to be completed online in the CANVAS web-based teaching management system. It was distributed, via links in emails and notifications from CANVAS, to the 70 CS UG students. The student may answer those questions anonymously and without any time limit in a three months time window after the mid-term.

Sample. The survey was distributed to a cohort of 70 final year CS UG students in my own module, in which there are 3 lectures per week for 12 weeks. The general teaching practice around LPQs is shown in Figure 1. Before each lecture, pre-recorded videos and slides with the quizzes (without answers) were sent to the students for pre-study. During the lectures, 2-3 LPQs were conducted every 15-20 minutes followed by live explanations and discussions of the answers. After the mid term when the students have sufficient experience of learning with my teaching practice with LPQs, the survey was distributed. Out of the 70 invited surveys, 30 responses were collected but with 2 invalid ones without any answers. That said, the later analysis is based on a sample of 28 valid responses, which was deemed statistically adequate.

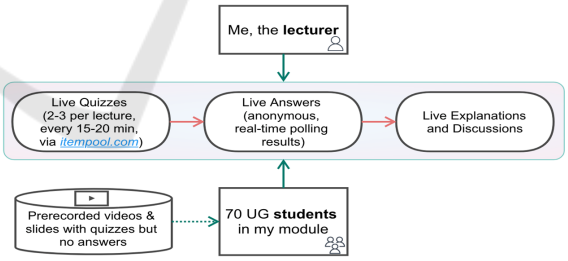

Figure 1: The teaching practice using LPQs in the CS module where students were surveyed.

Overview of Analysis Approaches. For the 12 multiple-choice questions, we perform the following quantitative analysis:

- Summarise and presenting the answer distribution of each question, showing the central tendency and spread of responses.
- Investigate correlations between questions using a correlation matrix of Pearson correlation coefficient, and understand which questions have strong positive or negative correlations.

For the 2 fill-in-the-blank questions, not all respondents provide informative answers. Thus, a simple qualitative analysis are conducted and reported in the next section.

3 RESULTS AND DISCUSSIONS

All survey data and quantitative analysis code are publicly available at our project repository[1].

3.1 Data with Basic Statistics

For the 12 multiple-choice questions, the Q1-Q4 are about general feedback regarding the module, while the last 8 questions (Q5-Q12) are more specifically designed to assess perspectives on LPQs. This division of question types may later reveal correlations between students' overall perceptions of the module and their specific reflections on the use of LPQs.

Q1: I Am Confident I Can Succeed in this Module. The majority of respondents (about 71.4%) expressed agreement or strong agreement with this statement, cf. Figure 2. This suggests most students feel confident in their ability to succeed in the module. However, about 28.6% were neutral or expressed disagreement. This indicates a substantial minority may have lower self-efficacy. This distribution suggests that while most students are confident, we should be aware that some may need more support in developing self-efficacy. Targeted interventions could identify and assist students with lower confidence levels. More importantly, regarding LPQs, we will later exam if the level of confidence correlated with how student perceive the use of LPQs.

Q2: I Feel Connected with Other Students and Teaching Staff on this Module. Responses were more positive on this question compared to Q1. Around 85.7% agreed or strongly agreed they felt connected. A small portion (10.8%) were neutral on their feelings of connection. This suggests they did not perceive a strong sense of connection, but did not actively feel disconnected either. Only 1 respondent disagreed to some extent, signalling they felt disconnected from peers and the lecturer. Again, it would be very useful to later exam if the feeling of connected correlated with how student perceive the use of LPQs.

[1]https://github.com/x-y-zhao/LPQ_survey_study

Q3: I Believe I Am Contributing to and Engaging Effectively with the Module (e.g., Participating in Discussions and Other Learning Activities). As shown in Figure 2, a majority of respondents, 75%, agreed or strongly agreed that they were actively contributing and engaging with the module. The remaining 25% were neutral, neither agreeing nor disagreeing about their participation. So in fact, most students responding to the survey did perceive that they were actively involved and participating in the module learning activities. This might hint the positive outcome of using LPQs, which needs more investigation later.

Q4: at this Stage in the Module I Understand How My Learning Will Be Assessed on this Module. Almost every respondent (27 out of 28) agreed or strongly agreed that they understand how their learning will be assessed in the module. Only 1 respondent was neutral, neither agreeing nor disagreeing with the statement. This indicates that, despite the extensive use of LPQs in lectures, it did not confuse students about how the module would be assessed at the end of the term. As long as clear statements about assessment are provided in the module specification and reiterated verbally during lectures, the inclusion of LPQs throughout the course does not appear to obscure the end-of-term evaluation methods.

Q5: How Often Did You Attend this Module with LPQs? And How Often Did You Attend Other Modules Without LPQs? As shown in Figure 2, the majority (64.3%) are neutral in terms of if the use pf LPQs helps the attendance. A substantial proportion (32.1%) suggests the LPQs may have increased motivation and engagement, leading to higher lecture attendance rates. That said, 1 respondent attended other lectures more frequently without LPQs. So, while LPQs may have encouraged attendance, they do not fully explain the variation in lecture attendance rates. Other factors are likely also at play.

Q6: Did the LPQs Help You Better Understand the Lecture Material? The vast majority of respondents (approximately 93%) answered "Yes" that the LPQs helped them better understand the lecture material. Only a very small number answered "Not sure", indicating they were uncertain about the impact. The overwhelmingly positive response suggests the LPQs were broadly viewed as beneficial for comprehending the lecture content. This aligns with the intent of using active learning techniques like polling (Arthurs and Kreager, 2017) to check understanding and clarify knowledge gaps during lectures.

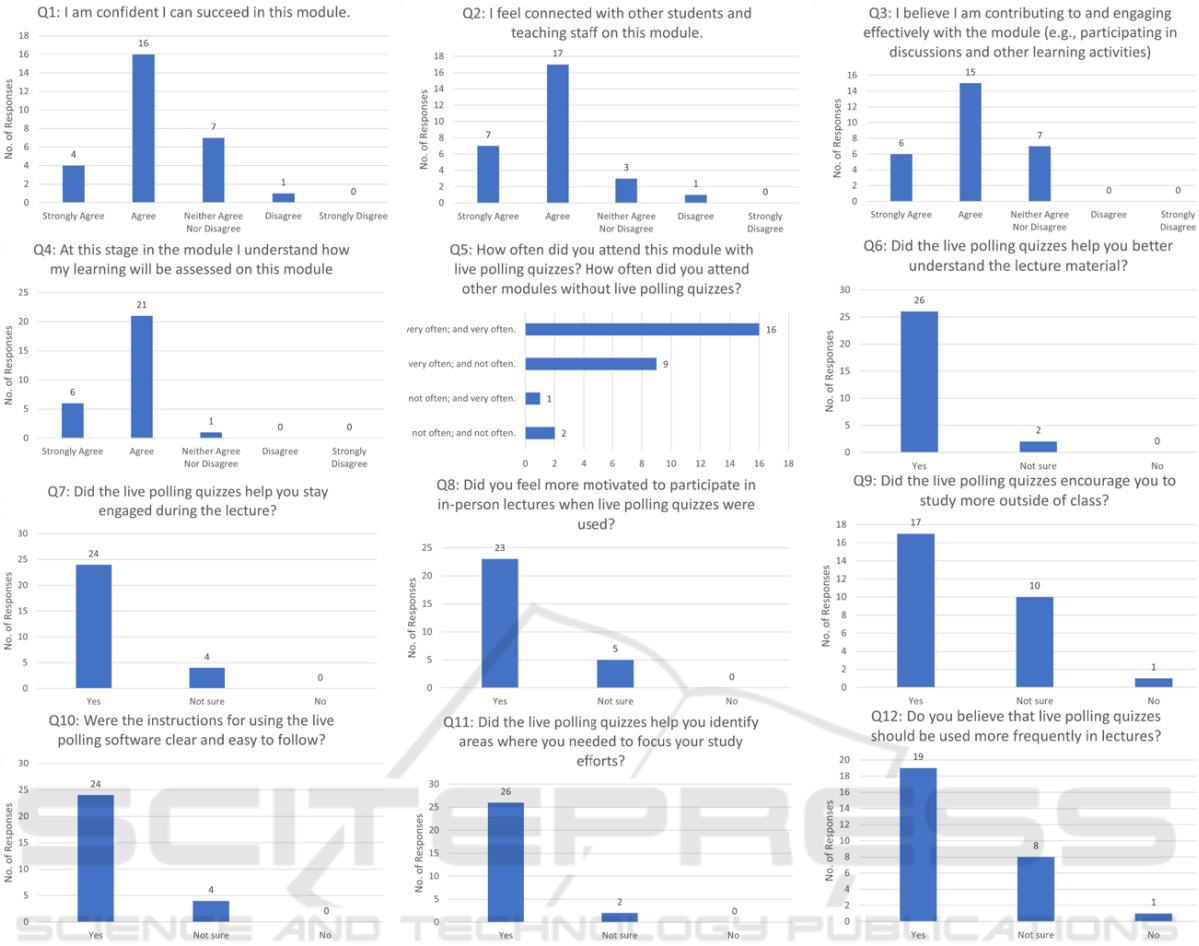

Figure 2: Survey results of Q1-Q12.

Q7: Did the LPQs Help You Stay Engaged During the Lecture? The majority of respondents (around 85.7%) answered "Yes" that the LPQs helped them stay engaged during lectures. However, the rest were uncertain. Overall, the responses indicate LPQs were broadly effective at keeping most students' attention and participation during lectures.

Q8: Did You Feel More Motivated to Participate in in-person Lectures when LPQs Were Used? Similarly to Q7, the use of LPQs motivated participation for most students, a few were uncertain on their motivation levels, as shown in Figure 2.

Q9: Did the LPQs Encourage You to Study More Outside of Class? Compared to the very positive feedbacks in Q7 and Q8, there is a clear drop in the number of responses with a positive "Yes", cf. Figure 2. Responses to this question were relatively mixed—60% answered "Yes", indicating the quizzes encouraged them to study more outside of class, while 40% were uncertain or feel LPQs did not affect their study habits outside classes which indicates LPQs have limited positive impact on study habits outside classes.

Q10: Were the Instructions for Using the Live Polling Software Clear and Easy to Follow? Analysing the responses, the majority (∼86%) answered "Yes" that the instructions for using the polling software were clear and easy to follow. However, ∼24% were "Not sure". This suggests that while the instructions seem adequately clear overall, there is room for improvement to make them more universally understandable. Moreover, we exam how this correlates answers to other questions to understand the importance of a clear instruction of using the software.

Q11: Did the LPQs Help You Identify Areas Where You Needed to Focus Your Study Efforts? As presented in Figure 2, we got very positive outcome of this question—93% respondents feel LPQs helped identify areas needing further study, while

only 7% are uncertain. We may confidently conclude that the majority of students found LPQs useful for highlighting areas to concentrate their studying on.

Q12: Do You Believe that LPQs Should Be Used More Frequently in Lectures? The responses were relatively mixed compared to previous questions, despite those positive aspects of using LPQs. Approximately 68% of students answered "Yes" that LPQs should be used more frequently. Around 29% were "Not sure" if increased usage was beneficial, and 1 answered "No". This suggests that increased LPQs frequency may benefit some students but risks overuse for others if not managed carefully.

3.2 Correlation Analysis

To perform quantitative correlation analysis between the 12 multi-choice questions, we first encode the answers into numerical values:

- Strongly Agree =1; Agree=0.5; Neither Agree nor Disagree = 0; Disagree = -0.5; Strongly Disagree = -1
- Very often and very often = 0; No often and not often = 0; Very often and not often = 1; Not often and very often = -1;
- Yes = 1; Not Sure = 0; No = -1

Intuitively, we encode answers in favour of using LPQs as positive numbers, neutral answers as 0, and otherwise negative numbers.

Figure 3 shows the correlation matrix, in which each correlation coefficient ranges from -1 to +1. A positive value indicates a positive correlation, a negative value indicates a negative correlation, and a value close to 0 indicates little to no linear correlation (Carlson and Herdman, 2012). Although there are several correlation coefficients we can use, we present the most common Pearson correlation coefficient (Cohen et al., 2009) in the matrix.

We first highlight those positively correlated questions/answers with sufficiently high degree (> 0.3). As expected, the answers of the first 4 questions (Q1–Q4) regarding general feedbacks of the module are all strongly correlated, indicating the validity of the responses collected. The answers to Q1 and Q6, as well as Q2 and Q6, show a positive correlation. This correlation implies that the extent to which students use LPQs to understand learning material is positively associated with both their confidence in being successful and their sense of connection with others in the lectures. In other words, the more students effectively utilise LPQs, the more likely they are to feel confident

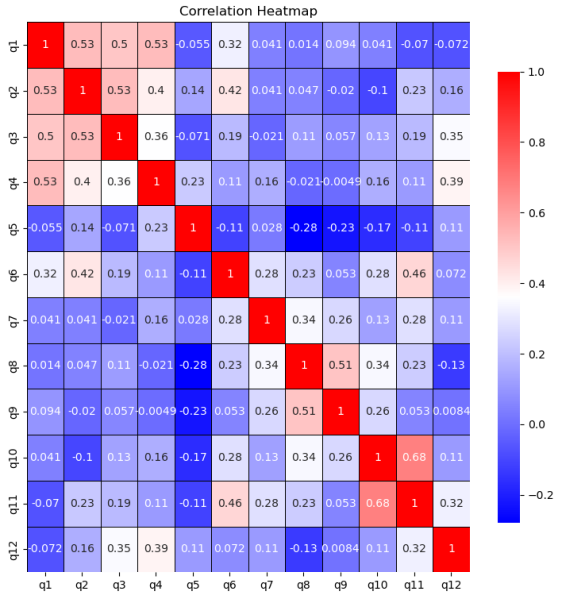

Figure 3: The correlation matrix of the 12 multi-choice questions, showing the Pearson correlation coefficients.

about succeeding and connected with their peers during lectures. Q7 and Q8 show a positive correlation, indicating that if LPQs help a student stay engaged during lectures, then they are also more likely to motivate that student to attend lectures in person. The positive correlations between Q8 and Q9, as well as between Q8 and Q10, indicate that feeling motivated by LPQs to attend lectures is positively associated with both being encouraged to study more outside of class and quickly adapting to using learning software. The positive correlation between Q11 and Q6 says when LPQs help the student better understand the learning material, it also identify the area where the student need to focus. Very significantly, Q11 and Q10 are positively correlated, showing the clear instruction on using software positively correlates LPQs help in identifying areas to focus. Q12 shows positive correlations with Q3, Q4, and Q11 respectively. This says that students who are in favour of using LPQs more frequently also tend to report higher engagement in the module, better understanding of how the module will be assessed, and that LPQs helped them identify areas to focus on. In other words, students who want more regular use of LPQs believe they lead to greater engagement, clarity on assessments, and ability to pinpoint knowledge gaps.

While generally all negative correlations among those 12 questions/answers are not very significant, we highlight two pairs that have correlations smaller than -0.2—Q5 and Q8, and Q5 and Q9. This indicates: i) Students who attend lectures with LPQs relatively more often than lecturers without LPQs do not

necessarily feel more motivated because of the use of LPQs. ii) Students who attend lectures with LPQs relatively more often than lecturers without LPQs do not feel LPQs encourage them to study more outside of class. While a rigorous study with more data is needed to draw accurate conclusions, for now, we can interpret them as: i) LPQs might have encouraged attendance, but there are likely other relevant factors that contribute more than LPQs in this regard. ii) Students who attend in-person lectures with LPQs more often may rely too much on them, which diminishes their motivation to study outside of class.

3.3 Qualitative Analysis

To prevent respondent fatigue and ensure data quality, limited number of fill-in-the-bank questions should be used in the survey (Galesic and Bosnjak, 2009). That said, we included the following two open questions.

Q13: What One Thing Can We Do to Better to Improve Your Experience on this Module? This is a question regarding how the students perceive the module. In-total 9 answers were given out of 28 valid respondents, covering the points of asking for more exercises/tutorials, and more interesting examples.

Q14: What Suggestions Do You Have for Improving the Use of LPQs in Lectures? This question targeted LPQs, with 10 answers from 28 valid respondents. Notably, all 9 respondents who answered Q13 also answered Q14. Key points include the need for more accessible web-based LPQs and an increased number of LPQs per lecture.

Qualitative results suggest that LPQs can influence student behaviour and engagement. Making web-based LPQs more accessible with clear instructions, as highlighted by (Kay and LeSage, 2009), and increasing their frequency during lectures could enhance engagement and learning for some students.

4 DISCUSSION ON USING LPQs PRE- AND POST-COVID19

Pre-COVID Use of LPQs. Before the COVID19 pandemic, LPQs were increasingly popular as an active learning strategy in higher education settings. Research has shown that integrating live polling activities, where students respond to questions posed by the lecturers using digital devices, can increase student attention, participation, and understanding of the course materials (Bode et al., 2009; Kay and LeSage, 2009; Miller et al., 2013). One of the pioneering studies in this area was conducted by (Draper and Brown, 2004) in 2004. They examined the use of personal response systems (clickers) in large university lectures across multiple disciplines. Their findings showed that these systems could increase student engagement and provide valuable feedback to instructors. A 2009 review paper by (Kay and LeSage, 2009) synthesized research on classroom response systems up to that point. They found that these systems generally had positive effects on classroom environment, learning, and assessment, while a detailed list of benefits and challenges are also summarised. (Beatty et al., 2006) explored different pedagogical approaches for integrating classroom response systems effectively. They emphasized the importance of question design and follow-up discussions to maximize learning benefits. The immediate feedback provided through live polling also allows lecturers to gauge student understanding in real-time and adjust their teaching timely (Voelkel and Bennett, 2014). In (Lantz and Stawiski, 2014), the study tested clickers' effectiveness in a controlled lab setting and found that clicker questions with immediate feedback significantly improved scores two days later compared to no-clicker controls. Additionally, the immediate feedback helped participants not only retain information but also correct lecture misconceptions. The work (Stowell, 2015) compares traditional clickers to mobile-based LPQs and investigates their impact on student engagement. It shows that Mobile device polling benefits include displaying questions and class response distributions directly on students' screens, lower costs, and suitability for open-ended responses. Unlike clickers, some mobile services also allow "hotspot" questions requiring image-based responses. However, mobile polling may lead to digital distractions, internet connectivity issues, and potential costs for students. (Sheng et al., 2019) finds students are dissatisfied when questions posed do not stimulate impactful discussions. Caveats are discussed by (Florenthal, 2019) on the "downside" of anonymity where some students may find it allows them to disengage and perhaps disrupt learning. The recent paper (Wood and Shirazi, 2020) identifies of the main factors affecting student experience of learning when using audience response systems in general.

New Perspectives in Post-COVID. While LPQs continue to help maintain student attention and comprehension (e.g., Q12 positively correlates Q3, Q4 and Q11), they now play a more critical role in rebuilding sense of connections disrupted by extended periods of remote learning. That is, post-pandemic students seem to value LPQs not only as learning

tools but also as more essential to re-establishing social connection with peers and teachers (e.g., correlation analysis around Q2), which were impacted by the shift to remote and hybrid learning environments. With remote learning environments offering more flexibility, many students grew accustomed to passive engagement modes and self-paced study, which can make returning to active in-person participation more challenging. LPQs thus serve as an essential tool not only for engaging students but also for re-acclimating them to real-time interaction and sustained concentration in a physical classroom (e.g., correlations between Q7 and Q8).

Additionally, students now place greater emphasis on clear instructions and accessibility in digital tools, reflecting a heightened dependency on technology for learning during the pandemic (e.g., the correlation analysis of Q10 and Q11). Furthermore, our study suggests that students are more sensitive to the frequency and usability of LPQs, preferring an optimal balance that avoids overuse (analysis around Q12). While LPQs previously functioned as intermittent checkpoints for engagement, the study indicates that students now feel overwhelmed when quizzes are overly frequent, potentially viewing them as interruptions rather than engagement aids. This finding implies that students' tolerance for LPQ frequency has been influenced by the remote learning environment, where they had more control over when and how they interacted with course material.

5 THREATS TO VALIDITY

Construct Validity. It refers to the extent to which a survey instrument measures the theoretical construct or concept it claims to be measuring. In this study, the use of self-reported survey data is subjective and prone to self-reporting bias that may pose a threat. Students may have responded more positively due to wanting to please the lecturer who is also the researcher. To mitigate these two threats, we assure respondents that their responses will be kept confidential and anonymous. This can reduce the fear of social judgement and encourage more objective and accurate reporting. Students who had more positive views on LPQs may have been more inclined to take the survey, while others with negative views may be underrepresented. To mitigate this response bias, we have sent reminder messages to non-respondents to encourage their participation during the 3-months survey period, and tried to clearly communicate the purpose of the survey and its importance to all students regardless of their views.

Internal Validity. Threats may correspond to bias in establishing cause-effect relationships in our survey. When interpreting the results of our correlation analysis, we are fully aware that "correlation does not imply causation" is a fundamental principle in research and statistics. Confounding variables, i.e., factors other than the use of LPQs (e.g., physical learning environment and teaching material quality) may have influenced outcomes like attendance and engagement. To mitigate such threat, we plan to do Randomised Controlled Trials in the future by carefully considering and addressing confounding variables in the design and analysis. In this preliminary study with limited data, we only draw correlation conclusion.

External Validity. Factors limiting generalisability threaten external validity. The selection bias (e.g., only a group of UG CS student from one University was study) and small sample size are two threats in this regard. In addition, only one polling software (itempool.com) was studied that also poses a threat. To mitigate them, more sample needs to be collect with diversified data representing more students and software tools. In this preliminary study, we have explicitly discussed the limitations related to our sample's representatives.

6 CONCLUSION

After nearly 3 years of remote education, student behaviours and preferences may have shifted, necessitating a re-evaluation of LPQs in the context of COVID-19. This study surveyed CS UG students who attended lectures with and without LPQs, focusing on engagement, learning outcomes, polling frequency, and its correlation with course perceptions. The quiz questions were factual and objectively answerable.

Preliminary findings show that while live polling improved attendance and comprehension for most students, it was not the sole factor. Overuse risks diminishing motivation, and clear software instructions are critical. Although students found polls broadly beneficial, the pandemic's impact underscores the need for renewed investigation.

This study fills a literature gap by examining active learning technologies in the post-COVID-19 context, offering insights into the evolving role of LPQs in CS education. Future work includes ongoing monitoring, mitigating validity threats, and applying advanced analyses, such as clustering and factor analysis, as more data becomes available.

REFERENCES

Al Ansi, A. M. and Al-Ansi, A. (2020). Future of education post covid-19 pandemic: reviewing changes in learning environments and latest trends. *Solid State Technology*, 63(6):201584–201600.

Arthurs, L. A. and Kreager, B. Z. (2017). An integrative review of in-class activities that enable active learning in college science classroom settings. *International Journal of Science Education*, 39(15):2073–2091.

Beatty, I. D., Gerace, W. J., Leonard, W. J., and Dufresne, R. J. (2006). Designing effective questions for classroom response system teaching. *American journal of physics*, 74(1):31–39.

Bode, M., Drane, D., Kolikant, Y. B.-D., and Schuller, M. (2009). A clicker approach to teaching calculus. *Notices of the AMS*, 56(2):253–256.

Carlson, K. D. and Herdman, A. O. (2012). Understanding the impact of convergent validity on research results. *Organizational Research Methods*, 15(1):17–32.

Cicha, K., Rizun, M., Rutecka, P., and Strzelecki, A. (2021). Covid-19 and higher education: First-year students' expectations toward distance learning. *Sustainability*, 13(4):1889.

Cohen, I., Huang, Y., Chen, J., Benesty, J., Benesty, J., Chen, J., Huang, Y., and Cohen, I. (2009). Pearson correlation coefficient. *Noise reduction in speech processing*, pages 1–4.

DeSouza, E. and Fleming, M. (2003). A comparison of in-class and online quizzes on student exam performance. *Journal of Computing in Higher Education*, 14:121–134.

Draper, S. W. and Brown, M. I. (2004). Increasing interactivity in lectures using an electronic voting system. *Journal of computer assisted learning*, 20(2):81–94.

Florenthal, B. (2019). Students' motivation to participate via mobile technology in the classroom: A uses and gratifications approach. *Journal of Marketing Education*, 41(3):234–253.

Galesic, M. and Bosnjak, M. (2009). Effects of questionnaire length on participation and indicators of response quality in a web survey. *Public opinion quarterly*, 73(2):349–360.

Hennig, S., Staatz, C. E., Bond, J. A., Leung, D., and Singleton, J. (2019). Quizzing for success: Evaluation of the impact of feedback quizzes on the experiences and academic performance of undergraduate students in two clinical pharmacokinetics courses. *Currents in Pharmacy Teaching and Learning*, 11(7):742–749.

Hjersman, J., Mon, K., Nysak, S., Peng, R., and Freiwirth, R. (2022). Work-in-progress—post-covid: Adapting education to a changing educational environment through immersive technology. In *2022 8th International Conference of the Immersive Learning Research Network (iLRN)*, pages 1–3.

Imran, R., Fatima, A., Elbayoumi Salem, I., and Allil, K. (2023). Teaching and learning delivery modes in higher education: Looking back to move forward post-covid-19 era. *The International Journal of Management Education*, 21(2):100805.

Kay, R. H. and LeSage, A. (2009). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education*, 53(3):819–827.

Lantz, M. E. and Stawiski, A. (2014). Effectiveness of clickers: Effect of feedback and the timing of questions on learning. *Computers in Human Behavior*, 31:280–286.

Lim, W. N. (2017). Improving student engagement in higher education through mobile-based interactive teaching model using socrative. In *2017 IEEE Global Engineering Education Conference (EDUCON)*, pages 404–412. IEEE.

Miller, J., Risser, M., and Griffiths, R. (2013). Student choice, instructor flexibility: Moving beyond the blended instructional model. *Issues and trends in educational technology*, 1(1):8–24.

Phelps, C. and Moro, C. (2022). Using live interactive polling to enable hands-on learning for both face-to-face and online students within hybrid-delivered courses. *Journal of University Teaching and Learning Practice*, 19(3):8.

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., and Koole, M. (2021). Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education. *Postdigital Science and Education*, 3(3):715–742.

Reimers, F. M. (2021). In search of a twenty-first century education renaissance after a global pandemic. *Implementing deeper learning and 21st century education reforms: building an education renaissance after a global pandemic*, pages 1–37.

Salas-Morera, L., Arauzo-Azofra, A., and García-Hernández, L. (2012). Analysis of online quizzes as a teaching and assessment tool. *JOTSE: Journal of technology and science education*, 2(1):39–45.

Serrano, D. R., Dea-Ayuela, M. A., Gonzalez-Burgos, E., Serrano-Gil, A., and Lalatsa, A. (2019). Technology-enhanced learning in higher education: How to enhance student engagement through blended learning. *European Journal of Education*, 54(2):273–286.

Sheng, R., Goldie, C. L., Pulling, C., and Luctkar-Flude, M. (2019). Evaluating student perceptions of a multiplatform classroom response system in undergraduate nursing. *Nurse Education Today*, 78:25–31.

Stowell, J. R. (2015). Use of clickers vs. mobile devices for classroom polling. *Comp. & Education*, 82:329–334.

Voelkel, S. and Bennett, D. (2014). New uses for a familiar technology: introducing mobile phone polling in large classes. *Innovations in Education and Teaching International*, 51(1):46–58.

Wood, R. and Shirazi, S. (2020). A systematic review of audience response systems for teaching and learning in higher education: The student experience. *Computers & Education*, 153:103896.