RESEARCH ARTICLE

Student Perceptions of TabletPC Use in Mathematics Teaching, and Student Preferences of Different Delivery Modes

Alena Haddley, Department of Mathematical Sciences, University of Liverpool, Liverpool, UK.
Email: a.haddley@liverpool.ac.uk
Joel A. Haddley, Department of Mathematical Sciences, University of Liverpool, Liverpool, UK.
Email: j.a.haddley@liverpool.ac.uk

Abstract

Traditional mathematics education using a blackboard has, in recent decades, been complemented or replaced by emerging technologies. The pandemic was a notable catalyst for adoption of technology, as educators had no choice but to engage with technology so that learning and teaching could continue remotely. The present research was conducted at a large UK university which invested in TabletPCs to facilitate this remote education. The research verified that the benefits of TabletPCs described in the literature were indeed being achieved locally. The research further explored student perceptions and preferences of different lecture delivery modes, including TabletPCs and boards. The research was conducted before and after remote delivery to explore whether student opinions differed following this period of greater exposure to technology-driven education. The main result of the research is a student preference for multi-modal lecture delivery, which was slightly stronger in the post-pandemic survey. A further recommendation is for educators to consider the value of different tools and their individual advantages when planning teaching activities, rather than being led by a strong discipline culture.

Keywords: Mathematics Education, Lecture Delivery, TabletPC, Education Technology.

1. Introduction

The first modern blackboard was invented in 1801. Blackboard use proliferated following the 1870 Education Acts, which introduced free and compulsory education in England and Wales. The blackboard offered a solution to teaching at the larger scale that was now required. Manuals were soon produced that detailed the techniques – and etiquette – of effective teaching (Day, 1967; Wylie, 2012). Early articles describe how blackboards may have had an imposing presence in classrooms (Hester, 1902), and others advised on decorating the blackboard with images of seasonal flowers (Emerson, 1896). Blackboards are rarer in the present day, yet are still popular in higher education mathematics teaching as a suitable medium for the abstract reasoning of mathematics (Greiffenhagen, 2014). Indeed, studies have shown that some students prefer traditional 'chalk and talk' to static slides (Rudow and Finck, 2015). However, the TabletPC (a touchscreen laptop that accepts handwritten input) can recreate some of the advantages of a blackboard, due to live handwriting using a digital pen; and has further advantages of its own (Fister and McCarthy, 2008). A strong discipline culture is proposed as a reason for persistent belief that blackboards are the most suitable medium for mathematics teaching, and a reduction in use is partly due to necessity (e.g. available facilities or class sizes), and partly due to acceptance and adoption of new technologies (Billman et al., 2018). These factors have led to mathematics students experiencing a variety of delivery modes during their higher education studies. The authors ran a survey to explore students' relative preferences of delivery modes during the academic year 2021-22, asking participants to consider experiences both prior to the fully remote delivery necessitated by the pandemic, and modes of delivery within the fully remote context. The fully remote year required educators to rapidly

adopt and develop their confidence with digital education tools (Myyry et al., 2022), and students demonstrated increased expectation for digital delivery, or digital-supported delivery, following the fully remote year (Suleri, 2020). The authors repeated the survey post-pandemic, during the academic year 2022-23, focusing this time only on in-person delivery modes. This paper explores the comparative preferences of students pre-pandemic and post-pandemic; giving contemporary insight into preferences for delivery modes and exploring if this changed during the fully remote year.

2. Literature Review and Context

In this paper, we will focus on the development of Tablet PCs within education. Although educationally-focused Tablet PCs have been around since the late 1980s (Wiggins and Eglowstein, 2017), the technology advanced for mainstream educational use in the early part of the 21st century (Ellis-Behnke et al., 2003). In an early paper describing their use in mathematics education, Gorgievski et al (2005) surveyed the perceptions of calculus students of this emerging technology. Numerous benefits of TabletPCs have since been reported.

- Handwritten notes can be produced in real-time during teaching. The notes can be shared with students (Fister and McCarthy, 2008). A video capture of the teaching session can be shared with students (Galligan et al., 2012). This approach is very compatible with 'gapped notes' (Sambrook and Rowley, 2010).

- The Tablet PC is a full PC system, making it straightforward to switch between applications. For example, software demonstration, video playback, website navigation, text highlighting (and so on) can all be achieved on the same device and will all be captured in the video recording of the lecture.

- In-person teaching can be improved through eye contact. As the Tablet PC can be connected to a projector from any angle, a lecturer can face students while teaching, rather than facing a board (Billman et al., 2018).

- Eliminating chalk dust enhances air quality in classrooms and removes any potential associated health risk (Lin et al., 2015; Majumdar and William, 2009). Eliminating the use of dry erase pens reduces the risk they will end up in landfills. It is difficult to find statistics for recycling rates of dry erase pens, but an estimated 19% of plastic in the UK ended up in landfills in 2020 (PlasticsEurope, 2022). It should be noted for balance that laptop production also has environmental impacts (Hoang et al., 2009).

- Remote interactions between educators and students can be improved using Tablet PCs as they provide a means for real-time whiteboard collaboration, mimicking in-person interactions (Kohorst and Cox, 2007).

Comparative studies have indeed demonstrated strong student satisfaction with the use of Tablet PCs for teaching (Maclaren et al., 2017).

The present research was conducted with participants studying on mathematics programmes in a large UK university. At this university, several mathematics lecturers were using Tablet PCs to lead or support teaching delivery prior to the pandemic. When it became apparent that teaching would continue under a national lockdown, the institution made a bulk purchase of Tablet PCs for all mathematics lecturers, aiming to enhance the quality and value of remote teaching. The delivery modes both pre-pandemic and post-pandemic were (and are) varied, and students have consistently been likely to experience a diversity in approaches across all modules. The authors identified the

following lecture delivery modes in the department. In all cases, 'handwritten' means live during the teaching session, and 'slides' means pre-prepared presentation files such as PDF or PowerPoint:

- Handwritten notes on a board.
- Slides displayed on a projector, with no handwritten notes or annotations.
- Slides displayed on a projector, with handwritten notes on a separate board.
- Handwritten notes using a Tablet PC, using a digital pen, displayed on a projector.
- Slides displayed on a projector using a Tablet PC, using a digital pen, with handwritten notes and slide annotations on the Tablet PC.

3. Methodology

The study was conducted by administering an anonymous online survey to student participants, which consisted of three sections:

1. Perceptions of TabletPC delivery. Participants responded against a five-point Likert scale to provide insight into perceptions around TabletPC delivery. This section was based on the questions of Gorgievski et al (2005), and was used to verify that the benefits of TabletPC delivery found in the literature were being achieved in the local context.
2. Ranking of delivery modes. Participants were asked to rank the five delivery modes stated above, with an aim to identify trends or broad preferences shared among students. The methodology and presentation of results was based on Maclaren et al (2017), but with delivery modes changed for our context.
3. Open ended question. This allowed participants to clarify views on TabletPC delivery and/or their ranking of delivery modes. Thematic analysis was performed on responses.

The survey was deployed twice: first during the year of remote teaching (Survey 1), and again when in-person teaching resumed (Survey 2). During remote teaching, all students had previously experienced TabletPC delivery, and so all students in the department were invited to participate in the survey, reflecting on their in-person experiences. When in-person teaching resumed, some students may not have taken modules that used TabletPC delivery. Instead of inviting all students in the department to act as participants, the invitation was narrowed to students registered on modules which used TabletPC delivery. Hence all participants in the survey had experienced TabletPC delivery.

4. Results

4.1. Perceptions of TabletPC Use

Survey 1 had n_1=21 responses (population ~1000) and Survey 2 had n_2=66 responses (population ~500). Comparative bar charts are shown for the questions in the first section of both surveys (Figures 1-4), about the effectiveness of TabletPCs. Detailed data can be found in the Appendix (Tables 1 and 2).

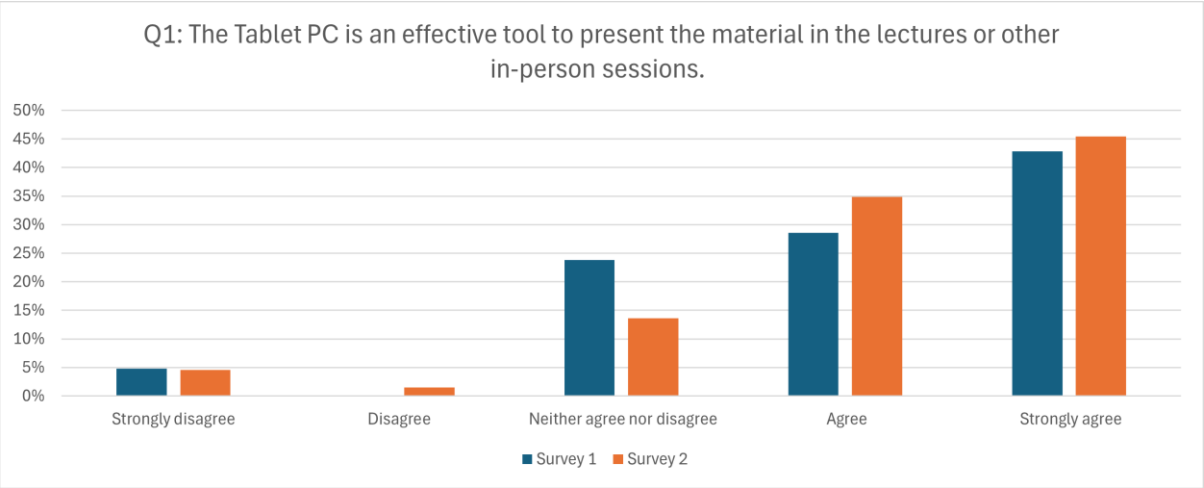

Figure 1: Breakdown of responses for Question 1 in Survey 1 and Survey 2

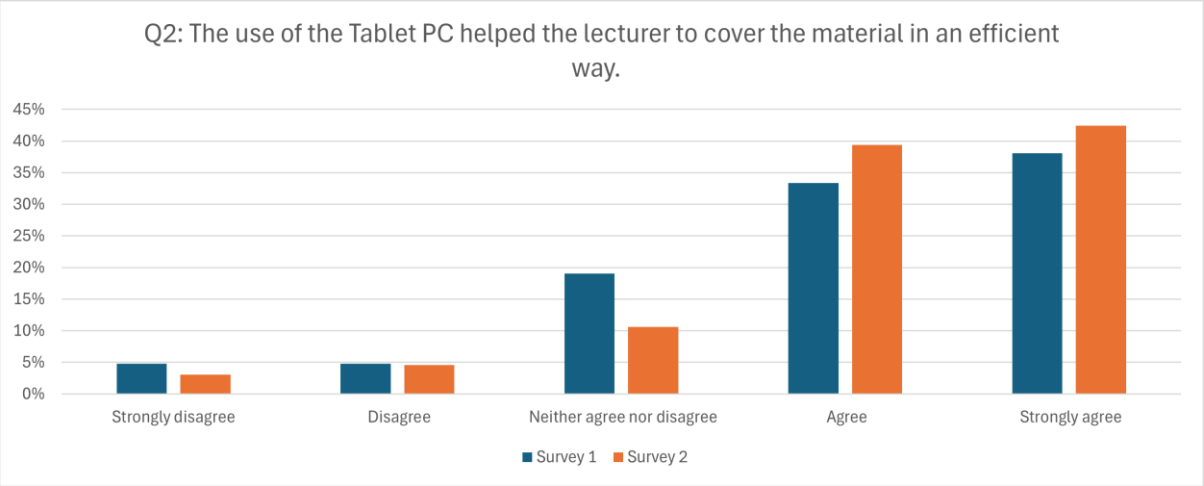

Figure 2: Breakdown of responses for Question 2 in Survey 1 and Survey 2

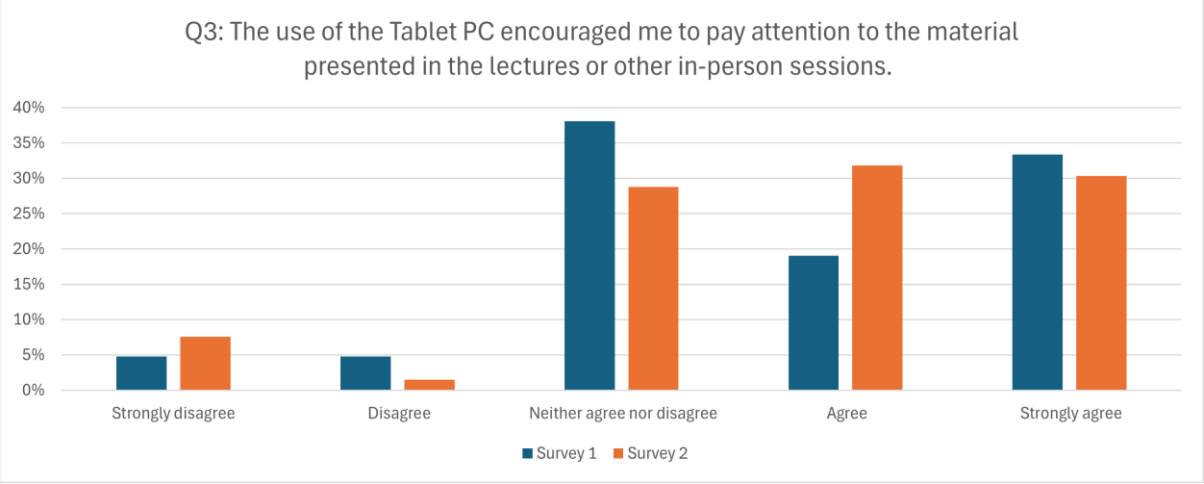

Figure 3: Breakdown of responses for Question 3 in Survey 1 and Survey 2

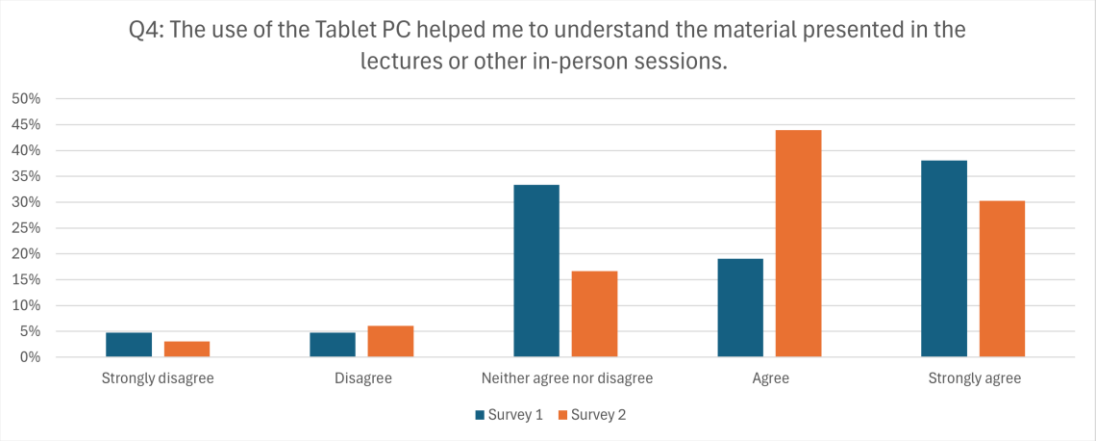

Figure 4: Breakdown of responses for Question 4 in Survey 1 and Survey 2

Each time the survey was deployed, a majority of participants responded with 'Agree' or 'Strongly Agree' for each question (although the majority for Q3 was narrow in Survey 1, due to a high neutral response). There was little change in the proportion of negative responses between the two surveys, and these responses were in the minority. Responses for Q1 and Q2 show a clear but slight positive trend. Q3 and Q4 in Survey 1 were bimodal, between 'Neutral' and 'Strongly Agree', but this polarisation was not seen in Survey 2: Q3 is more uniform at the positive end, and Q4 is unimodal with left skew towards positive.

4.2. Ranking Delivery Modes

Results are presented in diverging stacked percentile bar charts, with the vertical centre of neutral responses aligned (Figure 5). The order of the delivery modes on the questionnaire was presented as stated earlier, but the modes are ordered by preference in the chart: this turned out to be the same ordering for both deployments of the survey.

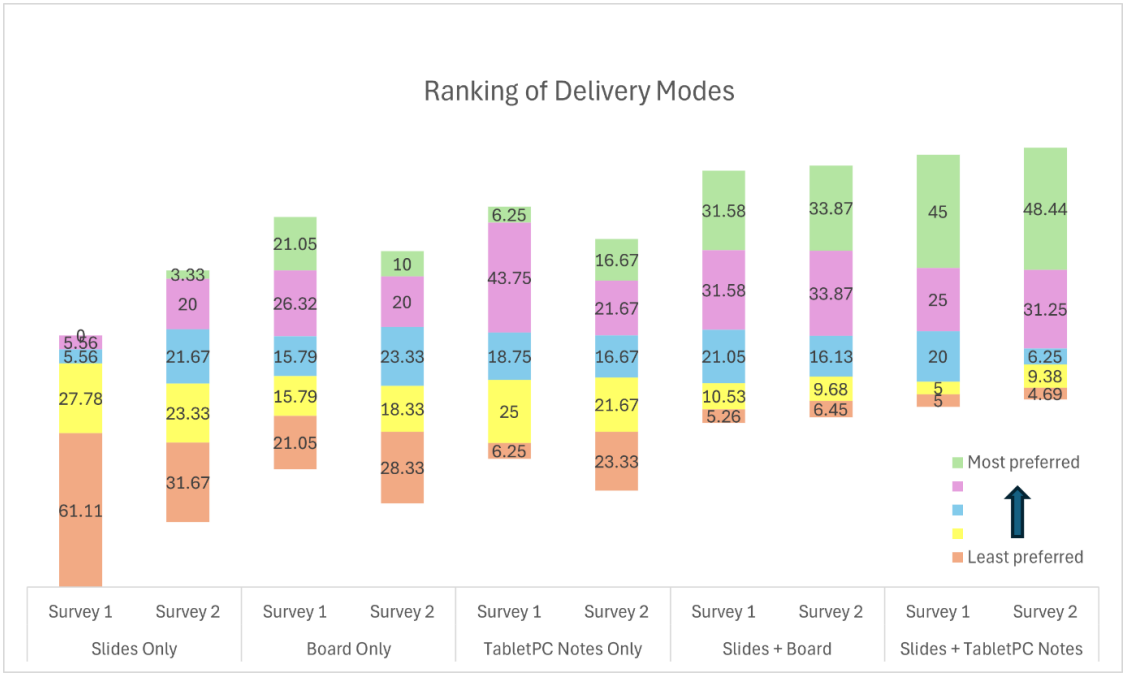

Figure 5: Diverging stacked percentile bar charts for ranking of delivery modes in Survey 1 and Survey 2

Survey 1 shows a notable negative perception of a slides-only approach relative to other delivery modes. It remained the most negatively perceived in Survey 2, but not as severely negative. The two 'notes-only approaches' were significantly less positively perceived in Survey 2 compared to Survey 1. The mixed modal approaches – slides and board, or slides and Tablet PC Notes – were consistently the most positively perceived delivery modes. Given these are relative perception scores (rankings), and the multi-modal approaches were almost constant between surveys, it appears the gap between 'slides only' and 'notes-only' approaches has narrowed; whereas the gap between 'unimodal' and 'mixed modal' approaches has widened.

4.3. Open Response Thematic Analysis

Out of n_1=21 responses for Survey 1, seven participants provided open responses; out of n_2=66 responses for Survey 2, 16 participants provided open responses. Identified themes follow:

Suitability for Online Context: Three responses in Survey 1 specifically praised TabletPCs in the remote teaching context, for providing increased clarity compared to capturing a board or notebook with a fixed camera. Although this was not asked, it is perhaps unsurprising that participants shared this as it was their most recent learning experience.

Multi-Modal Approaches and Engagement: In Survey 1, three responses reported that the mode is less important than how it is integrated into teaching, and combining approaches (i.e. a multi-modal approach) makes sessions more engaging, regardless of whether the live writing uses a TabletPC or a board. This was reinforced by five responses in Survey 2, which reported that multi-modal delivery made it easier to focus on learning during a teaching session, rather than focus on replicating notes delivered on the board. The live handwriting component was reported to be useful for understanding the material, and one response reported that the removal of the requirement to copy everything was inclusive practice, suitable for neurodiverse students (Boyle et al., 2015). It is noted that, although TabletPCs with annotation ranked higher than slides combined with writing on the board, the difference is not enough to draw a definitive conclusion about a common preference for one of them over the other.

Pace and Review: In Survey 2, six responses reported that the video and notes captured by the TabletPC provide an advantage for subsequent review of learning: something that is not always readily available for board capture at the institution. Of these respondents, 3 explained that this can compensate for faster-paced sessions, which risk being too fast if there is too much to write down.

Strong Blackboard Preference: In Survey 2, five responses strongly preferred boards, stating in categorical terms that it is the best delivery medium for mathematics. Three of these responses specifically mention blackboards. But even stronger than stating that it is currently the best medium, one response says it always has been ('a board and chalk has been used for thousands of years for mathematics'), and one response says it always will be ('nothing will ever beat chalk'). It is noted that four of these five respondents nevertheless stated their strongest preference was a multi-modal approach, involving slides and the board.

5. Discussion

5.1. Verifying results from the literature

Perceptions of TabletPCs in (Results Section 4.1) were mostly in line with the literature, except for a high neutral response for TabletPCs encouraging students to pay attention. Although this is not explained by thematic analysis of open responses, we hypothesise that it may be due to the novelty

wearing off. Literature from as early as 2013 (Schnackenberg, 2013) discussed how TabletPCs were prevalent in homes and workplaces, how adoption was growing within education, and how the devices could be effectively integrated into classrooms. A 2023 survey showed that almost half of all students own a tablet (UCAS, 2023).

5.2. Multi-Modal Delivery

Both Survey 1 and Survey 2 yielded the same overall ranking of preferred delivery modes, with multi-modal delivery rated higher than unimodal delivery. In Survey 1, the ranking within unimodal delivery modes had 'slides only' clearly earning the lowest ranking. In Survey 2, the gap was closed between 'slides only' and other unimodal delivery modes. This suggests that participants in Survey 2 were less discriminating between different unimodal delivery modes and had a stronger preference for mixed-modal delivery rather than strong preferences within these categories. This observed preference aligns with concepts of Cognitive Load Theory. Specifically, unimodal delivery modes are linked to the 'split attention effect' (Chandler and Sweller, 1992). This undesirable outcome occurs when learners are processing inputs that are not effectively integrated; for example, if information is presented on a slide and this information is also read to students, then this can trigger the split attention effect. Participants reported in open responses that the pace of unimodal delivery modes require relatively more effort from students to keep up: this means that student attention on replicating notes can detract from actively listening to and understanding the discussion, hence triggering the split attention effect. Conversely, the multi-modal delivery modes are linked to the 'mixed-modal effect' (Mousavi et al., 1995) in which cognitive load is reduced by having material presented in a mode complementary to the active delivery, meaning learners have immediate access to resources as needed, rather than taking up valuable space in working memory. It should be noted that the split attention effect and mixed modal effect occur based on how effectively information from different modes is integrated in the presentation and is not intrinsically linked to the modes surveyed; however, open responses suggest that the delivery modes are delivered in such a way as to link to these aspects of Cognitive Load Theory. The authors believe this to be practical evidence supporting the theoretical framework.

Participants also cited the inclusive practice of making resources available. All surveyed methods (dependent on the technology of the teaching space) afford the opportunity to record the audio and visual components of the teaching session. Only slides only, or multi-modal approaches, afford the opportunity to share some of these resources in advance of the session.

5.3. Discussing the claim that blackboard is best

It is not surprising, given results found elsewhere in the literature, that some respondents reported a strong preference for blackboard delivery. From the literature review, we know that blackboards have been integrated into mass education for around 150 years. It is unclear whether the participant is being figurative or literal when citing 'thousands of years,' but it is clear this is perceived to be the educational norm. Indeed, there is considerable advocacy for blackboards.

6. Conclusion and Recommendation

The surveys asked for student perceptions in a general sense, and did not consider the context of individual teaching activities. Some teaching activities might lend themselves more to one mode than another: e.g. student collaboration might be most effective on a large physical board, compared to a smaller TabletPC; conversely, software demonstration would be simple on a TabletPC but impossible on a board. The present study did not consider educator preferences and proficiencies, which are critical to ensuring benefits of a given mode are realised in practice. It would not be valid to conclude a particular mode as the definitive 'best,' especially as the preferred ranking was not

substantially different between the highest ranked modes. Having said that, the advantages of TabletPCs described in the literature were evidenced in the present research, and they are a suitable and effective tool for delivery of mathematics. The strong discipline culture might discourage some educators from considering them. This leads to the first recommendation.

Recommendation 1: Educators are recommended to consider the breadth of contemporary tools available, and their individual advantages, when determining the most appropriate delivery mode for a teaching activity.

The clearest preference arising from delivery mode rankings was for multi-modal approaches, which also aligns with Cognitive Load Theory.

Recommendation 2: Incorporate multi-modal delivery, combining dynamic presentation of delivery with complementary static presentation of information to reduce split attention effect arising from having to keep up with the pace.

In a similar vein, but also linked to inclusive practice, students reported that having resources in advance could support note-taking and active listening within the lecture.

Recommendation 3: Consider what resources may be provided in advance of the lecture, which can especially complement multi-modal delivery.

This paper concludes with a comment about the preference for blackboards, and the associated strong discipline culture. The authors were able to find sources which provided logical arguments supporting blackboard use, and socialised evidence supporting advantages such as speed, space, visibility and legibility (Greiffenhagen, 2014). Although such evidence is valid, the authors struggled to find direct evaluation of such advantages, and their implications for learning; either considering the medium independently, or comparatively against other media. Lew et al (2016) support the claim about lack of empirical evidence to support traditional mathematics instruction more generally, also demonstrating that what may traditionally be thought of as a good lecture may not have the intended learning value for students. The authors note an incongruity between the strength and breadth of the cultural preference for blackboard delivery, and a lack of empirical research to evidence its benefits.

7. Appendix

7.1. Survey 1 – breakdown of responses

1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree

	1	**2**	**3**	**4**	**5**
The Tablet PC is an effective tool to present the material in the lectures or other in-person sessions.	1	0	5	6	9
The use of the Tablet PC helped the lecturer to cover the material in an efficient way.	1	1	4	7	8
The use of the Tablet PC encouraged me to pay attention to the material presented in the lectures or other in-person sessions.	1	1	8	4	7
The use of the Tablet PC helped me to understand the material presented in the lectures or other in-person sessions.	1	1	7	4	8

Table 1: Breakdown of responses for Survey 1

7.2. Survey 2 – breakdown of responses

1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree

	1	2	3	4	5
The Tablet PC is an effective tool to present the material in the lectures or other in-person sessions.	3	1	9	23	30
The use of the Tablet PC helped the lecturer to cover the material in an efficient way.	2	3	7	26	28
The use of the Tablet PC encouraged me to pay attention to the material presented in the lectures or other in-person sessions.	5	1	19	21	20
The use of the Tablet PC helped me to understand the material presented in the lectures or other in-person sessions.	2	4	11	29	20

Table 2: Breakdown of responses for Survey 2

8. References

Billman, A., Harding, A. & Engelbrecht, J. 2018. Does the chalkboard still hold its own against modern technology in teaching mathematics? A case study. *International Journal of Mathematical Education in Science and Technology,* 49**,** 809-823, http://doi.org/10.1080/0020739X.2018.1431852.

Boyle, J. R., Forchelli, G. A. & Cariss, K. 2015. Note-taking interventions to assist students with disabilities in content area classes. *Preventing School Failure: Alternative Education for Children and Youth,* 59**,** 186-195, http://doi.org/10.1080/10459881003785506.

Chandler, P. & Sweller, J. 1992. The Split-Attention Effect as a Factor in the Design of Instruction. *British Journal of Educational Psychology,* 62**,** 233-246, http://doi.org/10.1111/j.2044-8279.1992.tb01017.x.

Day, R. S. The original teaching machine—The blackboard. The Educational Forum, 1967. Taylor & Francis, 195-201, http://doi.org/10.1080/00131726709338041.

Ellis-Behnke, R., Gilliland, J., Schneider, G. & Singer, D. 2003. Educational benefits of a paperless classroom utilizing tablet PCs. *Massachusetts Institute of Technology, Cambridge, Massachusetts-USA,*

Emerson, P. 1896. Ocean Circulation.—(II). *The Journal of Education,* 43**,** 330-331

Fister, K. R. & Mccarthy, M. L. 2008. Mathematics Instruction and the Tablet PC. *International Journal of Mathematical Education in Science and Technology,* 39**,** 285-292, http://doi.org/10.1080/00207390701690303.

Galligan, L., Hobohm, C. & Loch, B. 2012. Tablet technology to facilitate improved interaction and communication with students studying mathematics at a distance. *Journal of Computers in Mathematics and Science Teaching,* 31**,** 363-385

Gorgievski, N., Stroud, R., Truxaw, M. & Defranco, T. 2005. Tablet PC: A Preliminary Report on a Tool for Teaching Calculus. *International Journal for Technology in Mathematics Education,* 12**,** 95-102

Greiffenhagen, C. 2014. The materiality of mathematics: Presenting mathematics at the blackboard. *The British journal of sociology,* 65**,** 502-528, http://doi.org/10.1111/1468-4446.12037.

Hester, W. 1902. Promotion of Pupils. *The Journal of Education,* 56**,** 137-137

Hoang, A., Tseng, W., Viswanathan, S. & Evans, H. 2009. Life Cycle Assessment of a Laptop Computer and its Contribution to Greenhouse Gas Emissions.

Kohorst, K. & Cox, J. R. 2007. Virtual office hours using a tablet PC: E-lluminating biochemistry in an online environment. *Biochemistry and Molecular Biology Education,* 35**,** 193-197, http://doi.org/10.1002/bmb.50.

Lew, K., Fukawa-Connelly, T. P., Mejía-Ramos, J. P. & Weber, K. 2016. Lectures in advanced mathematics: Why students might not understand what the mathematics professor is trying to convey. *Journal for Research in Mathematics Education,* 47**,** 162-198, http://doi.org/10.5951/jresematheduc.47.2.0162.

Lin, C.-C., Lee, M.-K. & Huang, H.-L. 2015. Effects of chalk use on dust exposure and classroom air quality. *Aerosol and Air Quality Research,* 15**,** 2596-2608, http://doi.org/10.4209/aaqr.2015.04.0216.

Maclaren, P., Wilson, D. & Klymchuk, S. 2017. I see what you are doing: Student views on lecturer use of Tablet PCs in the engineering mathematics classroom. *Australasian Journal of Educational Technology,* 33, http://doi.org/10.14742/ajet.3257.

Majumdar, D. & William, S. P. 2009. Chalk dustfall during classroom teaching: particle size distribution and morphological characteristics. *Environmental monitoring and assessment,* 148**,** 343-351

Mousavi, S. Y., Low, R. & Sweller, J. 1995. Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of educational psychology,* 87**,** 319, http://doi.org/10.1037/0022-0663.87.2.319.

Myyry, L., Kallunki, V., Katajavuori, N., Repo, S., Tuononen, T., Anttila, H., Kinnunen, P., Haarala-Muhonen, A. & Pyörälä, E. COVID-19 accelerating academic teachers' digital competence in distance teaching. Frontiers in education, 2022. Frontiers Media SA, 770094, http://doi.org/10.3389/feduc.2022.770094.

Plasticseurope. 2022. *The Circular Economy for Plastics—A European Overview* [Online]. Available: https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-overview-2/ [Accessed 20th March 2025].

Rudow, S. R. & Finck, J. E. 2015. Pointing with Power or Creating with Chalk. *Contemporary Issues in Education Research,* 8**,** 123-134

Sambrook, S. & Rowley, J. 2010. What's the use of webnotes? Student and staff perceptions. *Journal of Further and Higher Education,* 34**,** 119-134, http://doi.org/10.1080/03098770903480338.

Schnackenberg, H. L. 2013. Tablet technologies and education. *International Journal of Education and Practice,* 1**,** 44-50

Suleri, J. 2020. Learners' experience and expectations during and post COVID-19 in higher education. *Research in hospitality management,* 10**,** 91-96, http://doi.org/10.1080/22243534.2020.1869463.

Ucas. 2023. *The shifting sands of student tech: What they're buying, how they're using it – and what this means for brands* [Online]. Available: https://www.ucas.com/connect/blogs/shifting-sands-student-tech-what-theyre-buying-how-theyre-using-it-and-what-means-brands [Accessed 7th March 2025].

Wiggins, M. & Eglowstein, H. 2017. *A short history of the Hindsight Letterbug, circa 1986-1987* [Online]. Available: http://www.overpricedsoftware.com/h87letterbug/ [Accessed 16th August 2024].

Wylie, C. D. 2012. Teaching manuals and the blackboard: accessing historical classroom practices. *History of Education,* 41**,** 257-272, http://doi.org/10.1080/0046760X.2011.584573.