The Pen vs. The Pixel: Designing Digital Assessment for the Human Learner

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ACTIVITY

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Digital Assessment Experience

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https://ahaslides.com/YJME1

Our Results

	Triangle Area	Graph Equation	Expression Equivalence
Time Limit	2 minutes	2 minutes	30 seconds
Evaluation	Anonymous	Anonymous	“Identified”
Stressful			
Fair			
Helpful for Learning			

RESEARCH

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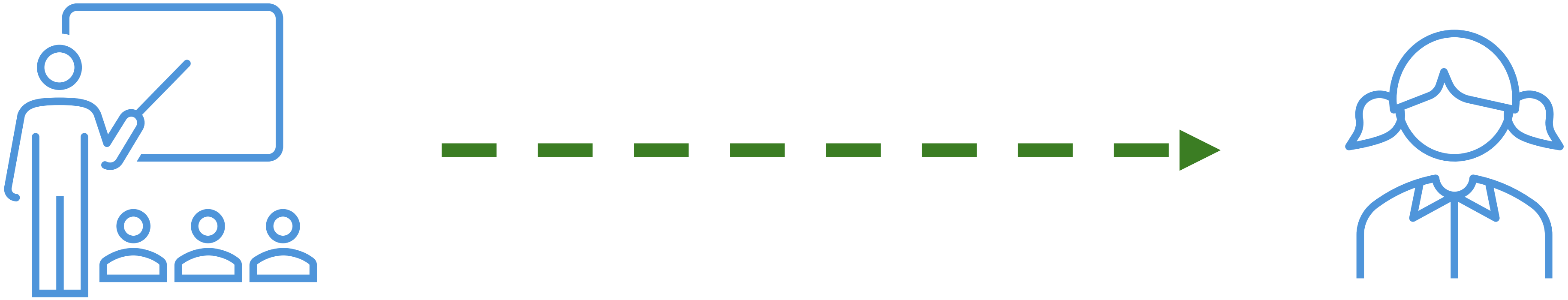
Introduction

- Digital assessment (DA) appears across all levels of education.
- International large-scale evaluations have moved to digital delivery.
- Research has surged on DA, particularly following the Covid-19 pandemic.
- Previous research on DA focused on perspectives of the test-maker.



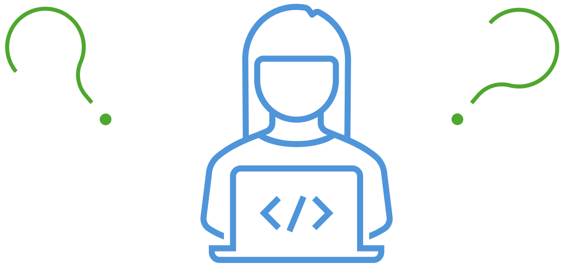
Background on Assessment

- Assessments can serve different purposes.
- Students' experiences vary between different assessments.
- There is concern groups of students may be disadvantaged by different formats.
- Regarding the incorporation of 'novel' assessment, "*students aren't nearly as enthusiastic as educators*" (Struyven & Devesa, 2016, p. 139).

Is DA still 'novel' and what role does it effectively play?

Digital Assessment (DA)

- DA refers to using digital devices (e.g., phones, tablets, computers) in delivering assessment.
- Concern new DAs are being incorporated more quickly than academic research is evaluating their effectiveness.
- A call was made to investigate different problem types and user interfaces (Katz & Gorin, 2016).
- Questions remain around the impact of DA on diverse students.



Digital Assessment (DA)

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Comparisons between students' experiences of DA and PPA

Whether DA disadvantages certain groups of learners

Students' experiences on different forms of DA

What features of DA research has indicated work well

Summary of the 64 Studies

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- Most studies researched students from W.E.I.R.D. countries (*n* = 38).
- Other European countries (*n* = 7), Asia (*n* = 7), Africa (*n* = 6), South America (*n* = 1), and international data (*n* = 5).
- **Topics:**

  (1) Approaches to and features used in formative assessment (*n* = 24)

  (2) Mixed or non-specific assessment approaches and features (*n* = 24)

  (3) Summative assessment (*n* = 5)

  (4) Other assessment formats or features (*n* = 11)

Table 1

Studies researching education level (*N* = 64)

Education Level	
Primary (ages 5-10)	5
Intermediate (ages 11-13)	5
Secondary (ages 14-18)	6
Various School (ages 5-18)	7
Undergraduate	37
Other levels / combinations	4

Comparing DA and PPA

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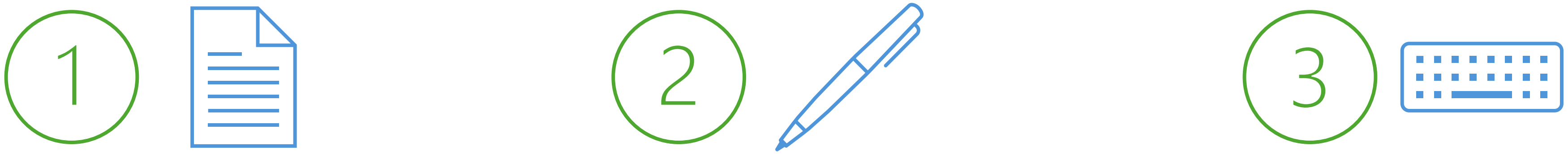
- Few studies attempt to evaluate differences between functionally equivalent assessments.
- Studies suggest students perform worse (Akın, 2022), the same (Davis et al., 2021; Massing et al., 2018; Smolinsky et al., 2019), or better in DA (Berková, 2017; Smolinsky et al., 2020; Tomal et al., 2021).
- Logan (2015) conducted a large study with grade six students and found they performed significantly better in DA than PPA, but **only three of the six content areas reflected this difference**.

Standardised Testing - DA and PPA

- Akyol (2021) found the PISA scores of 15-year-old Turkish students decreased by 5.9% from previous years after moving to computer-based delivery.
- Fishbein et al. (2018) collected data in more than 20 countries and found items were more difficult in the computer-based eTIMSS.
- Results may be country-dependent (Hamhuis et al., 2020; Jerrim, 2016; Scherer & Siddiq, 2015).

Perspectives - DA and PPA

- Some students prefer DA (Riegel & Evans, 2021), while others prefer PPA (Alshehri, 2023; Rønning, 2017).
- Davis et al. (2021) found 100 American secondary students overwhelmingly preferred PPA, followed by digital pen, and lastly, 80% ranked keyboard as their third choice.



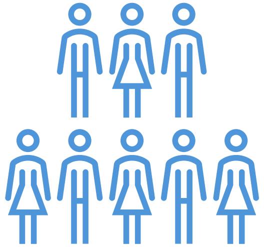
DA & Equity

- PISA data showed boys outperforming girls in both delivery modes for most countries, and by a somewhat larger margin in the digital context (Jerrim, 2016); girls marginally outperformed boys on the eTIMSS (Hamhuis et al., 2020).
- Fishbein et al. (2018) found TIMSS delivery mode did not affect gender – moreover, mode of delivery had uniform effects over socio-economic status and digital self-efficacy.

"common measures of educational inequality were consistently lower under the computer-based mathematics assessment, both in terms of the spread of achievement and the impact of family background"

(Jerrim, 2016, p. 513 – international PISA data)

- Akyol (2021) showed computer possession did not influence PISA performance on DA for Turkish students.



DA & Perceived Fairness

- Students' attitudes are influenced by how effectively and conveniently DA is utilized (Acosta-Gonzaga & Walet, 2018; Valdez & Maderal, 2021).
- Some students still lack confidence and trust in DA (Adelabu & Alex, 2023; Divjak et al., 2024; Juma et al., 2022a; Padayachee et al., 2018; Pezzino, 2018; Tatira & Kariyana, 2022), though not always (e.g., McCracken et al., 2024; Murchan and Oldham, 2017).
- A difficulty and barrier to perceived 'fairness' of DA in mathematics is communicating ideas in linear syntax and the inability to demonstrate reasoning (Adelabu & Alex, 2023; Alshehri, 2023; Brown & Lally, 2018; Davis et al., 2021; Divjak et al., 2024; Kinnear et al., 2022; Lowe & Mestel, 2020; Padayachee et al., 2018; Paiva et al., 2015; Tatira & Kariyana, 2022; Zegowitz, 2023).

DA & Perceived Fairness

- Students have reported cheating in DA, and that it is easy to do (Riegel & Evans, 2021; Rønning, 2017; Zegowitz, 2023).
- Some students are concerned about other cheating digitally (Alshehri, 2023), while others are not (Divjak et al., 2024).
- **Different approaches to managing academic integrity and how these affect students are severely lacking.**

Student Experiences of DA

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- Formative DAs generally result in improved mathematics achievement (Durandt et al., 2022; Faber et al., 2017; Hettiarachchi et al., 2015; Katalenić & Kolar-Begović, 2022; Lowe, 2015; Lowe & Mestel, 2020; Massing et al., 2021; Massing et al., 2018; See et al., 2022).
- Formative DA is received positively by the majority of students (Faber et al., 2017; Kudu et al., 2017; Lishchynska et al., 2021; Lowe & Mestel, 2020; Massing et al., 2018; Paiva et al., 2017; Paiva et al., 2015; Pezzino, 2018; Riegel & Evans, 2021; Valdez & Maderal, 2021).
    - Flexibility (Padayachee et al., 2018; Riegel & Evans, 2021)
    - Immediate feedback (Juma et al., 2022a; Padayachee et al., 2018; Rønning, 2017)
    - Supporting practice, self-monitoring, and confidence (Divjak et al., 2024; Hettiarachchi et al., 2015; Juma et al., 2022a; Lishchynska et al., 2021; Lowe & Mestel, 2020; Padayachee et al., 2018; Valdez & Maderal, 2021; Zegowitz, 2023)
    - improving motivation, available resources, technology practice, and a sense of reduced pressure in a digital environment (Padayachee et al., 2018; Riegel & Evans, 2021; Valdez & Maderal, 2021)
- Students hold mixed views on how often formative DA should occur (Hettiarachchi et al., 2015; Lowe & Mestel, 2020; Riegel & Evans, 2021).
- **Research is lacking on summative DA.**

What Works in DA?

Assessment Design and Delivery.

Method of Delivery

- Rutkowski et al. (2023) found no differences in performance between device type (desktop, laptop, or tablet).
- Digital pens: can resolve issues of demonstrating mathematical working, students can prefer; can increase the likelihood of learning-disabled students solving simpler problems (Davis et al., 2021; Wei et al., 2025).
- Students are concerned with transparency and fairness of DA, particularly their familiarity with all aspects and features (Divjak et al., 2024; Dyrvold and Bergvall, 2023).

What Works in DA?

Assessment Design and Delivery.

Engagement and Attitude

- Studies have found that there are peaks in students' accessing formative DA near summative assessment (Durandt et al., 2022; Hettiarachchi et al., 2015; Lowe, 2015; Massing et al., 2018; Paiva et al., 2015) and flexibility may cause problematic ways of engaging (Gruss & Clemons, 2023; Juma et al., 2022a; Massing et al., 2021).
- Summative component (Kinnear et al., 2022; Lishchynska et al., 2021; Lowe, 2015).
- Practice versions of a summative assessment / multiple attempts (Lowe & Mestel, 2020; Padayachee et al., 2018; Pezzino, 2018).
- Threshold grades (Hettiarachchi et al., 2015; Paiva et al., 2017).

What Works in DA?

Assessment Design and Delivery.

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Question Type

- **Example-generation**: performance was lower in DA than PPA (Kinnear et al., 2024a).
- **Adaptive problems and proof puzzles**: students were happy with (Gallaun et al., 2022).
- **Personalized assessment**: more effective in supporting achievement and correcting misconceptions (Wu et al., 2017).
- **Digital storytelling**: mixed responses (Hernandez-Martinez and Keane, 2024).
- **Gamified problems**: do not improve performance; preference wanes over time (Attali and Arieli-Attali, 2015).

What Works in DA?

Feedback

Balancing:

- timeliness and clarity (Brown & Lally, 2018; Divjak et al., 2024)
- detail (Lowe & Mestel, 2020; Padayachee et al., 2018; Rønning, 2017)
- **immediacy** (Gaona et al., 2018; Juma et al., 2022a; Padayachee et al., 2018; Rønning, 2017; Zegowitz, 2023)

- Interactive feedback and prompting during problem-solving can improve the performance of school students, particularly those of low socio-economic background (Barana et al., 2021; Wu et al., 2017).
- Other methods of feedback have been explored (Liu et al., 2015; Robinson et al.,2015)

What Works in DA?

Digital Interactive Components (DICs)

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- Can be both problematic and beneficial (Dyrvold & Bergvall, 2023; Harris et al., 2021; Jiang et al., 2021)
- There is disagreement about whether DICs affect different subgroups differently (Alhadi et al., 2023; Jerrim, 2016).
- Liu et al. (2023) found that interactive components can improve engagement and accuracy in geometry problem-solving for secondary students with learning difficulties, particularly a pop-up glossary.
- Language accessibility:
  - Wei (2024) found students with disabilities and English language learners were more likely to use text-to-speech features, which generally related to better performance for these students.
  - Lopez (2024) reported bilingual accommodations were positively perceived and found useful at a middle school level.

Takeaways

- Evidence suggests DA does not negatively impact students of different genders, socio-economic backgrounds, digital literacy, and computer self-efficacy.
- For students to perceive DA as effective, it should be transparent, intentionally designed, and well-resourced.
- There is some evidence that certain features of DA may be more effective for specific groups of students.
- Most studies investigated formative DA and demonstrate it is an effective and enjoyable resource.

REDESIGN

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Redesign

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Based on the key takeaways from this talk, pick one of the three questions we engaged with (area of a triangle, equation of a parabola, expression equivalence) and, in a group, think about how this might be redesigned to capture mathematical thinking fairly and equitably, for formative and/or summative purposes.

How would you change/improve the question design?

What problems do you run into?

Where does it make sense to compromise?

Would you use this question for summative purposes?

References

*Acosta-Gonzaga, E., & Walet, N. R. (2018). The role of attitudinal factors in mathematical on-line assessments: a study of undergraduate STEM students. *Assessment & Evaluation in Higher Education*, *43*(5), 710-726. https://doi.org/10.1080/02602938.2017.1401976
*Adelabu, F. M., & Alex, J. K. (2023). Mathematics online baseline assessment: Senior phase first-year student teachers' views. *Research in Social Sciences and Technology*, *8*(3), 52-66. https://doi.org/10.46303/ressat.2023.22
*Akın, A. (2022). The effectiveness of web-based Mathematics instruction (WBMI) on K-16 students' mathematics learning: a meta-analytic research. *Education and Information Technologies*, *27*, 8015-8040. https://doi.org/10.1007/s10639-022-10931-x
*Akyol, P. (2021). Comparison of computer-based and paper-based exams: Evidence from PISA. *Boğaziçi Journal Review of Social, Economic and Administrative Studies*, *35*(2). https://doi.org/10.21773/boun.35.2.2
*Alhadi, M., Zhang, D., Wang, T., & Maher, C. A. (2023). Digitalized interactive components in computer-based-assessment in mathematics for K12 students: A research synthesis. *Computers in the Schools*, *40*(1), 56-84. https://doi.org/10.1080/07380569.2022.2116622
*Alshehri, S. M. (2023). Students' perceptions in undergraduate online math courses. *Cogent Education*, *10*(1), 2203069. https://doi.org/10.1080/2331186X.2023.2203069
*Attali, Y., & Arieli-Attali, M. (2015). Gamification in assessment: Do points affect test performance? *Computers and Education*, *83*(57-63). https://doi.org/10.1016/j.compedu.2014.12.012
*Barana, A., Marchisio, M., & Sacchet, M. (2021). Interactive feedback for learning mathematics in a digital learning environment. *Education Sciences*, *11*, 279. https://doi.org/10.3390/educsci11060279
*Berková, A. J. (2017). Effect of the use of computer-aided assessment system in the teaching of mathematical analysis with regard to students' approaches to learning. *Journal on Efficiency and Responsibility in Education and Science*, *10*(3), 71-75. https://doi.org/10.7160/eriesj.2017.100302
Brown, G. T. L. (2022). Student conceptions of assessment: Regulatory responses to our practices. *ECNU Review of Education*, *5*(1), 116-139. https://doi.org/10.1177/20965311211007869
*Brown, K., & Lally, V. (2018). Rhetorical relationships with students: A higher education case study of perceptions of online assessment in mathematics. *Research in Comparative and International Education*, *13*(1), 7-26. https://doi.org/10.1177/1745499918761938
*Davis, L. L., Morrison, K., Schnieders, J. Z., & Marsh, B. (2021). Developing authentic digital math assessments. *Journal of Applied Testing Technology*, *22*(1), 1-11.
*Divjak, B., Žugec, P., & Pažur Aničić, K. (2024). E-assessment in mathematics in higher education: A student perspective. *International Journal of Mathematical Education in Science and Technology*, *55*(8), 2046-2068. https://doi.org/10.1080/0020739X.2022.2117659

References

*Durandt, R., Herbst, S., & Seloane, M. (2022). Teaching and learning first-year engineering mathematics at a distance: A critical view over two consecutive years. *Perspectives in Education*, *40*(1), 143-163. https://doi.org/10.18820/2519593X/pie.v40.i1.9

*Dyrvold, A., & Bergvall, I. (2023). Computer-based assessment in mathematics: Issues about validity. *LUMAT: International Journal on Math, Science and Technology Education*, *11*(3), 49-76. https://doi.org/10.31129/LUMAT.11.3.1877

*Faber, J. M., Luyten, H., & Visscher, A. J. (2017). The effects of a digital formative assessment tool on mathematics achievement and student motivation: Results of a randomized experiment. *Computers and Education*, *106*, 83-96. https://doi.org/10.1016/j.compedu.2016.12.001

Falchikov, N., & Boud, D. (2007). Assessment and emotion: The impact of being assessed. In D. Boud & N. Falchikov (Eds.), *Rethinking assessment in higher education* (pp. 154-166). Routledge. https://doi.org/10.4324/9780203964309-19

*Fishbein, B., Martin, M. O., Mullis, I. V. S., & Foy, P. (2018). The TIMSS 2019 Item Equivalence Study: Examining mode effects for computer-based assessment and implications for measuring trends. *Large-scale Assessments in Education*, *6*(11). https://doi.org/10.1186/s40536-018-0064-z

*Gallaun, D., Kruse, K., & Seifert, C. (2022). High-quality tasks for e-assessment in mathematics. *Teaching Mathematics and Its Applications*, *41*, 270-279. https://doi.org/10.1093/teamat/hrab036

*Gaona, J., Reguant, M., Valdivia, I., Vásquez, M., & Sancho-Vinuesa, T. (2018). Feedback by automatic assessment systems used in mathematics homework in the engineering field. *Computer Applications in Engineering Education*, *26*, 994-1007. https://doi.org/10.1002/cae.21950

*Gruss, R., & Clemons, J. (2023). Does question order matter on online math assessments? A big data analysis of undergraduate mathematics final exams. *Journal of Computer Assisted Learning*, *39*, 1539-1552. https://doi.org/10.1111/jcal.12816

*Hamhuis, E., Glas, C., & Meelissen, M. (2020). Tablet assessment in primary education: Are there performance differences between TIMSS' paper-and-pencil test and tablet test among Dutch grade-four students? *British Journal of Educational Technology*, *51*(6), 2340-2358. https://doi.org/10.1111/bjet.12914

*Harris, D., Logan, T., & Lowrie, T. (2021). Unpacking mathematical-spatial relations: Problem-solving in static and interactive tasks. *Mathematics Education Research Journal*, *33*, 495-511. https://doi.org/10.1007/s13394-020-00316-z

*Hernandez-Martinez, P., & Keane, T. (2024). Learning mathematics and its relevance through a digital storytelling assessment task at university. *International Journal of Mathematical Education in Science and Technology*. https://doi.org/10.1080/0020739X.2023.2295895

*Hettiarachchi, E., Huertas, M. A., Mor, E., & Guerrero-Roldán, A. (2015). Improving student performance in high cognitive level courses by using formative e-assessment. *International Journal of Technology Enhanced Learning*, *7*(2), 116-133. https://doi.org/10.1504/IJTEL.2015.072027

Iannone, P., & Simpson, A. (2017). University students' perceptions of summative assessment: The role of context. *Journal of Further and Higher Education*, *41*(6), 785-801. https://doi.org/10.1080/0309877X.2016.1177172

References

Iannone, P., & Simpson, A. (2022). How we assess mathematics degrees: the summative assessment diet a decade on. *Teaching Mathematics and Its Applications*, *41*(1), 22-31. https://doi.org/10.1093/teamat/hrab007

*Jerrim, J. (2016). PISA 2012: how do results for the paper and computer tests compare? *Assessment in Education: Principles, Policy & Practice*, *23*(4), 495-518. https://doi.org/10.1080/0969594X.2016.1147420

*Jiang, Y., Gong, T., Saldivia, L. E., Cayton-Hodges, G., & Agard, C. (2021). Using process data to understand problem-solving strategies and processes for drag-and-drop items in a large-scale mathematics assessment. *Large-scale Assessments in Education*, *9*(2). https://doi.org/10.1186/s40536-021-00095-4

*Juma, Z. O., Ayere, M. A., Oyengo, M. O., & Osang, G. (2022a). Evaluating engagement and learning based on a student categorization using STACK, exam data, key informant interviews, and focus group discussions. *International Journal of Emerging Technologies in Learning*, *17*(23), 103-114. https://doi.org/10.3991/ijet.v17i23.36619

*Juma, Z. O., Okoth, I. O., & Oyengo, M. O. (2022b). Delivery of integral calculus at Maseno university: Is STACK really playing an integral part? *International Journal of Emerging Technologies in Learning*, *17*(23), 64-68. https://doi.org/10.3991/ijet.v17i23.36621

*Katalenić, A., & Kolar-Begović, Z. (2022). Prospective primary school teachers' work in continuous online assessments in the course of didactics of mathematics. *Mathematics Teaching Research Journal*, *14*(4), 80-105.

Katz, I. R., & Gorin, J. S. (2016). Computerising assessment: Impacts on education stakeholders. In G. T. L. Brown & L. R. Harris (Eds.), *Handbook of human and social conditions in assessment* (1st ed., pp. 472-489). Routledge. https://doi.org/10.4324/9781315749136

*Kinnear, G., Iannone, P., & Davies, B. (2024a). Student approaches to generating mathematical examples: comparing e-assessment and paper-based tasks. *Educational Studies in Mathematics*. https://doi.org/10.1007/s10649-024-10361-1

*Kinnear, G., Wood, A. K., & Gratwick, R. (2022). Designing and evaluating an online course to support transition to university mathematics. *International Journal of Mathematical Education in Science and Technology*, *53*(1), 11-34. https://doi.org/10.1080/0020739X.2021.1962554

Kinnear, G., Jones, I., Sangwin, C., Maryam, A., Davies, B., Fearn, S., Foster, C., Heck, A., Henderson, K., Hunt, T., Iannone, P., Kontorovich, I., Larson, N., Lowe, T., Meyer, J. C., O'Shea, A., Rowlett, P., Sikurajapathi, I., & Wong, T. (2024b). A collaboratively-derived research agenda for e-assessment in undergraduate mathematics. *International Journal of Research in Undergraduate Mathematics Education, 10*, 201-231. https://doi.org/10.1007/s40753-022-00189-6

*Kudu, M., Genel, Y., Soydaş, H., Akça, Ü., Türkeri, J., & Aydin, S. (2017). Online Assessment for Mathematics Lecture. *TOJET: The Turkish Online Journal of Educational Technology.*

*Lishchynska, M., Palmer, C., & Cregan, V. (2021). Online mathematics supports in lieu of university tutorials during COVID-19: Student and lecturer perspectives. *Teaching Mathematics and Its Applications*, 1-19. https://doi.org/10.1093/teamat/hrab015

*Liu, C., Huang, C., Liu, M., Chien, Y., Lai, C., & Huang, Y. (2015). Does gender influence emotions resulting from positive applause feedback in self-assessment testing? Evidence from neuroscience. *Educational Technology & Society*, *18*(1), 337-350.

References

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*Liu, C., Zhang, D., Pandolpho, M., & Yi, J. (2023). Effects of principled digitalized interactive components on geometry computer-based assessment in high schoolers with learning difficulties in mathematics: A preliminary investigation. *Assessment for Effective Intervention*, *49*(1), 29-40. https://doi.org/10.1177/15345084231203235

*Logan, T. (2015). The influence of test mode and visuospatial ability on mathematics assessment performance. *Mathematics Education Research Journal*, *27*, 423-441. https://doi.org/10.1007/s13394-015-0143-1

*Lopez, A. A. (2024). Examining the use of bilingual accommodations in digital math assessments: User perceptions. *International Journal of Assessment Tools in Education*, *11*(4), 787-803. https://doi.org/10.21449/ijate.1529210

*Lowe, T. W. (2015). Online quizzes for distance learning of mathematics. *Teaching Mathematics and Its Applications*, *34*, 138-148. https://doi.org/10.1093/teamat/hrv009

*Lowe, T. W., & Mestel, B. D. (2020). Using STACK to support student learning at masters level: a case study. *Teaching Mathematics and Its Applications*, *39*, 61-70. https://doi.org/10.1093/teamat/hrz001

*Massing, T., Reckman, N., Blasberg, A., Otto, B., & Hanck, C. (2021). When is the best time to learn? Evidence from an introductory statistics course. *Open Education Studies*, *3*, 84-95. https://doi.org/10.1515/edu-2020-0144

*Massing, T., Schwinning, N., Striewe, M., Hanck, C., & Goedicke, M. (2018). E-assessment using variable-content exercises in mathematical statistics. *Journal of Statistics Education*, *26*(3), 174-189. https://doi.org/10.1080/10691898.2018.1518121

*McCracken, M., Bostic, J. D., & Folger, T. D. (2024). Middle school students' conceptualizations and reasoning about the fairness of maths tests. *TechTrends*, *68*, 946-961. https://doi.org/10.1007/s11528-024-00988-5

*Muhammad, N., & Srinivasan, S. (2021). Online education during a pandemic - Adaptation and impact on student learning. *International Journal of Engineering Pedagogy*, *11*(3), 71-83. https://doi.org/10.3991/ijep.v11i3.20449

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). *TIMSS 2019 International Results in Mathematics and Science.* Retrieved from Boston College, TIMSS & PIRLS International Study Center website. https://timssandpirls.bc.edu/timss2019/international-results/

*Murchan, D., & Oldham, E. (2017). Exploring the role of computer-based assessment in diagnosing children's mathematical errors in primary education in Ireland. *Irish Educational Studies*, *36*(4), 489-510. https://doi.org/10.1080/03323315.2017.1393765

Newton, P. E. (2007). Clarifying the purposes of educational assessment. *Assessment in Education*, *14*(2), 149-170. https://doi.org/10.1080/09695940701478321

*Ng, D. T. K., & Fang, X. (2023). How to use Zoom to collect data in mathematics educational research: A case study in assessing students' online mathematics learning. *Asian Journal for Mathematics Education*, *2*(3), 274-298. https://doi.org/10.1177/27527263231188638

References

*Nurdin, E., Amir, Z., Nufus, H., Thakur, D., Shah, F. A., Dube, R., & Wijaya, T. T. (2021). Let your students cheat on mathematics online exams: students' perspectives. *Malikussaleh Journal of Mathematics Learning (MJML)*, *4*(2), 131-136. https://doi.org/10.29103/mjml.v4i2.3286

OECD. (2016). *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy*. OECD Publishing.

OECD. (2023). *OECD Digital Education Outlook 2023: Towards an Effective Digital Education Ecosystem*. OECD Publishing.

*Padayachee, P., Wagner-Welsh, S., & Johannes, H. (2018). Online assessment in Moodle: A framework for supporting our students. *South African Journal of Higher Education*, *32*(5), 211-235. https://doi.org/10.20853/32-5-2599

*Paiva, R. C., Ferreira, M. S., & Frade, M. M. (2017). Intelligent tutorial system based on personalized system of instruction to teach or remind mathematical concepts. *Journal of Computer Assisted Learning*. https://doi.org/10.1111/jcal.12186

*Paiva, R. C., Ferreira, M. S., Mendes, A. G., & Eusébia, A. M. J. (2015). Interactive and multimedia contents associated with a system for computer-aided assessment. *Journal of Educational Computing Research*, *52*(2), 224-256. https://doi.org/10.1177/0735633115571305

*Pezzino, M. (2018). Online assessment, adaptive feedback and the importance of visual learning for students. The advantages, with a few caveats, of using MapleTA. *International Review of Economics Education*, *28*, 11-28. https://doi.org/10.1016/j.iree.2018.03.002

*Riegel, K., & Evans, T. (2021). Student achievement emotions: Examining the role of frequent online assessment. *Australasian Journal of Educational Technology*, *37*(6), 75-87. https://doi.org/10.14742/ajet.6516

*Robinson, M., Loch, B., & Croft, T. (2015). Student perceptions of screencast feedback on mathematics assessment. *International Journal of Research in Undergraduate Mathematics Education*, *1*, 363-385. https://doi.org/10.1007/s40753-015-0018-6

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, *15*(1), 20-27. https://doi.org/10.1016/j.tics.2010.09.003

*Rønning, F. (2017). Influence of computer-aided assessment on ways of working with mathematics. *Teaching Mathematics and Its Applications*, *36*, 94-107. https://doi.org/10.1093/teamat/hrx001

Rowland, C. A. (2014). The effect of testing versus restudy on retention: A meta-analytic review of the testing effect. *Psychological Bulletin*, *140*(6), 1432-1463. https://doi.org/10.1037/a0037559

*Rutkowski, L., Rutkowksi, D., Valdivia, D. S., Underhill, S., & Canbolat, Y. (2023). Measurement properties as a possible cause of digital device effects on a standardized assessment of learning. *Studies in Educational Evaluation*, *77*, 101261. https://doi.org/10.1016/j.stueduc.2023.101261

*Scherer, R., & Siddiq, F. (2015). The Big-Fish-Little-Pond-Effect revisited: Do different types of assessments matter? *Computers and Education*, *80*, 198-210. https://doi.org/10.1016/j.compedu.2014.09.003

References

Scouller, K. (1998). The influence of assessment method of students' learning approaches: Multiple choice question examinatio n versus asssignment essay. . *Higher Education*, *35*(4), 453-472. https://doi.org/10.1023/A:1003196224280

*See, B. H., Gorard, S., Lu, B., Dong, L., & Siddiqui, N. (2022). Is technology always helpful?: A critical review of the impact on learning outcomes of education technology in supporting formative assessment in schools. *Research Papers in Education*, *37*(6), 1064-1096. https://doi.org/10.1080/02671522.2021.1907778

*Smolinsky, L., Marx, B. D., Olafsson, G., & Ma, Y. (2020). Computer-based and paper-and-pencil tests: A study in calculus for STEM majors. *Journal of Educational Computing Research 58*(7), 1256-1278. https://doi.org/10.1177/0735633120930235

*Smolinsky, L., Olafsson, G., Marx, B. D., & Wang, G. (2019). Online and handwritten homework in calculus for STEM majors. *Journal of Educational Computing Research*, *57*(6), 1513-1533. https://doi.org/10.1177/0735633118800808

Struyven, K., & Devesa, J. (2016). Students' perceptions of novel forms of assessment. In G. T. L. Brown & L. R. Harris (Eds.), *Handbook of Human and Social Conditions in Assessment* (1st ed., pp. 129-144). Routledge. https://doi.org/10.4324/9781315749136

Syahbrudin, J., Istiyono, E., Khairudin, M., Anggraini, A., Wusqo, I. U., Mariam, M., & Muflihan, Y. (2025). Computer-based assessment research trends and future directions: A bibliometric analysis. *Contemporary Educational Technology*, *17*(1), e554. https://doi.org/10.30935/cedtech/15743

*Tatira, B., & Kariyana, I. (2022). Defining formative electronic assessment in undergraduate mathematics: A reflective approach. *International Journal of Learning, Teaching and Educational Research*, *21*(7), 24-39. https://doi.org/10.26803/ijlter.21.7.2

*Tomal, J., Rahmati, S., Boroushaki, S., Jin, L., & Ahmed, E. (2021). The impact of COVID-19 on students' marks: A Bayesian hierarchical modeling approach. *METRON*, *79*, 57-91. https://doi.org/10.1007/s40300-021-00200-1

*Valdez, M. T. C. C., & Maderal, L. D. (2021). An analysis of students' perception of online assessments and its relation to motivation towards mathematics learning. *The Electronic Journal of e-Learning*, *19*(5), 416-431.

*Wei, X. (2024). Text-to-speech technology and math performance: A comparative study of students with disabilities, English language learners, and their general education peers. *Educational Researcher*, *53*(5), 285-295. https://doi.org/10.3102/0013189X241232995

*Wei, X., Zhang, S., & Zhang, J. (2025). Digital pencil usage and mathematics performance among students with learning disabilities and their general education peers. *Journal of Special Education Technology*, *0*(0), 1-13. https://doi.org/10.1177/01626434251314041

Weigand, H., Trgalova, J., & Tabach, M. (2024). Mathematics teaching, learning, and assessment in the digital age. *ZDM – Mathematics Education*, *56*, 525-541. https://doi.org/10.1007/s11858-024-01612-9

*Wu, H., Kuo, B., & Wang, S. (2017). Computerized dynamic adaptive tests with immediately individualized feedback for primary school mathematics learning. *Educational Technology and Society*, *20*(1), 61-72.

*Zegowitz, S. (2023). Evaluating the use of e-assessment in a first-year pure mathematics module. *Teaching Mathematics and Its Applications*, *42*, 109-125. https://doi.org/10.1093/teamat/hrac011

THANK YOU

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