ASCILITE 2023
People, Partnerships and Pedagogies

How can EdTech Personalise the Instruction for Tertiary Students Requiring Mathematics Support?

Benjamin Halpin, Paul Trotter and Robert Vanderburg
Central Queensland University

Many students enter mathematically intensive courses with deficiencies in their mathematical skills. Universities have responded to this challenge with additional support. However, existing approaches have exhibited limited success. This paper proposes research into the effectiveness of a personalised approach to mathematical remediation driven by the affordances of EdTech.

Keywords: Mathematics, Personalised Learning, Remediation, EdTech

Introduction

Concerns regarding the inability of some students to successfully meet the demands of mathematically intensive courses at the tertiary level have been of longstanding disquiet (Fitzmaurice et al., 2021; Rylands & Coady, 2009). The consequences of these deficiencies impact pass rates and retention levels and can potentially limit academic pathways (King & Cattlin, 2015). Universities have responded to these challenges by offering additional courses and remediation programs (Rylands & Shearman, 2018). Fredriksen (2021), whilst recognising that traditional lecture-based teaching remains the norm in tertiary mathematics education, reports that EdTech has been found to impact student success and reduce failure rates positively. However, few studies have utilised the full potential of EdTech (Mullen et al., 2022) to personalise the remediation process, and the need to adapt instructional practises to the needs of a growingly diverse population of students would seem essential (Alexander et al., 2019). Given the diversity of students' needs (Tomlinson, 2017), this work proposes exploring personalised learning models powered by EdTech's affordances. It reports on preliminary findings from a pilot study with the research objective: "Does a personalised approach to mathematics instruction that deploys the affordances of EdTech enhance tertiary students' mathematics learning?".

The problem of mathematical deficiency

It has been suggested that students are entering mathematics-dependent disciplines with fewer essential numerical skills required to succeed (King & Cattlin, 2015). Rylands & Coady (2009) report Australian academics' concern over nursing students being unable to calculate dosage, engineering students coping poorly with algebra, and science students lacking statistics skills. This research then compared these outcomes to their performance in secondary school mathematics. Rylands & Coady (2009) found that students' prior experience in secondary school mathematics significantly predicted tertiary success and that these 'under-prepared' students exhibited a broad range and combination of concerns that involved significant gaps in their knowledge of mathematical concepts critical to their future success. Perhaps unsurprisingly, Rylands & Coady (2009) also found that students who had trouble with mathematics in secondary school continued to experience difficulty at the tertiary level. Recently, Geisler et al. (2023) sampled 274 first-year students enrolled in mathematics or teacher education programs and found that 100 students dropped out during or directly after their first year of study. This study found that these students' mathematical self-concept was a good predictor of early dropout. Geisler et al. (2023) reasoned that students with a high self-concept seemed able to work through challenges and were more persistent. They also noted that mathematical self-concept is reciprocal to achievement (see Wu et al., 2021). Interestingly, Rylands & Coady (2009) also note that whilst some students struggled to pass mathematical components of their tertiary studies, others found the same components easy and unchallenging, supporting the contention that students' needs in this area remain diverse. Rylands & Coady (2009) intimate that remediation of these challenges lies in a more differentiated, personalised approach to supporting students with the further implication from the work of Geisler et al. (2023) suggesting that mitigating the issue prior to or immediately upon tertiary entry may be critical if dropout rates are to be arrested.

Examining Existing Attempts at Mathematics Support

It has been suggested that a relaxation of entry requirements for mathematics-dependent tertiary study has compounded the challenge of supporting students with gaps in their mathematical understanding (King & Cattlin, 2015). The shift from hard prerequisites to assumed knowledge, whilst positively empowering greater numbers of students to study at tertiary level from evermore diverse backgrounds, may have had unexpectedly negative impacts on pass and retention rates. King & Cattlin (2015) interviewed 40 Australian and New Zealand academics. They found that 69% of interviewees reported difficulty adapting their teaching to cater to student's diverse needs. It was found that bridging programmes were required to start at a much lower mathematical level, with 77% of respondents reporting that students without assumed knowledge posed a significant challenge to their teaching efficacy. Rylands & Shearman (2018) examined the effect of a math support programme provided to first-year engineering students at an Australian university that utilised in-person and online components. Initially, 268 students sat a placement test, from which 145 enrolled in a preliminary mathematics course instead of a standard mathematics course. The identified students had access to support workshops, online quizzes, tutorials, and various additional resources hosted online. It was determined that using a placement test seemed to motivate students to engage more with the available support. Rylands & Shearman (2018) further explain that a close examination of their findings revealed that the most significant progress was made by those students who accessed the support materials the most. However, despite the relatively high use of support, the failure rate of students remained stubbornly high at almost 38%. Mullen et al. (2022) interviewed students and academic staff from universities in Ireland and Australia. The primary means of provision of mathematics support prior to the COVID-19 pandemic had been via a drop-in model, in which students access assistance from a tutor of their own volition for face-to-face assistance. Mullen et al. (2022) found that the move online resulted in a decrease in students accessing support. Tutors found diagnosing students' problems harder, but tutors also reported that they tended to answer students' questions more fully online and drew on a broader range of resources. Likewise, students seemed more confident in asking questions using chat facilities online than when in person. Mullen et al. (2022) report that students who experienced online mathematical support praised it, noting that their support was more interactive and equitable. Students also reported that they were provided with a learning experience adapted to individual needs. This research would suggest that, whilst the recent impetus for online support may have stemmed from the pandemic, there are positive lessons to be learned. Significantly, the apparent ability of Edtech to support individual student needs should be examined.

Examining the Potential of a Technology-Enhanced Personalised Learning Approach

However, studies focusing on using technology-enhanced personalised learning of mathematics instruction at the tertiary level remain scarce. Evidence for the effectiveness of such an approach comes from Vanderburg et al. (2022) who developed a digital mathematics portal that empowered students to develop their mathematical competence using technology. Students were encouraged to identify their deficiencies using a pre-test and create their learning pathways by engaging with a wide range of support materials using an LMS platform. The platform incorporated general discussion and error/suggestion forums that enabled feedback. Research by Mullen et al. (2022) reinforced the need for social interaction within mathematics support initiatives. This need seems to have grown in importance considering the after-effects of the pandemic, with tutors and students alike concerned by the lack of peer connection online and the effects of this on the quality of their learning. A significant observation was that much valuable mathematical learning can occur socially among peers, which happens most effectively in in-person interactions. (Mullen et al., 2022, p. 77). Quantitative data from the Vanderburg et al. (2022) study showed statistically significant improvement in students' mathematical skills. Additionally, qualitative data supported the overall effectiveness of the approach. However, it also revealed that students found the flexibility of the portal key and its capacity to personalise their learning invaluable.

Fredriksen (2021) examined the effectiveness of a mathematics support system incorporating in-person tutorials and online support materials. This study focused on computer engineering students in their first year of tertiary studies at a Norwegian university. Examination of classroom observations suggested that student performance was enhanced with increased engagement with the online learning materials. The study found that a key benefit of this approach over traditional lectures was an apparent increase in student engagement and participation with student interactions shifted from the procedural acquisition of skills towards deeper conceptual understanding and problem-solving. The Fredriksen (2021) study characterised the contention that EdTech can be deployed to enhance mathematical understanding. A recent study (Mullen et al., 2023) compared and contrasted students' perceptions of differing models of mathematical support. A series of six surveys were conducted across two universities, rating the quality of their experience and preferences for future support. Three groups were examined, with one group receiving both traditional and online support, a second receiving predominantly online support and a third with predominantly traditional support. Results highlighted statistically significant differences between groups that had experienced traditional support and those that had received support supplemented by EdTech. Whilst students did express a preference for in-person support, there was a definite desire for EdTech to supplement that offering. When asked about future mathematical support, students expressed a clear desire for a blended approach to continue, with increased emphasis on the learning experience's flexibility and personalisation. Students wanted to study at a time of their choosing and have increased access to private consultations and increased guidance.

A significant study specifically focused on the effect of personalised learning came from the work of the RAND Corporation, an American-based non-profit organisation**.** (Pane et al., 2015; Pane et al., 2017). This study involved approximately 11,000 students across the USA and sought to evaluate whether technology-enhanced personalised learning practices positively impacted student attainment. They employed comprehensive measures, including site visits, interviews, teacher logs, surveys, and student attainment data. This study employed individualised learner profiles and enabled learners to embark on their personalised learning pathways powered by the affordances of technology. The RAND study (Pane et al., 2015; Pane et al., 2017) concluded that a majority of students in the study exhibited positive effects associated with progress in mathematics performance throughout the study. Many students with lower starting achievement levels experienced greater growth than their peers. Further evidence for the effectiveness of a personalised learning approach came from the Bendigo Education Plan (Prain et al., 2013; Prain et al., 2017; Waldrip et al., 2014). The project sought to investigate students' learning experiences in regional Australia, involving approximately 3400 subjects. This was a wide-ranging study with several sub-components; one was to examine students' perceptions of how they had been provided with a personalised learning environment using a survey of 2407 students, along with a case study of one attempt to apply a personalised approach to mathematics instruction. In general, an improvement in students' motivation was observed. Quantitative improvements in student attainment reinforced perceptions of improvements highlighted by qualitative means. Students who participated in the study increased their scale scores by 46 points compared to a state mean of 39.7.

As Tomlinson (2017) explains, the goal of honouring the learning needs of the individual and embracing the tenet that our students are diverse would seem unarguably laudable. However, questions remain regarding how such an approach can be successfully implemented (Bradford et al., 2021; Tomlinson, 2017). One such challenge comes from the work of Pane et al. (2015; Pane et al., 2017) who report that many teachers reported that allowing students to progress at their own pace through content was challenging. This was especially so when students did not complete work at an acceptable pace. They perceived a tension between offering student choice and the need to address standards, noting that extensive student choice made collaboration challenging. Definitions of personalised learning commonly incorporate notions of student-centred learning that value the individual's prior knowledge and experience. Definitional consensus seems to have emerged with Bray and McClaskey (2014, 2015) aligning their definition of personalised learning with the theorist Lev Vygotsky and the concept of social constructivism whilst simultaneously incorporating student choice as a critical element that differentiates such an approach from that of individualisation. Inherent in this definition remains the potential for tension between subcomponents of the definition. As Ballard and Butler state, "a focus on personal choice within this agenda is often contradictory to personalised learning, which in essence must seek to discover and deliver the optimal instruction for a particular learner" (2011, p. 21). This points to an underlying tension between student choice and teacher responsibility that can be challenging to reconcile (Sebba et al., 2007).

Applying Technology-Enhanced Personalised Learning to Mathematics Support

Given those inherent tensions (Ballard & Butler, 2011) and a lack of research evidence (Albeshree et al., 2022), this proposed study will be guided by the research objective of ascertaining whether a technology-enhanced personalised learning approach to mathematics instruction can be used to enhance students' learning using the following research questions (RQ):

RQ1. Does the use of technology-enhanced personalised learning improve students' mathematical skills?
RQ2. What elements of the technology-enhanced personalised learning initiative were perceived as most beneficial?

A quantitative method would seem appropriate as RQ1 examines whether technology-enhanced personalised learning impacts students' mathematical skills. Conversely, RQ2 aims to provide an in-depth intervention analysis, and a qualitative method would seem appropriate. As a result, a convergent mixed methods approach will be adopted (Creswell & Clark, 2011). This mixed methods approach collects and analyses two data sources, one quantitative and the other qualitative, before merging the two databases for comparison.

Additionally, given the intimate relationship between secondary school performance in mathematics and tertiary-level success in mathematically dependent courses (see Geisler et al., 2023), any potential impact should be measured in both the secondary and tertiary sectors. The purpose of targeting both sectors would be to determine the most pertinent timing of any future intervention should the potential efficacy of a personalised approach be realised. Geisler et al. (2023) found that 36.5% of students dropped out of tertiary education during or immediately after their first year of study. This would provide insight into whether technology-enhanced personalised learning should be employed prior to or alongside students' commencement of tertiary study.

The intervention will blend in-person support with an online component that will involve a pre-test that will be used to inform students about their specific level of mathematical attainment. Students will be supported to use the pre-test diagnostically to set targets for their learning and produce a personalised learning plan. The students will then choose from various learning activities specific to their individual learning goals. A conventional learning management system (LMS) will provide students with a range of optional video materials, worked examples, and other online materials on their targeted areas for development. Critically, the students will also have access to an online mathematics tool that will provide students with targeted questions. Adaptive question technology will modify the complexity of questions provided to each individual depending on their performance. Students experiencing difficulty will receive easier questions, and correct answers will increase the difficulty. Partially correct answers will require refinement before the next question can be attempted. The mathematics intervention will also give students hints and question-specific video support. At the end of each student-selected activity, the students will also have the option to complete personalised remediation work based on their most challenging questions. Throughout the process, tutors will be available to students using online forums and chat facilities. The intervention will involve a range of online tools to support social interaction, enabling students to interact with each other. A post-test will then be administered to enable progress to be quantitively measured. Qualitative data from online forum participation will then be thematically analysed (Guest et al., 2011).

Significance and Expected Outcomes

At this early stage of the research, the mathematical support intervention is under development and small-scale trials have commenced, with early findings tentatively emerging. However, caution must be exercised given the preliminary nature of this work and that the pilot's sample is currently limited to secondary students with work with tertiary level students not yet instigated. Rather than label these findings as preliminary, we should discuss expected outcomes informed by ongoing evidence from the pilot. When this project is fully operationalised, students taught using a technology-enhanced personalised learning approach are expected to outperform those traditionally instructed. Quantitative data from the initial pilot suggests that a program tailored to the individual's needs is more effective at improving mathematical performance than present orthodox approaches. Across various mathematical topics, students from the pilot study who experienced the personalised learning intervention outperformed their peers. Substitution of the intervention to a different group of students seemingly reversed this trend, and the group who had made comparatively slow progress using a traditional approach now increased their rate of progress given the personalised approach. Longstanding concerns regarding the inability of some students to successfully meet the demands of mathematically intensive courses at the tertiary level have been compounded by the disruption to learning brought about by the COVID-19 pandemic. Universities' efforts to support students have pivoted to online instruction through necessity. Despite the challenges of these unexpected world events, the affordances of technology have re-emerged to meet the ever-diverse needs of learners. Recognising the limitations of a one-size-fits-all would seem laudable. However, questions remain regarding how such an approach can be successfully implemented (Bradford et al., 2021; Tomlinson, 2017). The purpose of this proposed study is to contribute to formulating those answers.

References

Albeshree, F., Al-Manasia, M., Lemckert, C., Liu, S., & Tran, D. (2022). Mathematics teaching pedagogies to tertiary engineering and information technology students: a literature review. *International journal of mathematical education in science and technology*, *53*(6), 1609-1628. https://doi.org/10.1080/0020739X.2020.1837399

Alexander, B., Ashford-Rowe, K., Barajas-Murph, N., Dobbin, G., Knott, J., McCormack, M., Pomerantz, J., Seilhamer, R., & Weber, N. (2019). *Horizon report 2019 higher education edition*.

Ballard, J., & Butler, P. (2011). Personalised Learning: Developing a Vygotskian Framework for E-learning. *International Journal of Technology, Knowledge and Society*, *7*(2), 21-36. https://doi.org/https://doi.org/10.18848/1832-3669/CGP/v07i02/56198

Bradford, B. C., Beier, M. E., & Oswald, F. L. (2021). A Meta-analysis of University STEM Summer Bridge Program Effectiveness. *CBE life sciences education*, *20*(2), ar21-ar21. https://doi.org/10.1187/cbe.20-03-0046

Bray, B., & McClaskey, K. (2014). *Make learning personal: The what, who, wow, where, and why*. Corwin Press.

Bray, B., & McClaskey, K. (2015). Personalization vs differentiation vs individualization. *Viitattu*(16), 1-13.

Creswell, J. W., & Clark, V. P. (2011). *Mixed methods research*. SAGE Publications.

Fitzmaurice, O., Walsh, R., & Burke, K. (2021). The 'Mathematics Problem' and preservice post primary mathematics teachers - analysing 17 years of diagnostic test data. *International journal of mathematical education in science and technology*, *52*(2), 259-281. https://doi.org/10.1080/0020739X.2019.1682700

Geisler, S., Rach, S., & Rolka, K. (2023). The relation between attitudes towards mathematics and dropout from university mathematics—the mediating role of satisfaction and achievement. *Educational studies in mathematics*, *112*(2), 359-381. https://doi.org/10.1007/s10649-022-10198-6

Guest, G., MacQueen, K. M., & Namey, E. E. (2011). *Applied thematic analysis*. sage publications.

King, D., & Cattlin, J. (2015). The impact of assumed knowledge entry standards on undergraduate mathematics teaching in Australia. *International journal of mathematical education in science and technology*, *46*(7), 1032-1045. https://doi.org/10.1080/0020739X.2015.1070440

Mullen, C., Cronin, A., Pettigrew, J., Shearman, D., & Rylands, L. (2023). Optimising the blend of in-person and online mathematics support: the student perspective. *International journal of mathematical education in science and technology*, 1-21.

Mullen, C., Pettigrew, J., Cronin, A., Rylands, L., & Shearman, D. (2022). The rapid move to online mathematics support: changes in pedagogy and social interaction. *International journal of mathematical education in science and technology*, *53*(1), 64-91. https://doi.org/10.1080/0020739X.2021.1962555

Pane, J. F., Steiner, E. D., Baird, M. D., & Hamilton, L. S. (2015). *Promising evidence on personalized learning*. https://www.rand.org/pubs/research_reports/RR1365.html

Pane, J. F., Steiner, E. D., Baird, M. D., Hamilton, L. S., & Pane, J. D. (2017). *How does personalized learning affect student achievement?* https://www.rand.org/pubs/research_briefs/RB9994.html

Prain, V., Cox, P., Deed, C., Dorman, J., Edwards, D., Farrelly, C., Keeffea, M., Lovejoy, V., Mow, L., Sellings, P., Waldrip, B., & Yagera, Z. (2013). Personalised learning: lessons to be learnt. *British Educational Research Journal*, *39*(4), 654-676.

Prain, V., Waldrip, B., Sbaglia, R., & Lovejoy, V. (2017). Towards personalising learning in school science: Making this learning more relevant. *Teaching Science*, *63*(1), 27-33.

Rylands, L. J., & Coady, C. (2009). Performance of students with weak mathematics in first-year mathematics and science. *International journal of mathematical education in science and technology*, *40*(6), 741-753.

Rylands, L. J., & Shearman, D. (2018). Mathematics learning support and engagement in first year engineering. *International journal of mathematical education in science and technology*, *49*(8), 1133-1147. https://doi.org/10.1080/0020739X.2018.1447699

Sebba, J., Brown, N., Steward, S., Galton, M., James, M., & Publications, D. (2007). *An investigation of personalised learning approaches used by schools*.

Tomlinson, C. A. (2017). Let's celebrate personalization: But not too fast. *Educational Leadership*, *74*(6), 10-15. http://www.ascd.org/publications/educational-leadership/mar17/vol74/num06/Let's-Celebrate-Personalization@-But-Not-Too-Fast.a

Vanderburg, R. M., Gibson, N., & Cowling, M. A. (2022). Conquering the LANTITE: Exploring Digital Mathematics Instruction & Test Taking Strategies using a Cognitive Multimedia Framework Based Portal. *International Journal for Technology in Mathematics Education*, *29*(1).

Waldrip, B., Cox, P., Deed, C., Dorman, J., Edwards, D., Farrelly, C., Keeffe, M., Lovejoy, V., Mow, L., Prain, V., Sellings, P., & Yager, Z. (2014). Student perceptions of personalised learning: development and validation of a questionnaire with regional secondary students. *Learning Environments Research*, *17*(3), 355-370. https://doi.org/10.1007/s10984-014-9163-0

Wu, H., Guo, Y., Yang, Y., Zhao, L., & Guo, C. (2021). A meta-analysis of the longitudinal relationship between academic self-concept and academic achievement. *Educational Psychology Review*, 1-30.

Halpin, B., Trotter, P. & Vanderburg, R. (2023). How can EdTech Personalise the Instruction for Tertiary Students Requiring Mathematics Support? In T. Cochrane, V. Narayan, C. Brown, K. MacCallum, E. Bone, C. Deneen, R. Vanderburg, & B. Hurren (Eds.), *People, partnerships and pedagogies*. Proceedings ASCILITE 2023. Christchurch (pp. 415–419). DOI: https://doi.org/10.14742/apubs.2023.530