ASCILITE 2024

Navigating the Terrain:

Emerging Frontiers in Learning Spaces, Pedagogies, and Technologies

Preparing students for success: From pedagogical foundation to online personalised learning journeys in mathematics

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With increased demand for skilled professionals in science and technology, universities are broadening entry requirements resulting in students entering these specialised degrees with potential knowledge gaps. This presents an opportunity to uplift student capability through personalised learning journeys, enhancing their university readiness. This report details the Monash College's new maths uplift program, which uses skills analysis tools and self-assessment processes to determine “where students are” on their learning journey, both at entry to the Monash College and through to their first year of university. Mapped to the maths requirements of their chosen degree, this program comprises three key components: (1) a comprehensive Teaching and Learning progression that maps the learning trajectory via six core domains of mathematics, (2) a set of skills analysis tests aimed at different entry and exit points in mathematics, and (3) a large set of self-paced online learning modules recommended to students based on the outcomes of their individual skills analysis tests. The three key components work together to provide a tailored educational experience supporting students towards their destination degrees. This paper reports on the development of this uplift program and presents preliminary findings indicating positive impacts on student preparedness and engagement.

Keywords: Mathematics education, university readiness, personalised learning, data analytics, learning diagnostics

Introduction

The rapidly evolving world demands skilled professionals in science and technology, as well as graduates across all disciplines who are proficient in numerical reasoning and data analysis. Universities are addressing this need by broadening entry requirements (van der Merwe et al., 2020), leading to students entering technical degrees with potential knowledge gaps (Deekin et al., 2020). This highlights the necessity to support students in their development of mathematical and technical capabilities. A difficulty when designing any mathematics program to meet this challenge is the diverse teaching of mathematics both within the Australian context and globally (Leung et al., 2006). Effective teaching in today's classrooms hinges on a deep understanding of where students are in their learning journeys and how institutions can guide them towards their goals. Learning progressions, as outlined by Waters (2018), offer a valuable tool to meet these challenges, as they can act as a roadmap, describing the expected path students take as they develop knowledge and skills in a specific domain, like mathematics. Paired with a skills analysis test, students can be placed on the learning progression, giving a clear path for their advancement to the next level of capability in a given subject. To further support this strategy, a range of independent online learning modules were developed and provided to students for their math review and skill enhancement. Dividing content into smaller, independent modules (French, 2015) allows educators to cater to diverse student needs and backgrounds, offering only the necessary content to fill gaps or develop specific skills. Modular teaching, based on dividing the curriculum into independent, non-sequential, and short-duration units, provides greater flexibility and student agency. This method addresses student diversity, promotes independent learning styles, and enhances performance, as evidenced by the study conducted in the Philippines (Papasan, 2015).

Students at the Monash College come from diverse backgrounds, representing over 97 countries in the past decade, with the largest cohort from China, followed by Asia Pacific nations and the Middle East. Their prior education varies widely, ranging from Year 11 equivalents to undergraduate levels, and includes qualifications such as O Levels, A Levels, GAO, and IB. This diversity results in significant differences in students' mathematical knowledge, language proficiency, learning skills, and cultural influences, which all impact their performance in mathematics and their transition to university. With a diverse cohort of international students and a wide array of destination degrees, developing a support program at our institution presented significant challenges. To address this, we leveraged technology to (1) deliver a modularised curriculum and (2) anchor it within coherent learning progressions informed by diagnostic testing. The outcome of this is a personalised, learning journey characterised by assigned online learning modules. Additionally, individual learning journeys are mapped to destination requirements, enabling students to pursue the most efficient and effective path to their goals. This content sits alongside students' normal curriculum as supporting material.

The underlying philosophy is to identify “where students are'' in their mathematics learning journey and map this against their desired outcomes or “where they want to go”, thereby creating a clear path towards the discipline-specific mathematical needs of their degree programs. By illuminating individual learning journeys in this manner, we can target areas requiring improvement and deprioritise areas of existing strength, thus facilitating efficient and impactful learning enhancement.

Method

Teaching and learning progression
The National Numeracy Learning Progression (Australian Curriculum, Assessment and Reporting Authority, 2024) and the ACER Mathematics Learning Progression (ACER, 2024) provide useful guidance on the development of maths capabilities across grade levels. These level descriptors, however, are too broad for classroom teaching and assessment purposes. This can make it difficult to design assessment items that target varying levels of maths proficiency and tailor instruction accordingly. To fill this gap, an in-house Teaching and Learning Progression of mathematics was built. It is given the label of “teaching and learning” over a pure learning progression, as it is primarily based on the structure of curriculum and not on observed student learning abilities in mathematics. Starting with the six areas of study from the Victorian Certificate of Education (VCE), these were mapped as domains on a learning progression each having between two to five strands. Under each strand was a set of capabilities and then indicators. Further to this, indicators have relevant quality criteria levels, which map the progress from Year 9 and under up to a first year university capability level. Note that as the focus was on the skills deemed essential for success at entry points of the university, not all areas of mathematics were mapped at all levels. Despite this, in total there are 938 level statements for 181 indicators. This magnitude shows the breadth that the material covered.

Skills analysis test
Once the Teaching and Learning Progression was developed, skills analysis tests were designed to diagnose students’ maths ability for various entry points at Monash College. The test development followed a standard process including planning, content definition, item development, test design, administration, scoring, standard setting, score reporting, item banking, and technical reporting (Downing, 2006). Due to insufficient overlap in content among the three central entry points of Business, IT, and Engineering, three separate tests were developed. Each test targeted relevant domains, strands, capabilities, and indicators informed by the Teaching and Learning Progression. Table 1 details the intended student groups, the targeted levels, the item numbers, and the content structure of these tests. A distinguishing feature of these tests is the use of open-ended, short-answer questions instead of objective types like multiple choice. The System for Teaching and Assessment using a Computer algebra Kernel (STACK) assessment platform, embedded in Moodle (Sangwin2015), allows for high-level cognitive questions, enabling students to input mathematical symbols, expressions, and reasoning steps with automated marking. This approach increases score reliability by reducing the chances of guessing correct answers.

Table 1 *Descriptions of three Skills analysis tests*

Test name	Intended student group	External level reference	Item number	Content and structure
Preliminary Skills Analysis Test	Diplomas Part 1	Equivalent to Foundational skills, Year 11 maths, and General Maths units 3 and 4	33	Algebra number and structure (11 items); Data analysis probability and statistics (7 items); Discrete mathematics (4 items); Space and measurement (8 items); Functions Relations and Graphs (3 items)
Intermediate Skills Analysis Test	Diplomas Part 2 for Science and Business, equivalent to Year 12	Equivalent to Foundational skills, Year 11 maths, and Maths Methods units 3 and 4	28	Algebra number and structure (10 items); Space and measurement (5 items); Relations, Functions and Graphs (8 items); Calculus (5 items)
Advanced Skills Analysis Test	Diplomas Part 2 for IT and Engineering	Equivalent to Foundational skills, Year 11 maths, and Maths Methods units 3 and 4	32	Algebra number and structure (9 items); Space and measurement (5 items); Relations, Functions and Graphs (10 items); Calculus (8 items)

The three skills analysis tests were piloted in Trimester 3 of 2023 on Diplomas Part 1 students in Science, Business, IT, and Engineering. Classical test theory and Rasch modelling (Rasch, 1960) were used to evaluate the psychometric properties of the tests and items. Items with poor measurement properties or content issues were reviewed, revised, or replaced by subject matter experts (SMEs). For items fitting the Rasch model and showing appropriate measurement properties, scales of mathematics proficiency levels were produced from each test's data. SMEs reviewed these scales, ensuring the descriptions of knowledge and skills were meaningful and demonstrated clear progressions of increasing competence, providing evidence of construct validity (Glaser, 1963; Wright & Masters, 1982). Items misaligned on the scales were also reviewed and adjusted by SMEs, as guided by the Teaching and Learning Progression. Following validation and revision, the Preliminary Skills Analysis Test was administered to over 600 Diplomas Part 1 students in Trimester 1 of 2024. Further validation was conducted before utilising item-level scores and test scores to guide students on which online learning modules to undertake for refreshing or enhancing their maths knowledge and skills.

Online learning modules
A multimodal design methodology following Universal Design for Learning (UDL) principles (CAST, 2024) and multimedia cognitive theory (Mayer, 2024) was used to develop the online learning modules. Core concepts were presented by math teachers and shown visually and textually in formats like video, interactive graphs, and written descriptions, catering to diverse learners. Interactive on-screen questions prevented passive watching and encouraged engagement. Quiz questions followed topic exposition to reinforce learning (Karaca & Akyuz, 2024). Built on Moodle, the modules covered six mathematical domains and were assigned based on diagnostic test results. This personalised approach allowed students to engage with relevant content. Each module included an introduction, learning journeys, activities, practice questions, and a final self-check. Students needed to score 80% or higher to complete a module, promoting mastery-based learning through unlimited attempts. The flexible structure of the modules let students prioritise activities in areas needing improvement, while the learning material itself focussed on real-world application, driving enhanced engagement and retention. The Moodle plugin STACK enabled the use of higher-order questions and offered automated grading and immediate feedback. This ensured faster progression for students mastering concepts quickly and targeted guidance for those needing extra practice. We identified three key challenges in teaching mathematics online. The first challenge is English language proficiency (Karaca & Akyuz, 2024). The second challenge, also noted by Karaca & Akyuz (2024), was the lack of interaction with teachers and peers, leading to disengagement. Codding et al. (2023) also highlighted that a lack of connection between independent modules

and formal courses could result in disengagement. To address the first challenge, we ensured that material targeted the appropriate language level of the students and reducing text in later revisions to lower cognitive load. To solve the second and third challenges, we built a community through a program called Passport 2 Maths, starting with face-to-face orientation and continuing with the Maths Hub, a drop-in space dedicated to maths support. Weekly maths workshops further promoted engagement, and teacher participation focused on aligning online modules with study areas and assessments, motivating students with clear expectations. The modules were piloted in Trimester 1 2024 with a cohort of Diploma Part 1 students. Engagement with the modules was tracked and then analysed based on two sets of students: 1) high achievers, those scoring above 70% in final exams and 2) low achievers, those scoring below 60%. Midtier students were not analysed. Engagement was categorised as no attempt, partial attempt (completing some modules), full attempt (completing all recommended modules), and extra attempt (completing more modules than recommended).

Preliminary results

While it is early in the delivery of this new program, initial findings indicate the maths uplift program is successful. The soundness of the design of the Teaching and Learning Progression has been measured against predictive performance in a unit. Early data indicates that skills analysis test results are a strong predictor of final grades in the piloted units. This gives confidence that the specific areas students need further growth are correctly being identified. Validity testing was conducted for each of the three skills analysis tests and is presented below.

Preliminary Skills Analysis Test
66 students took the pilot Preliminary Skills Analysis Test in Trimester 3, 2023. Data analysis showed that the test scores were highly reliable (Cronbach's alpha coefficient was 0.89, item separation index was 0.90, and person separation index was 0.77). There was a good item spread over the item difficulty-person ability scale. 31 out of 33 test items fit the Rasch measurement model. 2 items were found to misfit the model; they also had low discrimination indices (under 0.2). SMEs' feedback showed that there was a clear progression of maths ability from low to high for many items, suggesting a high level of overall construct validity. SMEs suggested changes to the two flagged items. The revised test was administered in Trimester 1, 2024 on 538 students, and empirical data showed higher test score reliability and better item fit and discrimination indices.

Intermediate Skills Analysis Test and Advanced Skills Analysis Test
Following the same analysis above, these two tests were also piloted on small groups of 43 to 45 Diplomas Part 2 students in Trimester 3, 2023. The test scores were validated, and in each of the tests, a small number of items were found to misfit the Rasch measurement model and/or exhibit low discrimination indices. These items were later reviewed by SMEs, and changes to the test items and the instructions to STACK questions were introduced for better clarity. This process ensures the reliability and validity of the set of items making up the two tests.

Learning module results
In one of the pilot units, among 33 high achievers, 39% completed extra modules, while 62.5% of the 40 low achievers did not attempt the modules. Similarly, in the second unit, 48% of the 23 high achievers showed moderate engagement, while 64% of the 22 low achievers had high non-participation rates. The data indicates a clear trend where high achievers tended to engage more with the online support modules, with a significant number of them completing extra modules and performing better in the Self Check-ins. In contrast, low achievers tended to show lower engagement with a substantial proportion not attempting any support modules. As is common with low performing students, increasing participation in support material, in this case the online support modules, could potentially enhance their academic performance.

Conclusion

One of the foundations for the success of this project was the strong pedagogical foundation of the teaching and learning progression. The teaching and learning progression helped inform key decisions during the development of both the skills analysis tests and the online learning modules. Built on this foundation, the skills analysis tests have early signs of strong predictive ability and correctly identify areas students need to develop. Further to this, the strong level of engagement in the online modules by high achievers demonstrates the strength of design of the personalised, modularised learning material. These elements collectively highlight the strength and impact of the Monash College's new maths uplift program in enhancing student preparedness, engagement, and performance.

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