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A narrative review on the integration of digital technologies in MFP1501: A mathematics module for foundation phase pre-service teachers in OdeL

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ABSTRACT

This narrative paper focuses on redesigning the MFP1501, a mathematics module for Foundation Phase pre-service teachers offered at a higher education university in South Africa, an Open Distance e-Learning (ODeL). ODeL means physical distance from the university, self-managed studies, and mostly digital interactions, with written study materials. This study examined the MFP1501 to prepare pre-service teachers to integrate digital technologies in teaching mathematics. The Technological Pedagogical Content Knowledge (TPACK) framework underpinned this study because it provides a lens on interconnected content, pedagogy and technology to guide pre-service teachers in teaching mathematics to young learners. Through Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), fourteen studies from 2020 to 2025 were selected from Google Scholar, Research Gate, Scopus (Elsevier), Web of Science (Clarivate), and the Directory of Open Access Journals (DOAJ) and reviewed to tap into how other higher learning institutions design their modules. The findings revealed that pre-service teachers have limited knowledge of integrating digital technologies and pedagogical approaches in their practice, with access to digital tools and uneven professional development limiting their readiness in the practical world. This paper suggests guidelines for redesigning MFP1501 to integrate content, pedagogical and technological knowledge to support pre-service teachers in their practical work environments. This research contributes to a transformative approach to the redesign of modules using the TPACK framework within the ODeL context, not limited to the MFP1501 module.

Keywords: Foundation Phase, Mathematics, MFP1501, Pre-service Teachers, TPACK

INTRODUCTION

The growing demands of the 21st-century classroom, especially in early years of schooling, call for a transformative approach to teacher training, one that embraces digital innovation to enhance mathematical thinking and pedagogy. Alenezi, Wardat and Akour and Fernández et al. indicate that higher education content should respond to the call for transformation by incorporating pre-service teacher training approaches that effectively integrate digital technologies.[1] Although Khoza and Ngcobo do not focus on mathematics for Foundation Phase pre-service teachers, their research shows that mathematics education in

[1] Mamdouh Alenezi, Saja Wardat, and Mohammed Akour, "The Need of Integrating Digital Education in Higher Education: Challenges and Opportunities," *Sustainability* 15, no. 6 (March 8, 2023): 4782, https://doi.org/10.3390/su15064782; Antonio Fernández et al., "Digital Transformation Initiatives in Higher Education Institutions: A Multivocal Literature Review," *Education and Information Technologies* 28, no. 10 (October 9, 2023):12351–82, https://doi.org/10.1007/s10639-022-11544-0.

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higher education needs to focus on technology to align with the curriculum in the Department of Basic Education (DBE).[2] Higher education should be transformative through digital technologies for the effective preparation of pre-service teachers for the implementation of the curriculum in schools.[3]

However, none of the literature focused on transforming digital technology mathematics module for Foundation Phase teachers, especially offered in open distance e-learning (ODeL) institutions, a gap this study addresses. As a result, this paper focuses on rethinking the integration of digital technologies in MFP1501, a mathematics module for pre-service Foundation Phase teachers in higher education.

MFP1501 is a mathematics module offered by the University of South Africa (UNISA), an ODeL university. This module guide was designed in 2020 to equip second-year pre-service teachers studying towards a four-year Bachelor of Education in the Foundation Phase with knowledge of teaching mathematics to young learners.[4] This module has seven (7) units, including Unit 1: number and number systems, Unit 2: additive relations, Unit 3: multiplicative reasoning, Unit 4: fractions, Unit 5: patterns and relations, Unit 6: space, shapes and measurements and Unit 7: data handling and probability. Therefore, the module benefits pre-service teachers with conceptual understanding of mathematics concepts using constructivist principles that value active learner engagement. A module in higher education should develop the pre-service teachers' understanding of preservice teachers use and application of teaching and learning theories in teaching mathematics.[5] Although the MFP1501 study guide includes digital tools such as videos, quizzes, and online discussion forums, it lacks clear guidance on how to apply them in classrooms, leaving the content fragmented and not well-suited for interactive Foundation Phase activities. The increased use of digital technologies in education has necessitated a critical examination of how effectively these tools are integrated into teacher training, particularly in distance and online learning environments where student-teachers may rely heavily on virtual resources for skill development.[6] However, this paper focused on rethinking the MFP1501 module to equip pre-service teachers with knowledge of digital diverse teaching strategies, including the use of virtual manipulatives, gamification and real-life problem contexts to teach mathematics in the Foundation Phase.

The study seeks to answer this question:

(1) How can the MFP1501 module be redesigned to support pre-service teachers' use of digital technologies in teaching mathematics in the Foundation Phase?

Guided by the research question, the following objectives underlie the study:

(1) To examine the MFP1501 module to support pre-service teachers' use of digital technologies in teaching mathematics in the Foundation Phase.
(2) To rethink the redesign of MFP1501 module to align with the development of technological and pedagogical approaches in mathematics teaching
(3) To suggest guidelines of redesigning MFP1501 module to integrate technological and pedagogical approaches in mathematics teaching for Foundation Phase learners.

LITERATURE REVIEW

Different higher education policies call for the integration of digital technologies in teaching and learning activities globally. Firstly, the United Nations Educational, Scientific and Cultural Organisations (UNESCO) and Incheon Education 2030 international framework emphasise the importance of Information

[2] Mfundo Mondli Khoza and Annatoria Zanele Ngcobo, "Forces Influencing Technical Mathematics Curriculum Implementation: Departmental Heads' Understanding of Their Practices to Enact Roles and Responsibilities," *Education Sciences* 15, no. 1 (January 18, 2025): 103, https://doi.org/10.3390/educsci15010103.

[3] Alenezi, Wardat, and Akour, "The Need of Integrating Digital Education in Higher Education: Challenges and Opportunities"; Fernández et al., "Digital Transformation Initiatives in Higher Education Institutions: A Multivocal Literature Review"; Khoza and Ngcobo, "Forces Influencing Technical Mathematics Curriculum Implementation: Departmental Heads' Understanding of Their Practices to Enact Roles and Responsibilities."

[4] UNISA, *MFP1501: Learning towards Teaching Mathematics in the Foundation Phase* (Pretoria: University of South Africa, 2023).

[5] Nafasov Ganisher Abdurashidovich, "Theoretical Basis Of Development Of Cognitive Competence Of Students Of Higher Education Institutions In The Process Of Teaching Elementary Mathematics.," *European Journal of Molecular and Clinical Medicine* 8, no. 1 (2021): 789–806.

[6] Lisbeth Amhag, Lisa Hellström, and Martin Stigmar, "Teacher Educators' Use of Digital Tools and Needs for Digital Competence in Higher Education," *Journal of Digital Learning in Teacher Education* 35, no. 4 (2019): 203–20.

Communication Technologies (ICT), Massive Open Online Courses (MOOCs) and distance learning models to expand educational access, equity and lifelong learning.[7] In addition, digital technologies must be integrated meaningfully into higher education, especially in pre-service training programmes.[8] The emphasis is on building digital competencies, modelling effective pedagogical use of ICT, and creating digitally rich environments that align with the shift toward inclusive, accessible, and future-fit education systems.[9] Second, the integration of up-to-date digital skills and innovation platforms is advocated to strengthen employability and teaching effectiveness in post-school education, aligning directly with Sustainable Development Goal 4 to improve the quality of education.[10] To support of these policy initiatives, UNISA's digital transformation aligns with its Vision 2030 and Catalytic Niche Areas (CNAs), which envision the institution as a fully blended and adaptive digital institution that supports lifelong and inclusive learning through equitable technology access.[11] Therefore, this paper responds to these policies by rethinking how digital technologies are integrated into MFP1501 to deliver theoretical content and pedagogical content knowledge and support the development of mathematics teaching practices for pre-service teachers.

More recent attention on the growing body of research has investigated the curriculum design, implementation and effectiveness of digital technology in mathematics and science modules for pre-service teachers in South African higher education. A growing body of research explores the design, implementation and effectiveness of digital mathematics modules tailored for Foundation Phase pre-service teachers. For example, a study was conducted at the Central University of Technology on the adoption of MindTap Math Foundations platform to support pre-service mathematics teachers.[12] It was suggested that the use of gamified adaptive systems should be considered in shaping future teachers' digital pedagogical skills in mathematics.[13] Although the focus was on numeracy in general, the findings highlight the potential of platforms like MindTap to inform the design of technology-integrated modules similar to MFP1501, especially in modelling digital pedagogical practice for future teachers. A different study explored how the Moodle e-learning platform was used to transform the curriculum delivery of the physical science module at the University of Kwa Zulu Natal.[14] Even though not specific to mathematics, the study provides rich insights into lecturers' reflective practices when designing interactive online modules and decolonising course content using technology, highlighting the significance of module design expertise, reflective pedagogy, and e-learning literacy among academic staff.[15]

Internationally, research was conducted at Mykhailo Drahomanov National Pedagogical University, Ukraine to establish the use of CoCalc, a cloud-based environment, to develop professional competencies in mathematics teachers.[16] The researcher systematically designed an online module with stages, tools and assessment criteria, demonstrating how cloud services can facilitate deeper conceptual understanding and modelling of mathematics teaching practices.[17] Students in rural higher education still need to have the knowledge of using various digital technologies in mathematics.[18] Similarly, to embed sustainable mathematics in higher education, the module designers need to use methods that include technology-based

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[7] UNESCO, " Education 2030: Incheon Declaration and Framework for Action Towards Inclusive and Equitable Quality Education and Lifelong Learning for All," 2015, https://iite.unesco.org/publications/education-2030-incheon-declaration-framework-action-towards-inclusive-equitable-quality-education-lifelong-learning/.

[8] UNESCO, *Reimagining Our Futures Together: A New Social Contract for Education* (Paris: UNESCO, 2021).

[9] UNESCO, *Reimagining Our Futures Together: A New Social Contract for Education*.

[10] Department of Higher Education and Training (DHET), *Draft Policy Framework for Enhancing Digital Learning in Post-School Education and Training (PSET)* (Pretoria: DHET, 2020).

[11] UNISA, "Catalytic Niche Areas. Pretoria: University of South Africa," 2025, https://www.unisa.co.za/sites/corporate/default/Colleges/College-of-Graduate-Studies/Catalytic-Niche-Areas/Areas.

[12] D.H. Delport, "Numeracy Students' Perspectives on a New Digital Learning Tool at a South African University," *South African Journal of Higher Education* 33, no. 5 (November 2019), https://doi.org/10.20853/33-5-3588.

[13] Delport, "Numeracy Students' Perspectives on a New Digital Learning Tool at a South African University."

[14] Cedric Bheki Mpungose, "Is Moodle or WhatsApp the Preferred E-Learning Platform at a South African University? First-Year Students' Experiences," *Education and Information Technologies* 25, no. 2 (March 6, 2020): 927–41, https://doi.org/10.1007/s10639-019-10005-5.

[15] Mpungose, "Is Moodle or WhatsApp the Preferred E-Learning Platform at a South African University? First-Year Students' Experiences."

[16] Maiia V. Popel, "Using Cocalc As A Training Tool For Mathematics Teachers' Pre-Service Training," *Information Technologies and Learning Tools* 68, no. 6 (December 27, 2018): 251, https://doi.org/10.33407/itlt.v68i6.2404.

[17] Popel, "Using Cocalc As A Training Tool For Mathematics Teachers' Pre-Service Training."

[18] Neliswa Gqoli, "Digital Technologies for Mathematics Learning in Rural Higher Education: Students' Perspectives," *Research in Social Sciences and Technology* 9, no. 1 (March 7, 2024): 265–78, https://doi.org/10.46303/ressat.2024.15.

methods.[19] The inclusion of gamification and game-based learning activities in vocational education and training was recommended, which requires the use of digital technology.[20]

THEORETICAL FRAMEWORK

The TPACK Lens

To orient the readers, a theoretical framework for this paper is used to support or contradict the findings.[21] This paper is underpinned by the framework of Technological Pedagogical Content Knowledge (TPACK), which provides a wide lens on understanding the interplay between content, pedagogy and technology to inform pre-service teachers in teaching of mathematics to young learners.[22] The framework was built upon the concept of pedagogical content knowledge (PCK) but adds the element of technological knowledge (TK).[23] While the literature highlights the potential of technology to transform mathematics curricula in higher education, Delport and Popel focused on pedagogical integration, with others examining delivery.[24] However, there is little research on structuring module templates that purposefully develop TPACKs for pre-service teachers to teach Foundation-Phase mathematics. This signals a crucial gap and a need to rethink the integration of technology through gamification and game-based learning in mathematics modules such as MFP1501 in higher education institutions.[25]

Drawing from the perspectives of Mishra and Koehler, because the MFP1501 module is designed to prepare pre-service Foundation Phase teachers, the TPACK framework offers a significant lens for rethinking how digital technologies can be integrated into this module offered to align with the curriculum in the Foundation Phase.[26] The 21st century education and the Fourth Industrial Revolution (4IR) stress that as education evolves, teachers should not only be equipped with knowledge of mathematics content pedagogies, but should also know how to integrate technology to transform learning experiences for young learners. Although the MFP1501 module incorporates the content of teaching mathematics in the Foundation Phase, there is a gap in pedagogical and technological knowledge of pre-service teachers on how to teach mathematics. Thus, from the TPACK lens, this paper focused only on pedagogical and technological knowledge to improve the redesign of the MFP1501.

Pedagogical Knowledge

Pedagogical knowledge (PK) indicates the ability to apply various pedagogical approaches including play-based, hands-on and interactive practices in the Foundation Phase.[27] Pre-service teachers need an understanding of how to use pedagogies to engage Foundation Phase learners in mathematics activities.[28] PK needs to reflect active learning, concrete manipulatives, game-based learning and visual representations in teaching and learning mathematics in the early years.[29] Other theorists state that children learn by implementing various pedagogical approaches that include active learning, scaffolding, and the Zone of

[19] Jayaluxmi Naidoo and Sarasvathie Reddy, "Embedding Sustainable Mathematics Higher Education in the Fourth Industrial Revolution Era Post-COVID-19: Exploring Technology-Based Teaching Methods," *Sustainability* 15, no. 12 (June 16, 2023): 9692, https://doi.org/10.3390/su15129692.

[20] Fazlida Dahalan, Norlidah Alias, and Mohd Shahril Nizam Shaharom, "Gamification and Game Based Learning for Vocational Education and Training: A Systematic Literature Review,"*Education and Information Technologies* 29, no.2(2024):1279–1317.

[21] R Salawu et al., "Theoretical and Conceptual Frameworks in Research: Conceptual Clarification," *European Chemical Bulletin* 12, no. 12 (2023): 2103–17.

[22] Punya Mishra and Matthew J. Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," *Teachers College Record: The Voice of Scholarship in Education* 108, no. 6 (June 1, 2006): 1017–54, https://doi.org/10.1177/016146810610800610.

[23] Lee S. Shulman, "Those Who Understand: Knowledge Growth in Teaching," *Educational Researcher* 15, no. 2 (February 1986): 4, https://doi.org/10.2307/1175860.

[24] Delport, "Numeracy Students' Perspectives on a New Digital Learning Tool at a South African University"; Popel, "Using Cocalc As A Training Tool For Mathematics Teachers' Pre-Service Training."

[25] Dahalan, Alias, and Shaharom, "Gamification and Game Based Learning for Vocational Education and Training: A Systematic Literature Review"; Naidoo and Reddy, "Embedding Sustainable Mathematics Higher Education in the Fourth Industrial Revolution Era Post-COVID-19: Exploring Technology-Based Teaching Methods."

[26] Mishra and Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," June 1, 2006.

[27] Yue Zeng, Weipeng Yang, and Alfredo Bautista, "Teaching Programming and Computational Thinking in Early Childhood Education: A Case Study of Content Knowledge and Pedagogical Knowledge," *Frontiers in Psychology* 14 (October 2, 2023), https://doi.org/10.3389/fpsyg.2023.1252718.

[28] Zeng, Yang, and Bautista, "Teaching Programming and Computational Thinking in Early Childhood Education: A Case Study of Content Knowledge and Pedagogical Knowledge."

[29] Di Chilvers, *How to Recognise and Support Mathematical Mastery in Young Children's Play: Learning from the'Talk for Maths Mastery'Initiative* (Routledge, 2021).

Proximal Development (ZPD).[30] Pre-service teachers must be equipped with strategies to incorporate pedagogical approaches, active engagement and assessments in mathematics classrooms.[31] Thus, pre-service teachers need to acquire this PK from the MFP1501 to implement it in their Foundation Phase mathematics classrooms.

Technological Knowledge

In this paper, TK refers to the knowledge of selecting, using, and evaluating digital tools relevant to teaching and learning mathematics in the Foundation Phase.[32] TK includes being familiar with interactive whiteboards, educational apps, digital manipulatives, game-based learning platforms and virtual learning environments in teaching and learning in classrooms. TK should be paired with the PK as it focuses not only on the delivery but also on the use of digital manipulatives, game-based learning and inquiry pedagogies to teach mathematics.[33] However, this gap is found in the MFP1501 module. Pre-service teachers report having limited access to appropriate technologies or insufficient training in usingthe technology in classrooms.[34] In the context of higher education, pre-service teachers must nevertheless develop their knowledge of technological tools in teaching mathematics, especially in rural schools. For example, pre-service teachers who are competent in these tools can adapt lessons to low-resource contexts (offline versions, mobile-friendly apps, or project-based approaches using limited technology). It is not only about knowing how to integrate technology into the classroom but how use it effectively and meaningfully to support teaching mathematics to Foundation Phase learners.[35] This background shows that MFP1501 pre-service teachers need to know how to use technology and address the challenges of limited digital devices in teaching mathematics to Foundation Phase learners. Therefore, this paper adovcates a rethinking of how digital technologies are integrated into the MFP1501 module.

METHODOLOGY

The author conducted a narrative literature review to critique and evaluate the strengths, weaknesses and gaps in existing literature on the phenomenon under study. A narrative literature review focuses on rigorous, in-depth analysis and systematically evaluates existing research to identify the gaps that the current study will fill.[36] Thus, this paper used a critical literature review on the integration of digital technologies in higher education. However, this approach lacks methodological rigour, transparency and limited comprehensiveness.[37] To mitigate these shortcomings of the narrative literature review in this study, transparency was improved by searching for the existing literature, determining inclusion and exclusion

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[30] Jerome Seymour Bruner, *Toward a Theory of Instruction* (Harvard university press, 1974); Lev S. Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*, vol. 86 (Harvard University Press, 1978); Punya Mishra and Matthew J. Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," *Teachers College Record: The Voice of Scholarship in Education* 108, no. 6 (June 2006): 1017–54, https://doi.org/10.1111/j.1467-9620.2006.00684.x.

[31] Michal Ayalon and Karina J. Wilkie, "Investigating Peer-Assessment Strategies for Mathematics Pre-Service Teacher Learning on Formative Assessment," *Journal of Mathematics Teacher Education* 24, no. 4 (August 27, 2021): 399–426, https://doi.org/10.1007/s10857-020-09465-1; Eric Sefa Boye and Douglas Darko Agyei, "Effectiveness of Problem-Based Learning Strategy in Improving Teaching and Learning of Mathematics for Pre-Service Teachers in Ghana," *Social Sciences & Humanities Open* 7, no. 1 (2023): 100453, https://doi.org/10.1016/j.ssaho.2023.100453.

[32] Emmanuel Agyei, Douglas Darko Agyei, and Isaac Benning, "In-Service Mathematics Teachers' Preparedness, Knowledge, Skills, and Self-Efficacy Beliefs of Using Technology in Lesson Delivery," *Cogent Education* 9, no. 1 (December 31, 2022), https://doi.org/10.1080/2331186X.2022.2135851.

[33] James Anthony Russo et al., "Examining Primary School Educators' Preferences for Using Digital versus Non-Digital Games to Support Mathematics Instruction," *International Journal of Mathematical Education in Science and Technology* 56, no. 9 (September 2, 2025): 1778–1803, https://doi.org/10.1080/0020739X.2024.2361699; Duncan Mhakure, "School-Based Mathematics Teacher Professional Learning: A Theoretical Position on the Lesson Study Approach," *South African Journal of Education* 39, no. Supplement 1 (September 30, 2019): S1–8, https://doi.org/10.15700/saje.v39ns1a1754; Jacques du Plessis, "Early Algebra: Repeating Pattern and Structural Thinking at Foundation Phase," *South African Journal of Childhood Education* 8, no. 2 (November 15, 2018), https://doi.org/10.4102/sajce.v8i2.578.

[34] Ramongwane Daniel Sephokgole, Moses Makgato, and Sammy Khoza, "Modelling the Transformation of Agricultural Program Teaching and Learning into Technology Integration," *Journal of Education Technology* 8, no. 3 (October 25, 2024): 421–30, https://doi.org/10.23887/jet.v8i3.76898.

[35] Matthew Koehler and Punya Mishra, "What Is Technological Pedagogical Content Knowledge (TPACK)?," *Contemporary Issues in Technology and Teacher Education* 9, no. 1 (2009): 60–70.

[36] Uchendu Eugene Chigbu, Sulaiman Olusegun Atiku, and Cherley C Du Plessis, "The Science of Literature Reviews: Searching, Identifying, Selecting, and Synthesising," *Publications* 11, no. 1 (2023): 2.

[37] Dennis Thomas, Elida Zairina, and Johnson George, "Methodological Approaches to Literature Review," in *Encyclopedia of Evidence in Pharmaceutical Public Health and Health Services Research in Pharmacy* (Cham: Springer International Publishing, 2023), 1–15, https://doi.org/10.1007/978-3-030-50247-8_57-1.

criteria, and analysing and synthesising data for the subjective nature of the review process.[38] The narrative reviews align with subjectivist and interpretivist paradigms, in which reality is subjective and dynamic as opposed to positivist.[39] Given that, this paper followed the philosophical assumptions of the interpretivist paradigm to interpret a wide range of literature to understand how to integrate digital technologies in the MFP1501 module offered in higher education institutions.

Narrative review aligns well with qualitative research as it requires in-depth and rich literature from different studies.[40] Furthermore, narrative reviews provide a qualitative overview of a research topic by summarising and interpreting the findings rather than using statistical analysis.[41] As a result, qualitative research was used within a narrative review. In narrative reviews, case studies can be interpreted, analysed and discussed to support the research problem within the review.[42] One of the inclusion criteria in sampling these studies was their relevance in the education field, published in top-tier journals, which included both empirical studies and conceptual papers.[43] Additionally, after a group of potential studies was identified, the studies conducted by UNISA were excluded to avoid conflicts of interest and biases while ensuring objectivity and validity.[44] As such, peer-reviewed empirical and conceptual studies with explicit focus on module design to support pre-service teachers' use of digital technologies in higher education institutions were included in this study while grey studies (including editorials in journals, conference abstracts without full papers, theses and dissertations) were excluded from sampling criteria. To do this, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was establishedused to ensure a transparent and systematic selection in qualitative research.[45] The selection process involved conducting a comprehensive search to remove the duplicates, screening the research titles and abstracts and retaining the final studies for synthesis. They tracked the number of studies identified, included, and excluded at each stage using a PRISMA framework.[46]

Finally, the screening of the studies included extracting data such as when, where, the methodologies used, and by whom the primary study was conducted. As a result, fourteen (14) studies were sampled, drawn from different regions, conducted in different higher education institutions indexed in major international databases such as Google Scholar, Research Gate, Scopus (Elsevier), Web of Science (Clarivate), and the Directory of Open Access Journals (DOAJ) between 2020 and 2025 were reviewed. Reviewing the studies from different regions helped to understand how other higher education institutions integrate digital technology into their modules.

A narrative analysis of the literature was conducted to create patterns and themes. Narrative analysis is employed in qualitative research because subjective insights allow for a narrative account of debates, gaps, similarities and inconsistencies in the literature.[47] This analysis was performed manually by creating patterns and themes that aligned with the theoretical framework underpinning this study. Each study reviewed revealed significant insights through an in-depth and rich analysis of how digital technologies are integrated in higher education modules for pre-service teachers. Simply put, selecting 14 studies from different regions offered an expansive, balanced, diverse and insightful analysis of how digital technology

[38] Robin Castro-Gil and Diego Correa, "Transparency in Previous Literature Reviews about Blended Learning in Higher Education," *Education and Information Technologies* 26, no. 3 (May 6, 2021): 3399–3426, https://doi.org/10.1007/s10639-020-10406-x.

[39] P. Paudel, "Examining Paradigmatic Shifts: Unveiling the Philosophical Foundations Shaping Social Research Methodologies," *Journal of the University of Ruhuna* 12, no. 1 (August 21, 2024): 45–58, https://doi.org/10.4038/jur.v12i1.8033.

[40] Javeed Sukhera, "Narrative Reviews: Flexible, Rigorous, and Practical," *Journal of Graduate Medical Education* 14, no. 4 (August 1, 2022): 414–17, https://doi.org/10.4300/JGME-D-22-00480.1.

[41] Sukhera, "Narrative Reviews: Flexible, Rigorous, and Practical."

[42] Muhammad Imran and Norah Almusharraf, "Analyzing the Role of ChatGPT as a Writing Assistant at Higher Education Level: A Systematic Review of the Literature," *Contemporary Educational Technology* 15, no. 4 (October 1, 2023): ep464, https://doi.org/10.30935/cedtech/13605.

[43] Castro-Gil and Correa, "Transparency in Previous Literature Reviews about Blended Learning in Higher Education."

[44] Diogo Maia et al., "Academic Performance and Perceptions of Undergraduate Medical Students in Case-Based Learning Compared to Other Teaching Strategies: A Systematic Review with Meta-Analysis," *Education Sciences* 13, no. 3 (February 23, 2023): 238, https://doi.org/10.3390/educsci13030238.

[45] Md Shamimul Islam et al., "Classification of Review in Green Supply Chain Management for Future Challenges in Methodological, Generic, and Domain-Based Review," *International Journal of Logistics Research and Applications*, February 21, 2025, 1–35, https://doi.org/10.1080/13675567.2025.2463475.

[46] Md Shamimul Islam, Md Al Mamun, and Imranul Hoque, "A Guide to Literature Reviews: A Comprehensive Flowchart beyond PRISMA for Sample Selection and Justifications," *Management Review Quarterly*, June 11, 2025, https://doi.org/10.1007/s11301-025-00528-2.

[47] Hani Morgan, "Understanding Thematic Analysis and the Debates Involving Its Use," *The Qualitative Report*, October 3, 2022, https://doi.org/10.46743/2160-3715/2022.5912.

can be integrated in higher education modules across different contexts, which enriched the study's scope. Table 1.1 provides an outline of the selected studies from 2020 to 2025 that focused on the integration of digital technology in higher education institutions conducted from the international, African and South African contexts.

Table 1.1: An outline of the selected studies from 2020 to 2025			
Authors	**Aim/hypothesis**	**Methodology**	**Findings**
Martínez-Zarzuelo et al. [48] *Universities in Madrid*	Using of technological tools, such as mathematical modelling, visualisation, automatic reasoning and artificial intelligence, significantly improves the teaching and learning of mathematics	Questionnaires from 140 pre-service teachers within quantitative research were conducted from three universities, including Universidad Complutense de Madrid, Centro Universitario La Salle and Universidad Rey Juan Carlos	Their findings indicate that there is still limited knowledge of TPACK and that Artificial Intelligence is still needed in programme development
Meyerink and Luo [49] *Northwest region of the United States universities*	To examine the perspectives of pre-service teachers on technology integration mathematics in the eighth grade	open-ended prompts were conducted to 19 undergraduate mathematics participants in phenomenological study, qualitative	Meyerink and Luo's findings revealed that pre-service teachers have limited knowledge of technology integration in mathematics teaching
Kartal[50] *Middle Anatolia, Turkey*	Examination of pre-service elementary mathematics teachers' TPACK in teacher preparation programme	A pilot study was used using a single-group presurvey-postsurvey design in a quantitative study. 38 pre-service teachers in undergraduate four-year programme participated	The findings reflected that teacher preparation programmes need to support pre-service teachers with pedagogical thinking in teaching mathematics
Akçay[51] *Turkey*	An investigation of various levels of cognitive tasks designed for mathematics and technology activities	Five pre-service teachers participated in showcase portfolios and lesson plans, were used to collect data in qualitative case study	The paper suggests that teacher programmes need to incorporate technology into mathematics to develop cognitive skills
Shuukwanyama et al.[52] *University of Namibia*	Uncovering the perceptions of mathematics lecturers regarding mother-tongue instruction in the University	Four mathematics lecturers in the department of early childhood (University of Namibia) participants were engaged in semi-structured interviews in qualitative research	Their findings highlighted that lectures understand the significance of mother tongue in teaching mathematics to pre-service teachers

[48] Angélica Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics," *Education Sciences* 15, no. 6 (2025): 782.
[49] Monte Meyerink and Fenqjen Luo, "K-8 Pre-Service Teachers' Technology Integration in Mathematics: Perspectives and Anticipated Practices," *Journal of Research in Science, Mathematics and Technology Education* 8, no. SI (June 15, 2025): 195–227, https://doi.org/10.31756/jrsmte.4112SI.
[50] Büşra Kartal, "Examining Preservice Mathematics Teachers' Technological Pedagogical Content Knowledge Development in the Natural Setting of a Teacher Preparation Program," *Ie: Inquiry in Education* 14, no. 2 (2022): 4.
[51] Ahmet Oguz Akçay, "Case Studies: Pre-Service Mathematics Teachers' Integration of Technology into Instructional Activities Using a Cognitive Demand Perspective.," *Mathematics Teaching Research Journal* 16, no. 1 (2024): 238–66.
[52] Tulonga T. Shuukwanyama et al., "The Language of Instruction in Mathematics Teacher Education for the Early Grades," *South African Journal of Childhood Education* 12, no. 1 (August 31, 2022), https://doi.org/10.4102/sajce.v12i1.1108.

Mukuka and Alex[53] *University of Zambia*	To assess and examine the readiness and proficiency of mathematics teachers to effectively use digital technology into mathematics education	Quantitative cross-sectional research design was used through an online semi-structured questionnaire and 104 MTEs across 16 colleges of education and 12 universities in Zambia	The findings indicated that the participants have low to moderate familiarity with various mathematics-related software applications, e-learning management systems and web-based video conferencing tools
Zulu[54] *South African university in Kwa Zulu Natal*	An exploration of the integration of educational technologies for pre-service mathematics teachers to enhance learners' visualisation of mathematical concepts	An interpretive qualitative study was conducted with 10 pre-service mathematics teachers, whereby questionnaire and focus group were administered	Zulu suggest adaptation and pedagogical strategies for visual mathematics concepts
Vale and Westaway[55] *South African university in Eastern Cape*	To find out Mental Starters Assessment Project (MSAP) materials support pre-service teachers in competently teaching mental mathematics	38 Bachelor of Education (Foundation Phase) third-year pre-service teachers participated in qualitative research	The pre-service teachers have content and pedagogical knowledge of using MSAP in teaching mathematics
Mukuka and Alex *South African university in Eastern Cape*	Examine the effect of the professional development training programme on the knowledge of pre-service mathematics teachers in mathematical concepts	In mixed-methods case study design where baseline and endline assessments were administered. Participant feedback surveys were used to 20 second-year in a four-year BEd programme pre-service mathematics teachers before and after the training	Mukuka and Alex's study found that there is a need for teacher training institutions to ensure that pre-service teachers understand teaching of mathematics in universities and schools. Furthermore, they suggest collaboration with other stakeholders to provide pre-service teachers with relevant and engaging professional development opportunities to improve their mathematical knowledge for teaching
Ngoako and Gilbert [56] *South African university*	To explore pre-service teachers' preparedness to integrate technology into mathematics teaching	A qualitative study used classroom observations and open-ended questionnaires were used forwith nine pre-service teachers, of whom three were in the Foundation Phase	Ngoako and Gilbert found that only two participants in the Foundation Phase used technological tools to teach 2-D shapes by integrating video songs using the teachers' device

[53] Angel Mukuka and Jogymol K. Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training," *Pythagoras* 45, no. 1 (June 20, 2024), https://doi.org/10.4102/pythagoras.v45i1.764.

[54] Mzwandile Wiseman Zulu, "Exploring the Tech-Twist: Preservice Mathematics Teachers' Implementation of Educational Technologies for Visualisation at Resource-Constrained Schools," 2025, https://doi.org/10.5772/intechopen.1010379.

[55] Pamela Vale and Lise Westaway, "The Development of Pre-Service Teachers' Competence to Teach Mental Calculation Strategies," *South African Journal of Childhood Education* 14, no. 1 (September 25, 2024), https://doi.org/10.4102/sajce.v14i1.1552.

[56] Rosina Nkadi Ngoako and Pule Kereng Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers," in *30th National Congress of the Association for Mathematics Education of South Africa (AMESA)* (Polokwane, 2025).

Nhlumayo and Pule [57] *South African universities*	The integration of ICT pedagogy in mathematics teacher training in South African universities	Review, scholarly chapter in a book	The finding indicates that even though South African universities have access to ICT tool, pre-service teachers need to be equipped with knowledge to integrate these ICT tools into their mathematics teaching approaches
Spangenberg[58] *South African university*	To compare pre-service teachers' experiences of teaching mathematics online during the Covid-19 pandemic	Qualitative data were collected from online guided reflection reports from 62 pre-service teachers enrolled in their fourth-year mathematics methodology module as part of a BEd degree at a South African university	Spangenberg highlights that pre-service teachers still have challenges of integrating Moodle and digital softwares in teaching mathematics online during Covid-19
Naidoo, and Reddy *South African university, Kwa Zulu Natal*	An exploration of postgraduate students and mathematics school teachers' experiences and views on technology-based teaching methods for mathematics	45 postgraduate students and mathematics school teachers were involved in a qualitative study conducted during the COVID-19 pandemic	Their findings suggest important aspects of using technology-based teaching methods in higher education mathematics contexts in the 4IR and post-COVID-19 era
Mavuso and Makeleni[59] *South African university*	Enhancing the integration of ICT in South African pre-service teacher education programmes	A review paper	The findings of Mavuso and Makeleni findings show a need to adopt ICT in preparing modules for pre-service teachers in higher learning institutions

[57] Buhle Stella Nhlumayo and Kereng Gilbert Pule, "The Integration of ICT Pedagogy: A Panacea to Mathematics Teacher Training in South African Universities," *Open Books and Proceedings*, March 10, 2025, https://doi.org/10.38140/obp3-2025-07.

[58] Erica Dorethea Spangenberg, "Pre-Service Teachers' Experiences of Teaching Mathematics Online during Practicum in an African Context Due to COVID-19," in *Information and Communications Technology in STEM Education* (London: Routledge, 2023), 116–44, https://doi.org/10.4324/9781003279310-8.

[59] Mzuyanda Percival Mavuso and Sive Makeleni, "Enhancing the Integration of Information and Communication Technology in South African Teacher Education Programmes," *Journal of Educational Studies* 2022, no. si1 (2022): 104–21.

Similarities and differences from the conducted studies

The reviewed studies revealed common patterns in integrating digital technologies in higher learning institutions' modules. For example, numerous studies focused on pre-service teachers' readiness, perceptions and knowledge of integrating technology in mathematics teaching modules offered in higher learning programmes.[60] It is against this background that the narrative analysis shows that recent research studies stress the significance of preparing pre-service teachers with pedagogical and technological knowledge of 21st-century and 4IR mathematics classrooms.

From the methodological perspective, studies conducted in both international and African studies show strong use of qualitative designs in collecting in-depth and rich data from the participants through interviews, focus groups, open-ended prompts or reflections.[61] However, quantitative surveys may be used to measure readiness and knowledge levels of pre-service teachers in integrating technological tools in mathematics teaching in higher education programmes.[62] A similar theme emerged from all the studies conducted in different regions, namely that pre-service teachers have limited knowledge of integrating digital technologies in mathematics teaching.

There are also significant differences between the studies conducted in developed regions[63] which focused on how to use digital tools, AI and advanced technologies software to prepare pre-service teachers. Sub-Saharan and South African studies[64] focused on challenges such as lack of ICT and considered the use of mother tongue in mathematics teaching.[65] In the same vein, studies were conducted in South African universities on professional development and curriculum-specific tools in mathematics teaching.[66] In essence, South African universities lag behind the revising module programmes for pre-service teachers to align them with the recent trends of ICT and 4IR in higher institutions.

Interrogating methodology used across all the reviewed studies in different regions shows that the international research focuses on large-scale quantitative or mixed-methods[67] while South African studies[68] rely more on the interpretive exploratory qualitative approach. As a result, guided by the studies conducted in Sub-

[60] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics"; Meyerink and Luo, "K-8 Pre-Service Teachers' Technology Integration in Mathematics: Perspectives and Anticipated Practices"; Kartal, "Examining Preservice Mathematics Teachers' Technological Pedagogical Content Knowledge Development in the Natural Setting of a Teacher Preparation Program"; Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training"; Wiseman Zulu, "Exploring the Tech-Twist: Preservice Mathematics Teachers' Implementation of Educational Technologies for Visualisation at Resource-Constrained Schools"; Ngoako and Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers."

[61] Meyerink and Luo, "K-8 Pre-Service Teachers' Technology Integration in Mathematics: Perspectives and Anticipated Practices"; Akçay, "Case Studies: Pre-Service Mathematics Teachers' Integration of Technology into Instructional Activities Using a Cognitive Demand Perspective."; Wiseman Zulu, "Exploring the Tech-Twist: Preservice Mathematics Teachers' Implementation of Educational Technologies for Visualisation at Resource-Constrained Schools"; Ngoako and Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers."

[62] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics"; Kartal, "Examining Preservice Mathematics Teachers' Technological Pedagogical Content Knowledge Development in the Natural Setting of a Teacher Preparation Program"; Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."

[63] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics"; Meyerink and Luo, "K-8 Pre-Service Teachers' Technology Integration in Mathematics: Perspectives and Anticipated Practices."

[64] Nhlumayo and Pule, "The Integration of ICT Pedagogy: A Panacea to Mathematics Teacher Training in South African Universities"; Spangenberg,"Pre-Service Teachers' Experiences of Teaching Mathematics Online during Practicum in an African Context Due to COVID-19."

[65] Shuukwanyama et al., "The Language of Instruction in Mathematics Teacher Education for the Early Grades."

[66] Vale and Westaway, "The Development of Pre-Service Teachers' Competence to Teach Mental Calculation Strategies"; Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."

[67] Kartal, "Examining Preservice Mathematics Teachers' Technological Pedagogical Content Knowledge Development in the Natural Setting of a Teacher Preparation Program"; Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics."

[68] Wiseman Zulu, "Exploring the Tech-Twist: Preservice Mathematics Teachers' Implementation of Educational Technologies for Visualisation at Resource-Constrained Schools"; Ngoako and Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers"; Naidoo and Reddy, "Embedding Sustainable Mathematics Higher Education in the Fourth Industrial Revolution Era Post-COVID-19: Exploring Technology-Based Teaching Methods."

Saharan countries,[69] this paper suggests a balance between case-specific qualitative and cross-sectional surveys (quantitative) and mixed-methods research. While the international research[70] emphasises advanced tools and AI in the integration of digital technologies in teaching mathematics for pre-service teachers, Sub-Saharan and South African studies reflect practical challenges in technology and mathematics teaching. Theme 2, which focuses on contextual challenges of integrating technology in mathematics teaching to pre-service teachers, emerged. In addition, Theme 3 was developed from the focus on using professional development approaches such as MSAP.[71] The narrative analysis assisted in identifying knowledge gaps from the reviewed studies on the integration of digital technologies in mathematics programmes for pre-service teachers.

Evidence-based knowledge gaps in the integration of digital technology in mathematics in higher universities

The narrative literature examined the perceptions, readiness and views of pre-service teachers on integrating digital technology in teaching mathematics.[72] However, few of these studies provide evidence of designing mathematics theoretical modules that explicitly integrate digital technologies in higher education learning. This shows a lack of a curriculum innovation programme that indicates how modules need to align with 21st-century mathematics teaching. Although there should be an alignment of TPACK in mathematics modules, research fails to show how content, pedagogy and technology are integrated in mathematics education modules.[73] This backdrop shows a significant gap in design-based research on digital technology and mathematics from previous studies, giving rise to Theme 4.

DISCUSSION OF FINDINGS

This narrative paper examined how pre-service teachers are prepared to integrate digital technology in mathematics teaching, which focused on the evidence of the studies conducted from 2020 to 2025 from different higher education institutions in various countries and the MFP1501, a module offered at UNISA. The TPACK framework anchored the discussion of the findings using four interconnected themes: (1) limited knowledge of digital integration and technological knowledge; (2) practical challenges in applying technology to mathematics teaching; (3) professional development approaches; and (4) Redesigning MFP1501 using TPACK framework.[74] The findings are further interpreted against the backdrop of UNISA's ODeL context, where self-directed learning shapes the mathematics pre-service teachers' thinking and knowledge and is acquired through online interaction.[75] The narrative review shows the challenges and opportunities of using digital technologies in MFP1501, with implications for how the module should be revised and taught at UNISA.

Theme 1: Limited knowledge of how to integrate technological knowledge

This theme supports the research question in this paper that highlights the need to redesign the MFP1501 module to equip pre-service teachers with pedagogical and technological knowledge to be used meaningfully in teaching

[69] Shuukwanyama et al., "The Language of Instruction in Mathematics Teacher Education for the Early Grades"; Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."

[70] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics."

[71] Ngoako and Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers"; Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."

[72] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics"; Meyerink and Luo, "K-8 Pre-Service Teachers' Technology Integration in Mathematics: Perspectives and Anticipated Practices"; Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."

[73] Wiseman Zulu, "Exploring the Tech-Twist: Preservice Mathematics Teachers' Implementation of Educational Technologies for Visualisation at Resource-Constrained Schools"; Ngoako and Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers."

[74] Mishra and Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," June 2006.

[75] Castro-Gil and Correa, "Transparency in Previous Literature Reviews about Blended Learning in Higher Education"; Paudel, "Examining Paradigmatic Shifts: Unveiling the Philosophical Foundations Shaping Social Research Methodologies."

mathematics in the Foundation Phase. Recurring patterns in the data show that pre-service teachers have limited knowledge of integrating digital technologies in mathematics teaching.[76] For example, even though pre-service teachers have access to digital software such as AI and visualisations, they still lack knowledge of how to integrate them into mathematics teaching. In addition, undergraduate mathematics pre-service teachers lack knowledge of digital integration.[77] The limitations of pre-service teachers in using digital technologies are that they are unfamiliar with the e-learning platforms and digital mathematics tools,[78] for example, they experienced challenges in using Moodle and other digital platforms during COVID-19.[79]

The findings show how the lived experiences of the participants have an impact on their preparation to teach in the Foundation Phase and how module units can be designed to integrate digital technologies within pedagogical and content practices in mathematics. The reviewed studies reveal a key gap in module design and a mismatch between pre-service teachers' digital literacy and their use of technology and pedagogy to support mathematics learning.

In ODeL learning activities in UNISA, students engage with MFP1501 largely using online platforms such as Moodle, unequal access to digital tools and readiness intensify these challenges. Students in higher learning institutions experience limited digital literacy due to a lack of access to technology devices.[80] Redesigning MFP1501 could address these challenges by blending traditional pedagogy with scaffolded digital activities and building students' digital literacy through Moodle lessons for mathematics teaching. In the same vein, TPACK stresses that there should be a dynamic relationship between pedagogy and technology in teaching and learning. There is a misalignment with TPACK, which stresses the interconnection of technological and pedagogical knowledge.[81] This supports the view that meaningful pedagogy and content knowledge must be embedded, as technology integration alone is not enough.[82] Given that, in ODeL institutions such as UNISA, where students have limited to no access to face-to-face lessons, the MFP1501 module needs to equip Foundation Phase pre-service mathematics teachers with skills to integrate content knowledge, pedagogy and technology knowledge within limited access to digital tools in schools.

Theme 2: Practical challenges in integrating technology and mathematics teaching to pre-service teachers

The research question seeks to find ways to redesign the MFP1501 module to address the contextual challenges the pre-service teachers face during work-integrated learning in the practical world. Theme 2 discusses the practical challenges that pre-service teachers face when integrating digital technologies from different studies reviewed in this paper. The reviewed studies indicate that pre-service teachers struggle with the practical use of digital technologies even when resources are available in classrooms. For example, while most pre-service teachers have access to digital tools, they lack the skills to apply pedagogical approaches for effectively visualising mathematics concepts.[83] Furthermore, pre-service teaching modules often neglect to support

[76] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics."
[77] Meyerink and Luo, "K-8 Pre-Service Teachers' Technology Integration in Mathematics: Perspectives and Anticipated Practices."
[78] Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."
[79] Spangenberg,"Pre-Service Teachers' Experiences of Teaching Mathematics Online during Practicum in an African Context Due to COVID-19."
[80] Molefi Matsieli and Stephen Mutula, "COVID-19 and Digital Transformation in Higher Education Institutions: Towards Inclusive and Equitable Access to Quality Education," *Education Sciences* 14, no. 8 (July 26, 2024): 819, https://doi.org/10.3390/educsci14080819.
[81] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics"; Meyerink and Luo, "K-8 Pre-Service Teachers' Technology Integration in Mathematics: Perspectives and Anticipated Practices"; Spangenberg, "Pre-Service Teachers' Experiences of Teaching Mathematics Online during Practicum in an African Context Due to COVID-19."
[82] Mishra and Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," June 2006.
[83] Wiseman Zulu, "Exploring the Tech-Twist: Preservice Mathematics Teachers' Implementation of Educational Technologies for Visualisation at Resource-Constrained Schools."

pedagogical thinking with technology.[84] There is also a limited readiness among pre-service teachers to use digital tools.

Only a small number of Foundation Phase pre-service teachers in a module offered in BEd for four years in one of the universities in South Africa were able to use digital manipulatives, such as online video songs, to teach 2-D shapes.[85] To contextualise the readers, digital manipulatives refer to interactive and technology-based resources that can be used to teach young learners mathematics skills.[86] The TPACK framework challenges the emphasis on the access of pre-service teachers to digital tools,[87] because virtual representations must be supported by strong pedagogical knowledge and reflective practice when teaching mathematics to young learners.[88] This tension with the TPACK framework highlights the need to redesign the MFP1501 module to embed digital manipulatives and pedagogical strategies, thereby equipping ODeL pre-service teachers with the skills required to teach mathematics effectively in the Foundation Phase. Pre-service teachers need to know how to use scaffolding and ZPD activities within various pedagogies in a digital classroom.[89]

Theme 3: Professional development approaches for MFP1501

Professional development embedded within the MFP1501 module is a noteworthy strategy to ensure that pre-service teachers are continuously developed to align with the recent trends of integrating technology in the Foundation Phase mathematics teaching. Theme 2 links with the research question to guide the redesign of the MFP1501 module to ensure that professional development approaches are included for pre-service teachers to integrate pedagogies and digital technologies effectively in teaching mathematics to Foundation Phase learners. There is a pressing need for professional development to build digital pedagogical competence in pre-service teachers in teaching mathematics.[90] In the same vein, postgraduate students appreciate training for technology-based methods in the 4IR era and post-COVID-19 context.[91] In addition, there is a need for professional development within modules to assist lecturers and pre-service teachers to integrate ICT tools and pedagogical approaches in teaching mathematics.[92] The findings from the literature align well with the TPACK on professional development by promoting integrated knowledge that allows pre-service teachers to integrate content, pedagogy and technology to develop Foundation Phase learners' mathematics thinking and logical skills.[93] Ultimately, the author suggests that the redesign of MFP1501 should incorporate professional development approaches that bridge the disconnect between theory and practice in the integration of technology and pedagogy in mathematics teaching. In addition, to rethink the module development of MFP1501, the assessment activities need to be linked with the technology and pedagogy of teaching and learning mathematics, which will take a different approach in the ODeL context of UNISA.[94] Having discussed how technology and

[84] Akçay, "Case Studies: Pre-Service Mathematics Teachers' Integration of Technology into Instructional Activities Using a Cognitive Demand Perspective."; Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."

[85] Ngoako and Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers."

[86] Gulnoza Yakubova et al., "Virtual Instruction in Teaching Mathematics to Autistic Students: Effects of Video Modeling, Virtual Manipulatives, and Mathematical Games," *Journal of Special Education Technology* 39, no. 1 (March 19, 2024): 51–66, https://doi.org/10.1177/01626434231177875.

[87] Ngoako and Gilbert, "The Role of Technology in Enhancing Mathematics Teaching: Perspectives from South African Pre-Service Teachers."

[88] Chilvers, *How to Recognise and Support Mathematical Mastery in Young Children's Play: Learning from the'Talk for Maths Mastery'Initiative.*

[89] Jerome S. Bruner, *Toward a Theory of Instruction* (Cambridge, MA: Harvard University Press, 1966); Lev S. Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*, ed. Michael Cole et al. (Cambridge, MA: Harvard University Press, 1978).

[90] Mukuka and Alex, "Foundational Mathematical Knowledge of Prospective Teachers: Evidence from a Professional Development Training."

[91] Naidoo and Reddy, "Embedding Sustainable Mathematics Higher Education in the Fourth Industrial Revolution Era Post-COVID-19: Exploring Technology-Based Teaching Methods."

[92] Nhlumayo and Pule, "The Integration of ICT Pedagogy: A Panacea to Mathematics Teacher Training in South African Universities"; Mavuso and Makeleni, "Enhancing the Integration of Information and Communication Technology in South African Teacher Education Programmes."

[93] du Plessis, "Early Algebra: Repeating Pattern and Structural Thinking at Foundation Phase"; Mhakure, "School-Based Mathematics Teacher Professional Learning: A Theoretical Position on the Lesson Study Approach."

[94] Ayalon and Wilkie, "Investigating Peer-Assessment Strategies for Mathematics Pre-Service Teacher Learning on Formative Assessment"; Boye and Agyei, "Effectiveness of Problem-Based Learning Strategy in Improving Teaching and Learning of Mathematics for Pre-Service Teachers in Ghana."

pedagogy can be integrated in the redesigning of the MFP1501 module, the next section suggests guidelines to address the challenges enlightened from the narrative review.

Theme 4: Using TPACK to suggest guidelines for redesigning MFP1501 to integrate digital technologies and pedagogical knowledge for pre-service teachers

This paper contributes to the growing body of research on integrating digital technologies and pedagogical knowledge in preparing pre-service teachers for mathematics teaching practice. As a result, in contrast to the broader literature, this theme suggests guidelines for redesigning MFP1501 using TPACK framework within the ODeL context. The narrative review showed that pre-service teachers have limited knowledge of integrating digital technologies with pedagogy, and uneven professional development and access to tools reduce their readiness to teach mathematics in the Foundation Phase. Figure 1. illustrates A suggested model diagram of the redesigning of MFP1501.

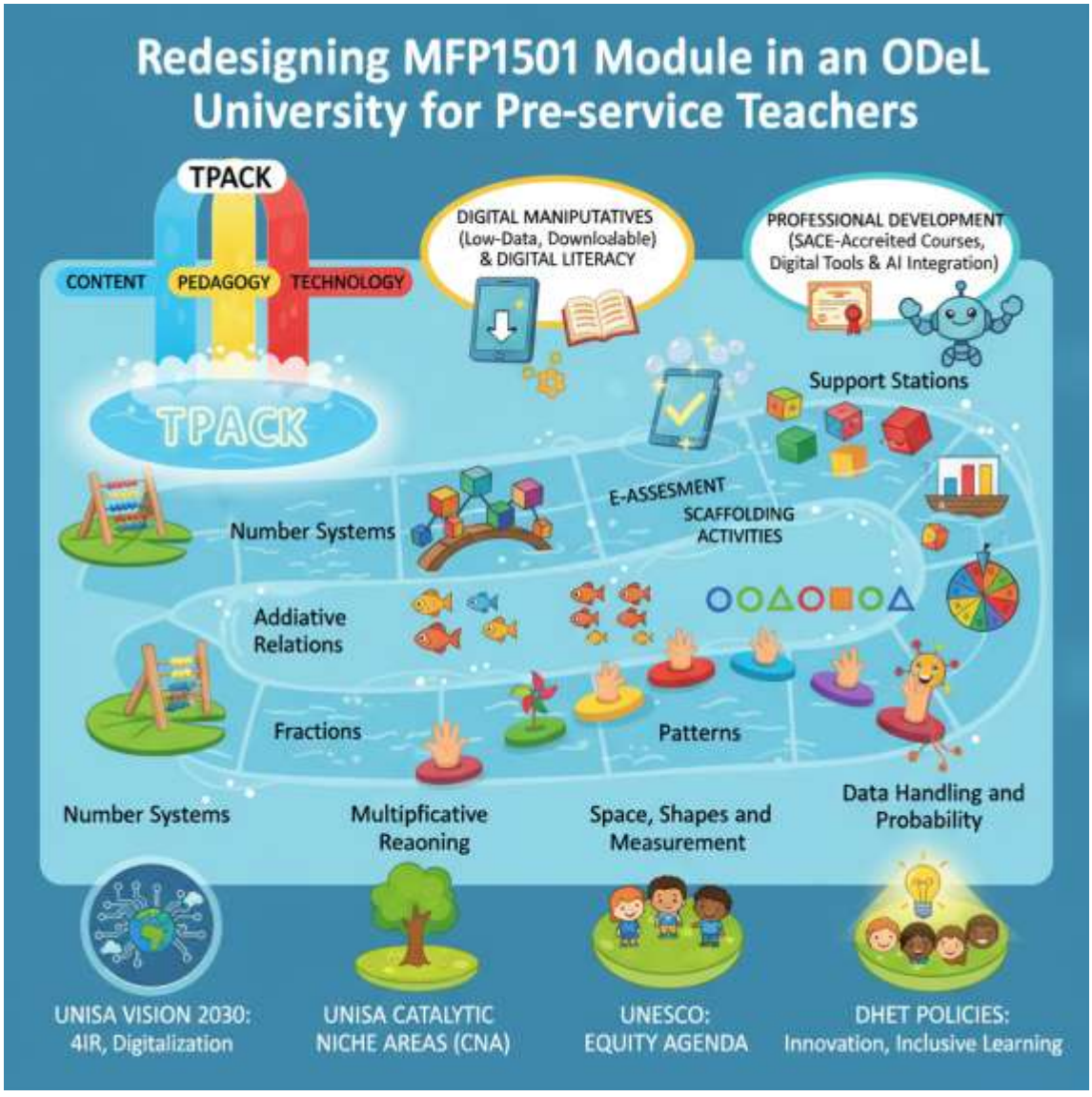

Figure 1: A suggested model diagram of the redesigning of MFP1501 (generated and edited using ChatGPT AI visuals)

Figure 1 demonstrates a model for redesigning MFP1501 in ODeL context to align with the TPACK lens, DHET and UNISA policies to equip pre-service teachers with the current trends of teaching mathematics in the Foundation Phase classrooms. In response, to redesign the MFP1501 module, pre-service teachers need to be prepared to use content, technology and pedagogies where digital manipulatives with various pedagogies can be integrated to teach Foundation Phase learners mathematics.[95] MFP1501 could be redesigned to align each of its seven units (number systems, additive relations, multiplicative reasoning, fractions, patterns, space/shape/measurement, data handling) with the TPACK framework. For example, in Unit 1 on number systems, pre-service teachers can be tasked to investigate the interactive digital manipulatives and relevant pedagogies, while Unit 2 on additive relations can develop their understanding of applications of digital technologies within different environments to teach mathematics to Foundation Phase learners. As illustrated in Figure 1.1, the suggested model aligns with UNISA's (2025) Vision 2030 and its Catalytic Niche Areas, focusing on 4IR, digitalisation, student support, and co-curricular activities to achieve a fully blended and adaptive digital university.

In addition, MFP1501 can build digital literacy by equipping pre-service teachers with strategies such as using low-data and downloadable digital manipulatives, making the module adaptable to both resource-rich and resource-constrained contexts.[96] In the same vein, pre-service teachers can support learning in the Foundation Phase through visualisations of mathematics using technological tools. For example, Units 3, 4, and 5 could be strengthened by training pre-service teachers to use low-data manipulatives and digital resources to teach multiplicative reasoning, fractions and patterns in the Foundation Phase. This suggestion directly corresponds to the UNESCO (2015) equity agenda and the DHET's (2020) emphasis on innovation, inclusive and equitable lifelong learning to promote quality education.

RECOMMENDATIONS

The findings highlight the need for professional development for pre-service teachers. The author recommends that pre-service teachers register for free SACE-accredited courses on play pedagogies, which provide knowledge on integrating digital tools and AI to enhance teaching across subjects. For the MFP1501 module, these free courses can provide professional development for improving understanding of pre-service teachers in integrating pedagogical and technological tools to teach young learners mathematics. In addition, in line with TPACK, assessment activities should be incorporated for the professional development of pre-service teachers. Thus, MFP1501 Units 6 and 7 could unpack how to integrate e-assessment, scaffolded, and ZPD approaches to prepare pre-service teachers to teach space, shapes, measurement and data handling to Foundation Phase learners. These recommendations align with UNESCO, DHET, and UNISA policies that require pre-service teachers to use content, technology and pedagogy together to teach Foundation Phase mathematics effectively.

CONCLUSION

This narrative review highlighted that pre-service teachers face limited knowledge, practical challenges and uneven professional development in integrating digital technologies for mathematics teaching. The findings indicate a disconnect between access to technology and pedagogical readiness, particularly in an ODeL context. Therefore, this paper suggests redesigning MFP1501 to integrate content, pedagogy and technology in ways that accommodate a digitally constrained environment, digital literacy and teaching competence within the TPACK framework. The suggested guidelines and recommendations would position MFP1501 as an innovative and transformative module to prepare pre-service teachers for teaching mathematics in the Foundation Phase.

[95] Vale and Westaway, "The Development of Pre-Service Teachers' Competence to Teach Mental Calculation Strategies."

[96] Martínez-Zarzuelo et al., "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Ttools for Outdoor Mathematics"; Angel Mukuka and Jogymol Kalariparampil Alex, "Profiling Mathematics Teacher Educators' Readiness for Digital Technology Integration: Evidence from Zambia," *Journal of Mathematics Teacher Education* 28, no. 2 (March 4, 2025): 315–39, https://doi.org/10.1007/s10857-024-09657-z; Wiseman Zulu, "Exploring the Tech-Twist: Preservice Mathematics Teachers' Implementation of Educational Technologies for Visualisation at Resource-Constrained Schools."

In essence, this paper emphasises the need for curriculum transformation in alignment with global, national and institutional policies that promote inclusive, equitable and inclusive education in higher learning institutions.

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