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Reimagining mathematics pedagogy through SoTL: A framework for South African Universities of Technology

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ABSTRACT

Mathematics education in South African Universities of Technology (UoTs) faces persistent challenges—high attrition in gateway courses, weak alignment with vocational practice, and limited pedagogical inclusivity—that undermine both student success and institutional mandates. This conceptual paper develops a SoTL-informed framework to reimagine mathematics pedagogy in UoTs. Situated within a constructivist epistemology and guided by the Research Onion, the study uses a transparent three-stage conceptual method (theoretical integration, targeted literature synthesis 2000–2024, and iterative framework construction) to ensure methodological coherence and defend theoretical choices. Drawing on Constructivism, Pedagogical Content Knowledge (PCK), Technological PCK (TPACK), and SoTL principles, the framework identifies five interrelated pillars—discipline-specific PCK, vocational relevance, inclusive and adaptive pedagogy, reflective SoTL inquiry, and digital integration—and explicates how they interlock to support vocational readiness, equity, and sustainable pedagogical change in UoTs. The paper's contributions are (1) a context-sensitive, theoretically grounded model specifically tailored to the UoT sector; (2) an explicit methodological and epistemological justification for conceptual framework development; and (3) practical institutional recommendations (professional development, SoTL institutionalisation, curricular alignment, and digital capacity building). Visual representations and summary tables accompany the framework to aid uptake and empirical testing. This work thus moves beyond descriptive review to offer a clearly articulated, actionable blueprint for scholarship and practice in mathematics teaching at UoTs.

Keywords: Scholarship of Teaching and Learning (SoTL), mathematics pedagogy, Universities of Technology, PCK, TPACK, constructivism, inclusivity.

INTRODUCTION

South Africa's Universities of Technology (UoTs) occupy a unique niche in the national higher education landscape. Their institutional mandate prioritizes vocational readiness, applied knowledge, and technological innovation, particularly in disciplines such as engineering, applied sciences, and information technology. Within this context, mathematics functions as both a *gateway subject* and a *disciplinary enabler* for professional practice. Yet, persistent challenges—including low pass rates, misalignment between secondary and tertiary curricula, and weak connections to workplace application—continue to limit student success and threaten the transformative mission of UoTs.[1]

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[1] Prem Padayachee and Samantha Maistry, "Pedagogical Transformation in University of Technology Mathematics," *Journal of Education* 88 (2022): 111–30.

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Traditional, transmissive pedagogies remain dominant in many UoTs, privileging content delivery over engagement and contextual relevance. These practices often alienate students, reinforcing perceptions of mathematics as abstract and disconnected from professional realities.[2] Consequently, mathematics—intended as a tool for empowerment—too often becomes a barrier to progression. In contrast, international and emerging South African scholarship highlights the potential of constructivist, learner-centered, contextually embedded, and digitally enriched pedagogies to enhance conceptual understanding and vocational competence.[3]

Despite isolated innovation, UoTs lack a coherent, theoretically grounded framework that systematizes these pedagogical advances. Most interventions are fragmented, short-term, or insufficiently theorized, leaving a critical research gap: *How can mathematics pedagogy in UoTs be reimagined to integrate inclusivity, vocational alignment, and digital competence through the lens of the SoTL?*

This study addresses that gap by proposing a SoTL-informed conceptual framework that integrates Constructivism, PCK, TPACK, and SoTL principles. Situated within a constructivist epistemology[4] and guided by the Research Onion,[5] the study employs a three-stage conceptual method—theoretical integration, literature synthesis (2000–2024), and framework construction—to ensure methodological transparency and theoretical coherence.[6]

The framework aims to (1) align mathematics pedagogy with the vocational and technological mandate of UoTs; (2) embed inclusive and adaptive teaching practices that respond to diverse learner profiles; and (3) institutionalize SoTL as scholarly practice, enabling continuous pedagogical reflection, evidence-based innovation, and dissemination.

Accordingly, the study is guided by three interrelated research questions:

1) How can SoTL principles address operational challenges in UoT mathematics pedagogy?
2) What theoretical foundations support the development of such a framework?
3) What pillars emerge as central to reimagining mathematics teaching for UoTs?

By addressing these questions, the paper contributes a theoretically robust and contextually grounded framework for advancing mathematics education at UoTs—transforming it from a source of exclusion into a catalyst for vocational readiness, equity, and institutional transformation.

LITERATURE REVIEW

Mathematics Education at UoTs and Vocational Relevance

Mathematics education in South Africa's UoTs exists at the intersection of disciplinary rigor and vocational application. While UoTs emphasize *applied learning* and *workplace readiness*, mathematics is often taught abstractly, reinforcing the perception that it lacks professional relevance.[7] This misalignment contributes to low student success rates in gateway courses, especially within engineering and applied sciences.

A persistent issue is the lack of constructive alignment between curriculum, pedagogy, and vocational competencies.[8] Studies demonstrate that when mathematics is embedded in authentic workplace problems—such as engineering design, industrial optimization, or health data analytics—

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[2] Jo Boaler, *Mathematical Mindsets: Unleashing Students' Potential through Creative Math, Inspiring Messages and Innovative Teaching* (San Francisco: Jossey-Bass, 2016), 33.

[3] Geoff Wake and Ros Sutherland, "Mathematics and Work: Contextual Learning," *Educational Studies in Mathematics* 109, no. 2 (2022): 157–74.

[4] Paul Ernest, *The Philosophy of Mathematics Education* (London: Falmer Press, 1991).

[5] Mark Saunders, Philip Lewis, and Adrian Thornhill, *Research Methods for Business Students*, 7th ed. (Harlow: Pearson Education, 2016).

[6] Sitwala Imenda, "Is There a Conceptual Difference between Theoretical and Conceptual Frameworks," *Journal of Social Sciences* 38, no. 2 (2014): 185–95.

[7] Hamsa Venkat, "Mathematics Pedagogy in South African Universities of Technology," *Perspectives in Education* 37, no. 2 (2019): 66–82.

[8] John, Biggs and Catherine Tang, *Teaching for Quality Learning at University: What the Student Does*, 4th ed. (Maidenhead: McGraw-Hill Education, 2011).

students demonstrate higher motivation and transfer of learning.[9] Despite these benefits, most UoTs have implemented such models only sporadically, without sustained theoretical grounding or institutional integration.[10]

Constructivism, PCK, and TPACK Foundations

Constructivism positions learners as active constructors of knowledge, emphasizing interaction, reflection, and contextual engagement.[11] For UoTs, this approach translates into vocationally authentic learning—embedding mathematical ideas in practical, industry-related tasks and collaborative inquiry. South African studies show that inquiry-based and project-driven approaches enhance conceptual understanding and self-efficacy in mathematics.[12] PCK, highlights the integration of disciplinary expertise and pedagogy.[13] Within UoTs, strong PCK allows lecturers to design inclusive and context-sensitive instruction, anticipating misconceptions while connecting abstract mathematics to real-world application.[14]

TPACK extends PCK by integrating digital competencies into teaching.[15] In UoTs—institutions inherently linked to technology—TPACK supports blended and simulation-based learning that mirrors workplace realities.[16] However, digital inequities and limited lecturer readiness continue to constrain its impact.[17] The COVID-19 pandemic revealed these disparities and underscored the need for systemic capacity building in digital pedagogy.[18]

The Scholarship of Teaching and Learning (SoTL)

The SoTL reframes teaching as a systematic, evidence-based inquiry[19]. In South Africa, SoTL aligns closely with higher education transformation agendas—advancing equity, inclusivity, and academic professionalism.[20] Within mathematics education, SoTL fosters reflective cycles of teaching improvement through collaborative lesson study, peer review, and dissemination.[21]

For UoTs, SoTL offers a means to institutionalize pedagogical innovation, enabling lecturers—many trained as disciplinary specialists rather than educators—to systematically investigate student learning, share insights, and build professional communities.[22] Yet, despite its transformative potential, SoTL remains underutilized in mathematics departments at UoTs, often perceived as optional rather than integral to teaching practice. Embedding SoTL as a structural norm would ensure that pedagogical reforms are scholarly, sustainable, and aligned with institutional missions.[23]

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9 Celia Hoyles, Richard Noss, and Phillip Kent, *Designing Connected Mathematics: Learning, Teaching and Technology* (London: Routledge, 2021).

10 Pathmanathan Moodley and Suresh Singh, “Contextual Mathematics Teaching in Universities of Technology,” *South African Journal of Higher Education* 36, no. 3 (2022): 221–37.

11 Ernest, *The Philosophy of Mathematics Education*.

12 Cyril Julie and Mbekwa Mbekwa, “Inquiry-Based Learning in South African Mathematics Classrooms,” *African Journal of Research in Mathematics, Science and Technology Education* 23, no. 1 (2019): 17–29.

13 Lee S Shulman, “Those Who Understand: Knowledge Growth in Teaching,” *Educational Researcher* 15, no. 2 (1986): 4–14.

14 N. Khanyile and L. Green, “Pedagogical Content Knowledge in Technical Mathematics Education,” *South African Journal of Education* 42, no. 1 (2022): 1–12.

15 Punya, Mishra and Matthew J. Koehler, “Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge,” *Teachers College Record* 108, no. 6 (2006): 1017–54; Khanyile and Green, “Pedagogical Content Knowledge in Technical Mathematics Education.”

16 R. Naidoo and V. Govender, “Digital Pedagogies in Mathematics Education,” *South African Journal of Education* 41, no. 1 (2021): 1–12.

17 Laura Czerniewicz, Cheryl Brown, and Sukaina Essop, “Inequities in Online Learning during COVID-19,” *South African Journal of Higher Education* 34, no. 4 (2020): 122–39.

18 Paul Drijvers, “Mathematics Education and Digital Tools after COVID-19,” *Educational Studies in Mathematics* 106, no. 2 (2020): 275–80.

19 Hutchings et al., *The Scholarship of Teaching and Learning Reconsidered*, 2011

20 Pat Hutchings, Mary Taylor Huber, and Anthony Ciccone, *The Scholarship of Teaching and Learning Reconsidered: Institutional Integration and Impact*, vol. 21 (John Wiley & Sons, 2011).

21 Barbara Jaworski, “Mathematics Teaching, Learning and the Scholarship of Teaching and Learning,” *International Journal for the Scholarship of Teaching and Learning* 13, no. 1 (2019): 1–14.

22 Mondli Hlatshwayo, “Institutionalising SoTL in South African Higher Education: Challenges and Opportunities,” *South African Journal of Higher Education* 36, no. 3 (2022): 1–18.

23 Brenda Leibowitz, “Reflections on SoTL and Transformation in South Africa,” *Teaching in Higher Education* 19 (2014): 268–81.

Gaps in Research and Emerging Directions

Three interlinked gaps dominate the literature

First, conceptual fragmentation: existing studies focus narrowly on specific pedagogical aspects (e.g., digital tools or inclusivity) without integrating them into a coherent, theory-driven model for UoTs. Second, limited SoTL institutionalization: while reflective inquiry is promoted at national level, few UoTs operationalize it within mathematics education.[24]Third, contextual neglect: most research draws from traditional universities, leaving UoTs under-theorized despite their distinctive vocational mandate.

Emerging global models—such as inquiry-based learning (IBL) and problem-based learning (PBL)—illustrate how mathematics can become more inclusive, contextualized, and digitally mediated.[25] These approaches demonstrate clear potential for adaptation to the UoT environment but require theoretical integration through constructs like Constructivism, PCK, TPACK, and SoTL to ensure coherence and sustainability.

Synthesis and Emerging Insights

A synthesis of local and international scholarship reveals a convergence of perspectives that underscore the need for an integrative approach to mathematics pedagogy within UoTs. Central to this synthesis is the alignment of constructivist theory, PCK, and TPACK to create a teaching framework that is simultaneously rigorous, vocationally relevant, and digitally adaptive. Constructivist learning theory posits that knowledge is actively constructed through interaction, experience, and reflection rather than passively received, thereby requiring educators to design learning environments that engage students in meaning-making.[26] When coupled with PCK—which emphasizes the nuanced understanding of how subject matter should be taught for conceptual clarity—and TPACK—which integrates technological competence into pedagogical design—mathematics instruction becomes more responsive to both disciplinary depth and contemporary digital realities.[27]

Furthermore, the SoTL emerges as a unifying epistemological and methodological lens that anchors these pedagogical constructs within a cycle of inquiry, reflection, and evidence-based improvement.[28] SoTL positions educators as reflective scholars who systematically investigate and disseminate insights about teaching and learning, fostering a culture of continuous professional growth and institutional learning. Within the UoT context, this is particularly significant, as SoTL promotes the bridging of theory and practice in vocationally oriented disciplines where mathematics underpins applied fields such as engineering, health sciences, and information technology.

Finally, inclusivity and contextual responsiveness are critical for addressing structural inequities that persist in mathematics education across South African higher education. By embedding inclusive pedagogies that recognize linguistic diversity, cognitive variation, and socio-economic disparities, institutions can advance transformation agendas while enhancing access and success for all students.[29]

Collectively, these insights justify the development of a SoTL-informed conceptual framework that integrates constructivism, PCK, and TPACK into a cohesive model for reimagining mathematics pedagogy at UoTs. The following section elaborates on this conceptual framework and its methodological underpinnings.

THEORETICAL FRAMEWORK

Reimagining mathematics pedagogy in South African UoTs requires a framework that is both theoretically rigorous and contextually responsive. Drawing on four interrelated theoretical perspectives—Constructivism, PCK, TPACKand the SoTL—this section establishes the conceptual

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[24] Council on Higher Education (CHE), *Framework for Institutional Quality Enhancement* (Pretoria: CHE, 2014); Mondli Hlatshwayo and Labby Ramrathan, "SoTL Implementation in Universities of Technology," *South African Journal of Higher Education* 35, no. 3 (2021): 90–106.

[25] Sandra Laursen and Chris Rasmussen, "Inquiry-Based Learning in Undergraduate Mathematics," *Studies in Higher Education* 44, no. 1 (2019): 120–34.

[26] Jerome Bruner, *The Culture of Education* (Cambridge, MA: Harvard University Press, 1996).

[27] Ernest L Boyer, *Scholarship Reconsidered: Priorities of the Professoriate.* (ERIC, 1990).

[28] Boyer, *Scholarship Reconsidered: Priorities of the Professoriate.*

[29] Catherine Bovill, "Co-Creation in Learning and Teaching: The Case for a Whole-Class Approach in Higher Education," *Higher Education* 79, no. 6 (2020): 1023–37.

foundation for the proposed model. These perspectives collectively respond to the challenges identified in the literature: weak vocational alignment, limited inclusivity, digital inequities, and fragmented pedagogical innovation.

Constructivism

Constructivist learning theory posits that learners actively construct knowledge through interaction, reflection, and engagement with meaningful tasks. Within UoTs, constructivism provides a philosophical anchor for transforming mathematics instruction from rote learning to *applied understanding*. Embedding mathematics within authentic workplace scenarios—such as industrial modeling, project-based learning, and problem-solving in vocational contexts—helps students perceive the relevance of abstract concepts. Research shows that such context-rich pedagogies increase engagement, self-efficacy, and conceptual transfer.[30] In diverse classrooms, constructivism also promotes collaboration and dialogic learning, aligning with transformation goals of inclusivity and equity.

PCK

Shulman's concept of PCK underscores the integration of *disciplinary expertise* with *pedagogical strategy*.[31] For mathematics educators at UoTs, this integration is essential for addressing heterogeneous cohorts—students with varied academic backgrounds, linguistic diversity, and differing levels of preparedness. Effective PCK enables lecturers to anticipate misconceptions, scaffold learning, and connect mathematical abstractions to vocational applications.[32] Strengthening lecturers' PCK capacity through professional development fosters inclusive teaching and ensures that mathematics instruction remains both rigorous and accessible.

TPACK

TPACK extends PCK by situating technology as a dynamic mediator between content and pedagogy.[33] In UoTs—where technological orientation is part of the institutional identity—TPACK is pivotal to achieving *digital fluency* and *21st-century workplace readiness*. Integrating simulations, visualization software, and blended learning environments enhances conceptual understanding and engagement.[34] Yet, without institutional investment in digital infrastructure and ongoing lecturer training, such integration risks being superficial. The framework thus positions TPACK as a strategic mechanism for systemic digital transformation within mathematics education, aligned with the Fourth Industrial Revolution and national digital policy priorities.[35]

SoTL

SoTL serves as the unifying theoretical lens in this framework. It redefines teaching as a scholarly, evidence-based practice rooted in reflection, collaboration, and dissemination.[36] In UoTs, where many mathematics lecturers originate from technical rather than educational backgrounds, SoTL provides the structure for cultivating pedagogical scholarship—promoting continuous inquiry into teaching effectiveness and student learning.[37] By embedding reflective cycles—plan, act, evaluate, share—SoTL

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[30] Wake and Sutherland, "Mathematics and Work: Contextual Learning."
[31] Shulman, "Those Who Understand: Knowledge Growth in Teaching," 1986.
[32] Hamsa Venkat and Jill Adler, "Developing Pedagogical Content Knowledge in Mathematics Education," *Journal of Mathematics Teacher Education* 15, no. 2 (2012): 121–39.
[33] 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.
[34] Naidoo and Govender, "Digital Pedagogies in Mathematics Education."
[35] Klaus Schwab, *The Fourth Industrial Revolution* (Geneva: World Economic Forum, 2017).
[36] Brenda Leibowitz and Vivienne Bozalek, "Institutionalising the Scholarship of Teaching and Learning," *Higher Education Research & Development* 35, no. 5 (2016): 1021–35.
[37] Clarence Sherran, "Enabling the Scholarship of Teaching and Learning in South African Universities: Reflective Pedagogies for Professional Growth," *Journal of University Teaching & Learning Practice* 18, no. 2 (2021): 1–17.

transforms isolated teaching innovations into institutionalized, collaborative, and data-driven practices.[38]

Table 1: Integrative Relevance to the UoT Context

Theoretical Lens	Core Principle	UoT Application	Key Outcomes
Constructivism	Learners build knowledge through contextual experience	Embed mathematics in vocational and real-world scenarios	Deepened understanding, relevance
PCK	Integration of content and pedagogy	Tailor instruction for diverse, underprepared cohorts	Inclusivity and improved access
TPACK	Fusion of technology, pedagogy, and content	Integrate digital tools for visualization and simulation	Digital fluency, engagement
SoTL	Teaching as scholarly inquiry	Reflective, evidence-based pedagogical innovation	Sustainability, transformation

Together, these theories provide the scaffolding for a SoTL-informed conceptual framework that is inclusive, vocationally aligned, and digitally adaptive—addressing both scholarly and institutional transformation mandates in South African UoTs.

METHODOLOGY

Research Design and Epistemological Positioning

This study adopts a conceptual research design situated within a constructivist epistemology. Constructivism posits that knowledge is co-constructed through engagement with theory, context, and reflection rather than discovered as objective truth.[39] This paradigm aligns with the study's aim: to *develop a theoretically integrated framework* for reimagining mathematics pedagogy in UoTs through the SoTL lens.

Unlike empirical studies that rely on primary data, conceptual research synthesizes and integrates existing theories to generate new explanatory models.[40] This design is therefore appropriate for the current inquiry, which seeks to address theoretical fragmentation and propose a coherent framework rather than test hypotheses.

Guided by the Research Onion,[41] the study's methodological architecture unfolds through distinct layers:

- Philosophical stance: *Constructivism*—knowledge arises through interpretation and meaning-making.
- Approach to theory development: *Inductive and interpretivist*—theory is built from synthesis rather than deduction.
- Research strategy: *Conceptual synthesis*—integration of multiple theoretical lenses.
- Methodological choice: *Qualitative, non-empirical analysis* drawing from literature.
- Time horizon: *Cross-sectional*—focused synthesis of scholarship from 2000–2024.
- Techniques and procedures: *Systematic literature analysis* and *iterative conceptual integration*.

This structure ensures methodological transparency and theoretical coherence, addressing reviewers' concerns about epistemological and methodological clarity.

Conceptual Research Process

The study's methodological process unfolded in three iterative and interconnected stages, each aligned with the Research Onion framework and designed to ensure internal coherence between philosophical stance, theoretical synthesis, and framework development.

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[38] Hlatshwayo, "Institutionalising SoTL in South African Higher Education: Challenges and Opportunities."
[39] Ernest, *The Philosophy of Mathematics Education*.
[40] Imenda, "Is There a Conceptual Difference between Theoretical and Conceptual Frameworks."
[41] Saunders, Lewis, and Thornhill, *Research Methods for Business Students*.

Stage 1: Theoretical Integration

This stage entailed a critical examination of four foundational perspectives—Constructivism, PCK, TPACK, and SoTL—to establish their complementarity and collective capacity to address UoT-specific pedagogical challenges: vocational relevance, inclusivity, and digital transformation. Drawing on Imenda, this stage operationalized *conceptual integration* by identifying intersections and divergences among the theories, producing a synthesized theoretical base that informed subsequent stages.

Stage 2: Targeted Literature Synthesis

A selective, integrative review of peer-reviewed scholarship (2000–2024) followed, emphasizing mathematics pedagogy, SoTL, vocational education, inclusivity, and digital integration in higher education. Both South African and international literature were analyzed to balance contextual specificity with global best practice.[42]The synthesis involved thematic coding of key insights, focusing on recurring pedagogical barriers and innovation enablers in UoTs. This stage served as the empirical grounding for framework construction.

Stage 3: Framework Development

Insights from the theoretical and literature stages were consolidated into a five-pillar conceptual framework encompassing:

1) Discipline-specific PCK,
2) Vocational relevance,
3) Inclusive and adaptive pedagogy,
4) Reflective SoTL inquiry
5) Digital integration

The framework was refined through iterative analysis to ensure internal coherence, theoretical saturation, and contextual applicability. Its structure directly responds to the Research Onion's inner layers—linking epistemology to method and outcome.

Ensuring Rigor and Trustworthiness

To enhance conceptual rigor, the study adhered to the following validation criteria:[43]

- Transparency: Clear documentation of inclusion criteria, theoretical scope, and methodological stages.
- Triangulation of sources: Integration of multidisciplinary and multi-contextual literature to avoid bias.
- Analytical consistency: Iterative peer debriefing and cross-checking of conceptual themes against established theory.
- Reflexivity: Continuous reflection on positionality to ensure congruence with the constructivist paradigm.

Ethical and Scholarly Considerations

Although no human participants were involved, the study followed scholarly ethics—accurate citation, integrity in interpretation, and acknowledgment of intellectual contributions. The conceptual framework generated here serves as a *foundation for subsequent empirical SoTL studies*, such as action research, case studies, or institutional pilots to evaluate its practical impact.

FINDINGS AND FRAMEWORK PRESENTATION

A SoTL-Informed Model for Mathematics Pedagogy in UoTs

The synthesis of theory and literature culminated in a SoTL-informed conceptual framework for reimagining mathematics pedagogy in South African UoTs. The framework integrates Constructivism, PCK, TPACK, and SoTL into a coherent model comprising five interrelated pillars. Each pillar

[42] Venkat, "Mathematics Pedagogy in South African Universities of Technology."
[43] Imenda, "Is There a Conceptual Difference between Theoretical and Conceptual Frameworks."

addresses a distinct operational challenge in UoT mathematics education while collectively advancing inclusivity, vocational relevance, and scholarly teaching practice. The framework directly responds to the three research questions:

1) How can SoTL principles address operational challenges in UoT mathematics pedagogy?
2) What theoretical foundations support the development of such a framework?
3) What pillars emerge as central to reimagining mathematics teaching for UoTs?

The five pillars are depicted in Figure 1, which visually illustrates their interconnections and the central role of SoTL as the integrative mechanism.

Pillar 1: Discipline-Specific Pedagogical Content Knowledge (PCK)
This pillar emphasizes the centrality of discipline-specific PCK in effective mathematics instruction. UoT mathematics educators must balance conceptual rigor with accessibility, ensuring that abstract ideas are presented in ways that connect with students' prior experiences and professional aspirations.[44]

Developing PCK capacity through structured professional development and peer collaboration enhances teaching quality and fosters inclusivity for diverse, often underprepared student cohorts. Within the framework, this pillar operationalizes the theoretical grounding of PCK and responds to Research Question 2 by situating pedagogical expertise as the foundation for improved learning outcomes.

Pillar 2: Vocational Relevance
The second pillar foregrounds vocational relevance as essential to UoTs' applied mission. Mathematics instruction must be contextually embedded in authentic, workplace-oriented tasks.[45] This pillar advocates for constructive alignment between mathematical concepts and professional applications—such as engineering simulations, data modeling, and statistical analysis in health sciences.

By linking mathematics learning to industry-based problems and work-integrated learning (WIL), the framework enhances student motivation and transferability of knowledge. This directly addresses Research Question 1, demonstrating how SoTL-informed pedagogy can align teaching with institutional mandates of employability and practical competence.

Pillar 3: Inclusive and Adaptive Pedagogy
This pillar recognizes inclusivity as a transformational imperative in South African higher education.[46] UoTs serve a socioeconomically and linguistically diverse student population, necessitating adaptive pedagogical strategies such as differentiated instruction, multilingual scaffolding, and formative feedback mechanisms.

Grounded in constructivist and culturally responsive approaches, this pillar reframes diversity as an asset rather than a deficit. By positioning inclusivity at the core of mathematics pedagogy, it directly addresses Research Question 3, highlighting the framework's responsiveness to equity and social justice within the UoT context.

Pillar 4: Reflective Inquiry through SoTL
The fourth pillar positions SoTL as the integrative mechanism for reflection, evidence-based improvement, and scholarly dissemination.[47] Mathematics educators are encouraged to engage in cyclical SoTL inquiry—planning, implementing, assessing, and sharing pedagogical practices.

By transforming teaching from an individual act to a collaborative scholarly pursuit, SoTL cultivates professional learning communities that enhance responsiveness to student needs and promote continuous innovation. This pillar thus answers Research Question 1 and Research Question 2, demonstrating how SoTL operationalizes scholarly teaching within vocationally oriented institutions.

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[44] Venkat and Adler, "Developing Pedagogical Content Knowledge in Mathematics Education."
[45] Moodley and Singh, "Contextual Mathematics Teaching in Universities of Technology."
[46] Leibowitz and Bozalek, "Institutionalising the Scholarship of Teaching and Learning."
[47] Sherran, "Enabling the Scholarship of Teaching and Learning in South African Universities: Reflective Pedagogies for Professional Growth."

Pillar 5: Digital Integration through TPACK

The fifth pillar underscores digital integration as a strategic enabler of modern mathematics pedagogy. Grounded in the TPACK framework, it calls for the purposeful fusion of content, pedagogy, and technology to promote interactive, simulation-based, and blended learning environments.[48] Digital integration not only enhances engagement but also cultivates 21st-century digital fluency essential for graduates entering technology-driven professions. To ensure equity, this pillar emphasizes institutional responsibility for infrastructure, training, and support, aligning with SoTL's principle of reflective institutional learning. It responds to Research Question 3 by demonstrating how technology can be pedagogically leveraged for both access and excellence.

Framework Synthesis and Visual Representation

Figure 1 (Conceptual Framework for Reimagining Mathematics Pedagogy at UoTs) integrates the five pillars into a holistic model.

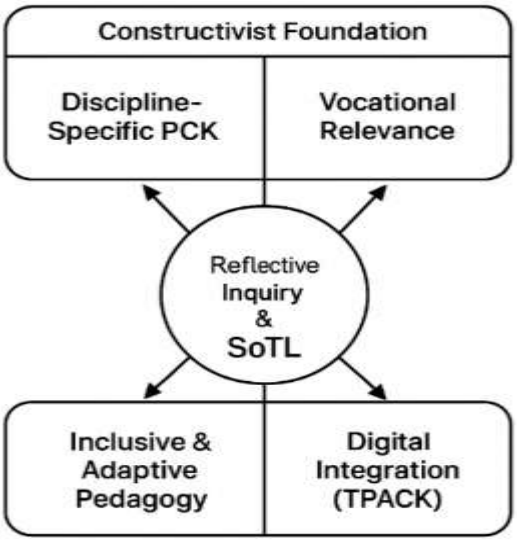

Figure 1. Conceptual Framework for Reimagining Mathematics Pedagogy at Universities of UoTs

At the core lies SoTL, symbolizing continuous reflective inquiry and scholarly practice. Surrounding it are the four complementary dimensions—PCK, vocational relevance, inclusivity, and digital integration—each connected by bidirectional arrows representing interaction and feedback loops.

Table 3: Summary of Framework Pillars and Theoretical Linkages

Pillar	Theoretical Foundation	Core Focus	Primary Outcome
Discipline-Specific PCK	Shulman (1986); Venkat & Adler (2012)	Pedagogical mastery within mathematical disciplines	Enhanced conceptual access
Vocational Relevance	Constructivism; Biggs & Tang (2011)	Applied, workplace-aligned learning	Motivation and employability
Inclusive & Adaptive Pedagogy	Constructivism; Gay (2010)	Cultural and cognitive inclusivity	Equity and retention

[48] Mishra and Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," 2006; Naidoo and Govender, "Digital Pedagogies in Mathematics Education."

Reflective Inquiry (SoTL)	Boyer (1990); Hutchings et al. (2011)	Scholarly, evidence-informed teaching	Continuous improvement
Digital Integration (TPACK)	Mishra & Koehler (2006)	Technology-enhanced pedagogy	Digital competence and engagement

Linking the Findings to the Research Questions (RQ)

The five pillars collectively respond to the study's research questions as follows:

- RQ1: Operational challenges in UoT mathematics pedagogy—such as abstraction, disengagement, and inequity—are addressed through vocational alignment, inclusivity, SoTL-led reflection, and digital innovation.
- RQ2: Theoretical foundations for framework development are articulated through the integration of Constructivism, PCK, TPACK, and SoTL.
- RQ3: The five pillars themselves represent the conceptual structure required to transform mathematics teaching into a vocationally relevant, inclusive, and scholarly practice.

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

Integrative Discussion

The findings from this conceptual study reaffirm that mathematics pedagogy in South African UoTs is at a critical juncture. Persistent challenges—ranging from low pass rates and limited inclusivity to weak vocational alignment—underscore the inadequacy of transmissive teaching models. The SoTL-informed five-pillar framework proposed here provides an integrated pathway to address these challenges through theoretically grounded, context-sensitive reform.

At the heart of this framework lies SoTL as a transformative mechanism, uniting the theoretical pillars of Constructivism, PCK, and TPACK. Together, these create a synergistic structure that supports reflective, inclusive, and vocationally relevant pedagogy. The model operationalizes transformation not merely as access, but as *epistemic inclusion*—ensuring that mathematics becomes both a bridge to knowledge and a platform for professional empowerment. This aligns with the Council on Higher Education and Department of Higher Education and Training imperatives emphasizing equity, employability, and relevance in higher education.[49]

By embedding constructivist epistemology within SoTL cycles of inquiry, mathematics educators are positioned as *practitioner-scholars* who investigate their own teaching, generate context-based evidence, and disseminate insights across UoTs. This paradigm shift transforms isolated innovation into institutional learning, positioning UoTs as centers of pedagogical scholarship rather than mere knowledge transmitters.

Implications for Educators

For mathematics educators in UoTs, the proposed framework necessitates a paradigmatic shift from teaching as the transmission of knowledge to teaching as a process of systematic scholarly inquiry.[50] Within this perspective, PCK serves as the foundation for designing instruction that is both cognitively responsive and epistemologically rigorous, allowing lecturers to address the diverse learning needs of students while maintaining disciplinary depth.[51] The integration of TPACK extends this foundation by

[49] Council on Higher Education (CHE), *Framework for Institutional Quality Enhancement*; DHET, " White Paper for Post-School Education and Training. Building an Expanded, Effective and Integrated Post-School System.," 2013.
[50] Boyer, *Scholarship Reconsidered: Priorities of the Professoriate.*
[51] Lee S. Shulman, "Those Who Understand: Knowledge Growth in Teaching," *Educational Researcher* 15, no. 2 (February 1, 1986): 4–14, https://doi.org/10.3102/0013189X015002004.

incorporating purposeful and contextually appropriate uses of technology that enhance conceptual visualization, collaborative learning, and digital accessibility.[52]

Moreover, SoTL encourages educators to systematically reflect on, document, and disseminate their pedagogical practices, transforming individual teaching experiences into collective professional knowledge.[53] Accordingly, professional development initiatives should prioritize not only disciplinary expertise but also pedagogical and digital fluency. Embedding SoTL within lecturer appraisal and promotion systems can incentivize scholarly engagement in teaching, while cross-institutional SoTL communities of practice may cultivate collaborative inquiry and mentorship in mathematics education.[54] Such strategies position educators as reflective practitioners contributing to both institutional and disciplinary advancement.

Implications for Institutions

Institutional transformation in the UoT sector depends on the strategic institutionalization of SoTL as a structural mechanism for teaching excellence and innovation. Institutions should integrate SoTL principles into teaching and learning policies, professional development frameworks, and promotion pathways, thereby recognizing teaching as a scholarly and research-informed practice.[55] Investment in digital infrastructure and staff training remains essential, particularly in contexts where technological inequities persist, to ensure equitable access and lecturer readiness.[56]

Furthermore, universities should promote interdisciplinary curriculum design linking mathematics with vocational disciplines such as engineering, health sciences, and information and communication technology (ICT), reinforcing the UoT mission of applied, socially responsive education.[57] Establishing funding and recognition schemes for pedagogical innovation and SoTL dissemination would further embed a culture of scholarly teaching. Through these measures, UoTs can align mathematics pedagogy with broader institutional goals of vocational readiness, innovation, and community engagement—thus positioning themselves as national leaders in applied STEM education reform.

Implications for Students

The adoption of this framework promises substantial benefits for students through the provision of engaging, inclusive, and career-relevant mathematics education. When mathematics is contextualized within authentic and vocationally oriented problem-solving scenarios, learners are more likely to develop intrinsic motivation and perceive the subject's practical relevance.[58] An inclusive pedagogy, incorporating differentiated instruction, multilingual scaffolding, and culturally responsive teaching, further supports learner equity and fosters a sense of belonging.[59]

In parallel, the purposeful integration of digital technologies prepares graduates for participation in technology-mediated workplaces characteristic of the Fourth Industrial Revolution(4IR).[60] Collectively, these pedagogical transformations can enhance student retention, throughput, and mathematical confidence, transforming mathematics from a perceived "gatekeeper" discipline into an enabler of opportunity and socio-economic mobility.[61]

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[52] Matthew J. Koehler and Punya Mishra, "TPACK (Technological Pedagogical Content Knowledge)," in *The SAGE Encyclopedia of Educational Technology* (Thousand Oaks, CA: SAGE Publications, Inc., 2015), 783–85, https://doi.org/10.4135/9781483346397.n318.

[53] Kathleen McKinney, *Enhancing Learning through the Scholarship of Teaching and Learning: The Challenges and Joys of Juggling* (San Francisco: Jossey-Bass, 2007).

[54] Etienne Wenger, *Communities of Practice: Learning, Meaning and Identity* (New York: Cambridge University Press, 1998).

[55] Joëlle Fanghanel et al., "Defining and Supporting the Scholarship of Teaching and Learning (SoTL): A Sector-Wide Study," *Higher Education Academy*, 2016, 1–43.

[56] Diana Laurillard, *Teaching as a Design Science: Building Pedagogical Patterns for Learning and Technology* (New York: Routledge, 2012).

[57] Council on Higher Education (CHE), *Review of Teaching and Learning in Higher Education* (Pretoria: CHE, 2020).

[58] Jean Lave and Etienne Wenger, *Situated Learning: Legitimate Peripheral Participation* (Cambridge: Cambridge University Press, 1991).

[59] Geneva Gay, *Culturally Responsive Teaching: Theory, Research, and Practice* (Teachers College Press, 2010).

[60] Klaus Schwab, *The Fourth Industrial Revolution*, *Group, New York* (New York: Crown Publishing Group, 2017).

[61] Thabo Mhlongo and Makgato Mpho, "Mathematics as a Gatekeeper in Universities of Technology," *Journal of Technical Education and Training* 14, no. 2 (2022): 56–70.

Implications for Policy and the Higher Education Sector

At a macro level, the framework aligns closely with the Department of Higher Education and Training (DHET) transformation agenda and the Council on Higher Education (CHE) imperatives emphasizing equity, inclusivity, and curriculum relevance in South African higher education.[62] Policymakers should therefore integrate SoTL as a criterion for teaching excellence awards and promotion systems and allocate targeted funding for capacity-building initiatives that develop PCK and TPACK competencies across the UoT sector.[63]

Furthermore, policy mechanisms should encourage sector-wide collaboration through SoTL-focused communities of practice, research networks, and national dissemination platforms, ensuring that institutional innovations inform systemic transformation.[64] The promotion of vocationally integrated curricula, linking mathematics with real-world and workplace applications, would further strengthen the alignment between academic preparation and labour market needs. Collectively, these policy measures would foster systemic coherence between national objectives, institutional practices, and classroom-level innovation, thereby reinforcing South Africa's STEM education pipeline and contributing to sustainable socio-economic development.

Implications for Future Research

As a conceptual contribution, this study lays a foundational theoretical basis for subsequent empirical exploration within the domain of student academic support and the SoTL in UoTs. Future research is therefore encouraged to operationalize and empirically validate the proposed framework through iterative, evidence-based inquiry. One promising approach would be the implementation of classroom-based action research or SoTL cycles to test the framework's feasibility, applicability, and pedagogical effectiveness in authentic teaching and learning contexts.[65] Such localized piloting would provide nuanced insights into how the framework mediates student engagement and learning outcomes within the UoT environment.

In addition, comparative case studies across multiple institutions could offer a deeper understanding of the contextual enablers and constraints that influence implementation.[66] By examining institutional cultures, leadership practices, and resource configurations, researchers may discern patterns that determine the adaptability of the framework to varying academic and vocational contexts.[67] Furthermore, longitudinal studies are warranted to evaluate the sustainability of the framework and its long-term impact on student learning, retention, and success.[68] Such temporal perspectives would contribute to assessing not only immediate outcomes but also systemic transformation within teaching and learning ecosystems.

Equally significant is the integration of the student voice through participatory and co-creative research methodologies. Involving students as research partners can strengthen the inclusivity, authenticity, and vocational relevance of the framework, aligning with contemporary calls for student partnership in curriculum design and pedagogical innovation.[69]

Ultimately, the empirical validation of this conceptual framework will deepen its scholarly legitimacy and enhance its practical utility. Continuous refinement through research-informed feedback loops will ensure that the framework evolves in response to the complex and dynamic realities of UoTs and the broader higher education landscape.

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[62] Council on Higher Education (CHE), *Higher Education Monitor Report* (Pretoria: CHE, 2023).
[63] Sioux McKenna and Johannes Strydom, "Systemic Transformation in South African Higher Education," *Studies in Higher Education* 46, no. 12 (2021): 2400–2415.
[64] Angela Brew, *Academic Tribes and Territories Revisited* (London: Open University Press, 2010).
[65] Keith Trigwell, "Approaches to Scholarship of Teaching and Learning Research," *Higher Education Research & Development* 32, no. 1 (2013): 95–108.
[66] Robert K. Yin, *Case Study Research and Applications: Design and Methods*, 6th ed. (Thousand Oaks, CA: SAGE Publications, 2018).
[67] Paul Trowler, *Doing Insider Research in Universities* (London: Bloomsbury, 2014).
[68] John Ward Creswell and John David Creswell, *Research Design Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. (Thousand Oaks, California: SAGE Publications Ltd, 2018).
[69] Bovill, "Co-Creation in Learning and Teaching: The Case for a Whole-Class Approach in Higher Education."

Table 3: Alignment of Framework with Transformation and SoTL Goals

Transformation Focus	Framework Pillar	SoTL Function	Expected Outcome
Equity & Inclusivity	Inclusive and Adaptive Pedagogy	Reflective inquiry; evidence-based differentiation	Increased access, retention, and belonging
Vocational Readiness	Vocational Relevance	Applied SoTL research in curriculum design	Enhanced employability and engagement
Pedagogical Innovation	PCK & TPACK Integration	Collaborative lesson study and digital inquiry	Enhanced teaching quality and digital competence
Institutional Transformation	SoTL Institutionalization	Policy alignment and communities of practice	Sustainable culture of scholarly teaching

CONCLUSION

This conceptual study set out to reimagine mathematics pedagogy in South African UoTs through the lens of the SoTL. Guided by a constructivist epistemology and framed within the Research Onion, the research synthesized four interrelated theoretical perspectives—Constructivism, PCK, TPACK, and SoTL—into a coherent five-pillar conceptual framework.

The framework responds to long-standing challenges that have constrained mathematics teaching at UoTs: low student success rates, limited inclusivity, weak vocational relevance, and uneven digital integration. By conceptualizing SoTL as the integrative core, the framework positions mathematics educators as reflective practitioner-scholars who investigate their own practice, use evidence to guide improvement, and contribute to institutional learning.

The five interlocking pillars—discipline-specific PCK, vocational relevance, inclusive and adaptive pedagogy, reflective SoTL inquiry, and digital integration—create a dynamic model that aligns teaching with equity, employability, and transformation imperatives. Collectively, they shift mathematics from a barrier subject to a vehicle for epistemic access and vocational empowerment.

The study thus advances both the scholarship of teaching and the practice of mathematics education in vocational higher education contexts. It offers UoTs a theoretically robust, context-sensitive, and actionable guide for policy, professional development, and curriculum renewal.

Contribution to the Body of Scholarship

This study contributes to the growing body of knowledge on mathematics pedagogy, SoTL, and higher-education transformation in three interrelated ways:

(1) Conceptual Contribution: It provides an original, integrative conceptual framework that unites four major theoretical strands—Constructivism, PCK, TPACK, and SoTL—into a single, operational model specifically tailored for UoTs. Whereas prior research has treated these theories in isolation, this study demonstrates their complementarity and interdependence, offering a new lens for understanding mathematics pedagogy in vocationally oriented institutions.

(2) Contextual Contribution: The framework contextualizes SoTL within South Africa's UoT sector, a domain under-represented in existing scholarship. By grounding the model in the unique mandates, student demographics, and technological imperatives of UoTs, the study extends the geographical and institutional reach of SoTL research. It highlights how SoTL can drive both teaching excellence and institutional transformation in post-apartheid, skills-focused higher education.

(3) Practical Contribution: Practically, the framework serves as a strategic guide for lecturers, curriculum designers, and institutional leaders. It offers actionable directions for:

- Embedding SoTL in teaching evaluation and professional development systems;
- Designing inclusive, technology-rich, and vocationally aligned mathematics curricula; and

- Building cross-disciplinary communities of practice that sustain innovation.

Through these mechanisms, the framework bridges the persistent gap between scholarly theory and pedagogical application, providing a replicable model for other STEM and vocational disciplines.

Future Outlook

The conceptual framework developed here lays the groundwork for empirical validation and adaptation. Future studies could operationalize its five pillars through action research, case studies, or SoTL projects across multiple UoTs to evaluate its effectiveness in improving student learning outcomes, lecturer development, and institutional culture. Continued inquiry will refine the model and ensure its relevance within evolving digital, vocational, and socio-educational landscapes.

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