

From knowledge acquisition to digital practice: Testing a prototype teaching module as a knowledge asset among nurse educators in the Republic of Maldives

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ABSTRACT

Digital transformation in higher education depends not only on access to technologies but on educators' capacity to integrate technological, pedagogical and disciplinary knowledge and translate that knowledge into practice. This study reframed Technological Pedagogical Content Knowledge (TPACK) as a professional knowledge asset and examined how a structured TPACK-N faculty-development intervention supported knowledge acquisition and subsequent digital teaching practice among nurse educators. An explanatory sequential mixed-methods design was used. In the quantitative phase, 118 nurse educators were randomised equally to intervention and control groups (n = 59 each). The intervention group completed a six-hour TPACK-N module and applied redesigned lessons over 12 weeks; the control group continued usual teaching. TPACK knowledge was measured using the 28-item TPACK.xs. The explanatory qualitative phase comprised five focus groups with 30 intervention educators. Baseline overall TPACK scores were comparable (106.12 vs. 105.37, $p = .793$), although teaching experience differed between groups. The intervention group demonstrated a greater mean gain than controls (17.07 vs. 4.71); an independent-samples t test showed a between-group change difference of 12.36 points, 95% CI [8.07, 16.64], $t(99.11) = 5.726$, $p < .001$, $d = 1.054$. Qualitative findings showed increased pedagogical confidence, purposeful integration of content, pedagogy and technology, and context-sensitive application, while time, infrastructure, technological readiness and continued support influenced utilisation. Integrated findings indicate a progression from knowledge acquisition to integration and digital practice, suggesting that TPACK-N can develop a professional knowledge asset whose sustained use depends on organisational support and continued renewal.

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INTRODUCTION

Digital transformation in higher education is often framed around the creation, adoption and adaptation of digital platforms, learning-management systems, artificial intelligence, simulation and other emerging technologies. However, the long-term and sustainable benefits of these technologies depend largely on the knowledge educators have and how effectively they integrate and apply that knowledge when making instructional decisions. This issue is particularly significant within professional education, where disciplinary expertise, pedagogical decision-making and technological competence need to function together rather than as separate areas of capability. Digital capability in recent literature has been highlighted as an essential pedagogical and professional competency rather than merely the ability to operate technological tools (Asal et al., 2025; Kulju et al., 2024; Pajari et al., 2024; Tischendorf et al., 2024). Similarly, recent reviews of higher education suggest that digital technologies generate meaningful institutional value when they facilitate the sharing, transfer and practical application of knowledge, rather than simply focusing on the implementation of technological systems (Kumar et al., 2024; Vyas, 2024).

The Technological Pedagogical Content Knowledge (TPACK) framework explains successful technology integration through the relationship between technological knowledge, pedagogical knowledge and content knowledge, as well as the areas where these forms of knowledge overlap (Mishra & Koehler, 2006). Subsequent developments of the framework have also highlighted the importance of contextual knowledge in shaping technology integration (Mishra, 2019). Recent scholarship further characterises TPACK as a contextual and evolving form of knowledge that relies on the ability to combine different knowledge domains rather than simply acquiring proficiency with individual digital technologies (Ait Ali et al., 2023; Fabian et al., 2024; Schmid et al., 2024). From a knowledge-management perspective, TPACK can therefore be understood as a professional knowledge resource held by nurse educators, which can contribute to organisational value when it is developed, implemented, modified according to circumstances, and effectively applied within teaching practice. Thus, a prototype of a TPACK module can become a knowledge asset to nurse educators, which would be addressed as TPACK-N.

Nurse educators offer a valuable setting for investigating how this process occurs. Although many nurse educators enter academic positions with extensive clinical experience, their formal preparation in teaching methods and digital education can differ considerably. Recent research has identified ongoing gaps and development requirements related to technological-pedagogical knowledge, digital competence, innovative teaching approaches, adaptability and systematic faculty-development initiatives (Alhonkoski et al., 2022; Bleijenbergh et al., 2023; Gilbert et al., 2024; Shon et al., 2024; Smith et al., 2023; Wolsey & Jacobsen, 2024; Zhou et al., 2024). Research involving multiple countries and consensus-based approaches also demonstrates that educators' digital-competence requirements and professional-development priorities are influenced by differences in their professional backgrounds and educational contexts (Koskimäki et al., 2025; Pajari et al., 2026; Štemberger Kolnik et al., 2026). Furthermore, the growing use of artificial intelligence in education has increased the importance of educators being able to evaluate and select technologies through informed, ethical and contextually appropriate judgement (Ali & Shaban, 2026; Hamilton et al., 2026; Rodger et al., 2025).

This study investigated TPACK-N as a professional knowledge resource among nurse educators. More specifically, it aimed to: (1) determine whether participation in a structured TPACK-N intervention improved nurse educators' ability to integrate technological, pedagogical and disciplinary knowledge in comparison with their usual teaching practices; and (2) investigate how educators incorporated the knowledge gained through the intervention into their digital teaching activities, including the contextual factors that supported or hindered its application. By examining both changes in educators' knowledge and their experiences of applying that knowledge in practice, the study seeks to broaden the understanding of TPACK beyond an educational-technology framework and position it within a knowledge-management perspective of professional capability.

Conceptual framing: TPACK as a knowledge asset

For this article, a knowledge asset refers to practical professional knowledge that strengthens both individual and organisational capability. TPACK is conceptualised as a combined knowledge asset because its usefulness does not depend on one particular type of knowledge, but rather on an educator's ability to bring together technological, pedagogical and disciplinary knowledge when responding to a particular teaching challenge. As nurse educators use this model to integrate nursing discipline and their teaching-learning environment into this knowledge asset, it would be further addressed as TPACK-N. Research on knowledge assets highlights that organisational value is influenced by the ways in which intangible knowledge resources are developed, managed and applied (Santarsiero et al., 2023). Similarly, intellectual-capital research in higher education describes how knowledge inputs can be transformed into knowledge outputs through institutional capabilities (Rehman et al., 2024). Based on this perspective, the TPACK-N intervention was viewed as a process for developing knowledge, lesson redesign represented the integration of that knowledge, classroom implementation reflected its utilisation, and ongoing reflection and interaction with peers were considered possible mechanisms through which knowledge could be retained and shared. This perspective is also consistent with evidence indicating that knowledge sharing within higher education is influenced by individual, organisational and technological factors (Fan & Beh, 2024).

From acquisition to integration

Recent research examining TPACK interventions suggests that professional development is more beneficial when it deliberately focuses on developing interconnected TPACK rather than concentrating mainly on technological knowledge (Fabian et al., 2024; Joshi, 2023). In the present study, educators were not merely introduced to new digital applications or tools. Instead, they were expected to establish connections between learning outcomes, nursing content, pedagogical approaches, educational technologies, learner activities and assessment methods when redesigning their lessons. This approach reflects higher-education research demonstrating that disciplinary expertise must be developed through pedagogical content knowledge in order to support effective teaching practices (Sarkar et al., 2024).

From integration to digital practice

Professional knowledge gains significance within an organisation when they are translated into actual practice. Therefore, the qualitative phase investigated how educators used the TPACK framework following the intervention and examined the contextual factors that influenced its implementation. This approach extends the quantitative focus beyond simply determining whether knowledge was acquired and instead considers how knowledge was used, adapted and developed into sustainable digital-teaching capability. Within higher education, knowledge sharing and knowledge-management practices are increasingly associated with innovation, institutional resilience and workplace practices. This further highlights the importance of examining how newly acquired knowledge is transferred from learning into practical use (Kim et al., 2025; Kumar et al., 2024; Vyas, 2024).

METHODOLOGY

Research design and setting

An explanatory sequential mixed-methods research design was adopted as part of a broader doctoral study. The quantitative phase involved a randomised controlled pretest-post-test study involving nurse educators from two higher-education institutions in the Maldives. This was followed by an explanatory qualitative phase involving educators who had participated in the intervention. The intervention took place

in April 2026, after which participants underwent a 12-week implementation period. The quantitative component was designed to determine whether educators' TPACK knowledge changed, while the qualitative component explored how these changes were experienced, incorporated into teaching and influenced by the educational context. The quantitative intervention was reported in accordance with the principles of CONSORT 2025 (Hopewell et al., 2025).

Participants and intervention

Participants were eligible if they were nurse educators with a minimum of one year of teaching experience and were currently employed in nursing education. Individuals who had previously received formal TPACK training were excluded. A total of 118 eligible educators were recruited and individually randomised through sequentially numbered, opaque, sealed envelopes. Of these participants, 59 were assigned to the intervention group and 59 to the control group. An a priori sample-size calculation using G*Power, based on a moderate effect size of 0.50, a two-sided $\alpha = .05$ and 80% statistical power, established a minimum required sample of 104 participants. All participants who were randomised completed both the pretest and post-test assessments. The intervention consisted of a six-hour TPACK-N module that combined theoretical explanation, demonstrations, guided practice and collaborative lesson redesign. The module covered TPACK domains, the alignment of nursing content and pedagogy, intentional technology selection, student-centred learning activities, technology-supported assessment and lesson redesign. Educators in the intervention group implemented their redesigned lessons over a 12-week period. Intervention fidelity was monitored using attendance records, implementation logs, submitted lesson plans, an implementation checklist and support from research assistants. Participants in the control group continued with their usual teaching practices.

Quantitative measurement and analysis

TPACK knowledge was assessed using the original 28-item TPACK.xs instrument, which consists of seven domains containing four items each: technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK) and integrated TPACK (Schmid et al., 2020). Each item was scored using a five-point scale, producing a possible total score ranging from 28 to 140. Descriptive statistics and Shapiro-Wilk tests were conducted to assess the distribution of the data. Chi-square tests were used to examine categorical characteristics at baseline. Changes in overall TPACK knowledge and individual domains were examined using paired-samples and independent-samples t tests. When the assumption of equal variances was violated, the unequal-variances estimate from the independent-samples t test was used. Effect sizes and 95% confidence intervals were reported, with two-sided $p < .05$ considered statistically significant.

Qualitative data collection

After completion of the quantitative phase, purposive sampling was applied to select intervention educators who could provide detailed and information-rich descriptions of their implementation experiences. Five focus group discussions were conducted, with six nurse educators participating in each group, resulting in a total sample of 30 participants ($n = 30$). A semi-structured discussion guide was developed based on the quantitative findings and relevant literature. The discussions examined areas including educators' pedagogical confidence, the integration of technology, pedagogy and nursing content, challenges encountered during implementation, professional-development requirements and perspectives on future digital teaching practices. Each focus group lasted approximately 60–80 minutes and was audio-recorded after obtaining participants' consent. Where clarification was required, meanings were checked with participants during the discussions. Data collection continued until the discussions no longer produced substantively new themes.

Qualitative data analysis and trustworthiness

The focus group data were examined using a hybrid deductive-inductive thematic analysis approach appropriate for explanatory mixed-methods research (Proudfoot, 2023). The deductive element was guided by the quantitative findings and the established TPACK domains, while inductive coding enabled participants' meanings and contextual experiences that were not predetermined by the framework to be identified. The analysis began with repeated familiarisation with the data, followed by the development of initial codes, comparison and refinement of related codes, organisation of codes into subthemes and their subsequent consolidation into broader themes. The coding process and emerging thematic framework were independently examined and cross-checked before the final themes were established. Trustworthiness and credibility were further strengthened through purposive sampling, achievement of saturation, the use of direct participant quotations and member checking. Participant meanings were clarified during the focus groups, after which participants were given the opportunity to review the researchers' interpretations and emerging themes to confirm their accuracy. Participant codes were used when reporting the findings to protect confidentiality while still allowing interpretations to remain connected to the evidence supporting them.

Mixed-methods integration

The quantitative and qualitative components were integrated in a sequential manner and brought together during interpretation. Findings from the quantitative phase guided the areas explored during the qualitative inquiry and provided an initial deductive framework for analysis. The qualitative findings subsequently provided explanations for how educators experienced and applied the changes in knowledge identified quantitatively, while also revealing contextual and implementation factors that could not be captured through numerical scores alone. During the interpretation stage, the two forms of evidence were compared using narrative weaving and a joint display. This process connected statistical findings with explanatory qualitative themes and supported the development of mixed-methods inferences concerning knowledge acquisition, integration, utilisation and renewal (Fetters & Tajima, 2022).

Ethical considerations

Ethical approval was obtained from the Universiti Teknologi MARA Research Ethics Committee (REC/06/2025/PG/MR/332) and The Maldives National University Research Development Office (RC/2026/ATCRMNU/01). Written informed consent was obtained from all participants. Participation was voluntary, participant codes replaced names, and focus group recordings, transcripts and analytical materials were handled confidentially with access restricted to the research team.

RESULTS

Participant profile and baseline characteristics

All 118 participants included in the quantitative study completed both the pretest and post-test assessments. As shown in Table 1, 74 participants (62.7%) were aged 35 years or above. In terms of educational qualifications, 38 participants (32.2%) had a master's degree, 60 (50.8%) held a bachelor's degree, 19 (16.1%) had a diploma and one participant (0.8%) held a PhD. The distribution of teaching experience was significantly different between the two groups, $\chi^2(2) = 32.69$, $p < .001$, Cramér's $V = .526$. This imbalance was substantial: 23 intervention educators (39.0%) had more than 10 years of teaching experience, compared with none in the control group, whereas educators with 5–10 years of experience were more common in the control group (52.5% vs. 18.6%). Postgraduate qualifications (master's degree or PhD) were also more common in the intervention group (49.2% vs. 16.9%), $\chi^2(2) = 15.19$, $p < .001$, Cramér's $V = .359$ (master's and PhD categories combined because of a sparse cell), whereas the difference

in age group was not statistically significant, $\chi^2(1) = 3.62$, $p = .057$. These baseline differences occurred despite individual randomisation and are treated as potential confounders when interpreting the intervention effects (see Sections 5 and 5.3).

Table 1. Characteristics of nurse educators by study group (N = 118)

Characteristic	Category	Intervention n (%)	Control n (%)	Total n (%)
Age group	18–35 years	17 (28.8)	27 (45.8)	44 (37.3)
	≥35 years	42 (71.2)	32 (54.2)	74 (62.7)
Highest qualification	PhD	1 (1.7)	0 (0.0)	1 (0.8)
	Master's degree	28 (47.5)	10 (16.9)	38 (32.2)
	Bachelor's degree	25 (42.4)	35 (59.3)	60 (50.8)
	Diploma	5 (8.5)	14 (23.7)	19 (16.1)
Teaching experience	1–5 years	25 (42.4)	28 (47.5)	53 (44.9)
	5–10 years	11 (18.6)	31 (52.5)	42 (35.6)
	>10 years	23 (39.0)	0 (0.0)	23 (19.5)

Quantitative evidence of TPACK knowledge acquisition

From Table 2 presented at baseline, the intervention and control groups demonstrated similar levels of overall TPACK knowledge. The intervention group recorded a mean score of 106.12 (SD = 13.52), while the control group had a mean of 105.37 (SD = 17.11), with no statistically significant difference between the groups, $t(116) = 0.263$, $p = .793$. Following the intervention, the mean score for the intervention group increased to 123.19 (SD = 12.12), compared with 110.08 (SD = 16.94) for the control group. This difference at post-test was statistically significant, $t(116) = 4.832$, $p < .001$, mean difference = 13.10, 95% CI [7.73, 18.47], $d = 0.890$. Within the intervention group, overall TPACK knowledge rose by 17.07 points, $t(58) = 9.410$, $p < .001$. The control group also demonstrated an increase of 4.71 points, $t(58) = 4.030$, $p < .001$. However, comparison of the change scores using an independent-samples t test indicated that the intervention group achieved a 12.36-point greater improvement than the control group, 95% CI [8.07, 16.64], $t(99.11) = 5.726$, $p < .001$, $d = 1.054$.

Table 2. Between-group comparison of changes in TPACK knowledge

Outcome	Intervention change M (SD)	Control change M (SD)	Mean difference	95% CI	t (df)	p	Cohen's d
TK	2.08 (2.47)	0.64 (1.31)	1.44	0.72 to 2.16	3.964 (88.33)	< .001	0.730
PK	2.41 (2.50)	0.53 (1.69)	1.88	1.10 to 2.66	4.794 (101.71)	< .001	0.883
CK	1.81 (2.47)	0.49 (1.45)	1.32	0.58 to 2.06	3.546 (93.99)	< .001	0.653
TCK	3.05 (3.18)	0.88 (1.90)	2.17	1.21 to 3.13	4.495 (94.82)	< .001	0.828
TPK	2.29 (2.55)	0.59 (1.64)	1.69	0.91 to 2.48	4.297 (99.10)	< .001	0.791
PCK	2.47 (2.88)	0.64 (1.54)	1.83	0.98 to 2.68	4.300 (88.57)	< .001	0.792
TPACK	2.61 (2.74)	0.68 (1.94)	1.93	1.07 to 2.80	4.423 (104.64)	< .001	0.814
Overall	17.07 (13.93)	4.71 (8.98)	12.36	8.07 to 16.64	5.726 (99.11)	< .001	1.054

Note. Change score = post-test minus pretest. Independent-samples t tests were used for between-group change-score comparisons; unequal-variances estimates were reported where the homogeneity-of-variance assumption was not met.

Qualitative findings: From knowledge acquisition to digital practice

Four themes explained how educators moved from acquiring TPACK concepts to applying and renewing that knowledge in practice: (1) developing pedagogical confidence as professional knowledge; (2) integrating knowledge into purposeful digital practice; (3) contextual conditions influencing knowledge utilisation; and (4) sustaining knowledge for future digital teaching.

Developing pedagogical confidence as professional knowledge

Educators differentiated their existing clinical expertise from the knowledge needed to effectively support and facilitate student learning. They viewed TPACK as a framework that helped them consider how nursing knowledge could be effectively communicated and taught. The intervention encouraged educators to recognise gaps in their pedagogical knowledge and increased their confidence in using alternative approaches to teach the same subject matter. One participant summarised this difference by stating, “I save lives in hospital, TPACK saves me in class” (NE01). Another educator explained that the framework “improves some of our knowledge, our confidence, and how to teach also” (NE20). These experiences indicate that educators understood knowledge acquisition as an improvement in their professional teaching capability rather than simply as gaining technical proficiency.

Integrating knowledge into purposeful digital practice

Educators reported shifting from viewing technology as an additional component of teaching toward intentionally matching learning objectives, nursing content, teaching strategies and digital technologies. They described selecting methods and tools such as discussions, scenarios, group activities, quizzes, PowerPoint, videos, Kahoot, Mentimeter and Padlet according to the specific learning outcomes they intended to achieve. NE08 explained that TPACK “helped me combine technology, teaching methods, and content effectively.” Participants also highlighted that nursing education has a strong practical and visual dimension. As NE20 explained, “Nursing is not just theoretical. It is a lot of hands-on practice. A lot of visualization and understanding.” Overall, this theme demonstrated how educators applied integrated knowledge by making teaching decisions that were responsive to the specific educational context.

Contextual conditions influencing knowledge utilisation

The implementation process involved ongoing experimentation, adjustment and further learning. Educators identified several barriers, including limited familiarity with technology, internet-connectivity difficulties, inadequate preparation time, students’ limited familiarity with certain digital tools and the difficulty of sustaining student engagement within the available teaching period. NE19 explained the need to “improve a lot on these technological updates” in order to keep up with students, while NE16 indicated that the initial learning session alone was not sufficient and that additional independent learning was required. These findings demonstrate that acquiring professional knowledge does not automatically result in consistent implementation. Instead, the extent to which knowledge is utilised is influenced by educators’ individual preparedness and the organisational conditions that support its application.

Sustaining knowledge for future digital teaching

Educators understood TPACK as an evolving knowledge base that needs to be continually updated in response to technological developments and changing learner expectations. Artificial intelligence was specifically identified as an important consideration for future teaching, and participants expressed support for expanding access to TPACK-related professional development. Reflecting on the growing role of artificial intelligence in education, NE17 anticipated that the approach would be “very useful” in “an era of AI” and further suggested that the approach “should be applied around the Maldives.” Participants’ future-focused perspectives extended beyond simply adopting new technologies. They emphasised the importance of ongoing pedagogical development, understanding the needs of different learners and selecting technology based on its educational purpose. This suggests that TPACK should be viewed as an evolving form of professional knowledge that requires continued development rather than as a competency achieved through a single training programme.

Mixed-methods integration: From knowledge acquisition to digital practice

Table 3 presents the integration of the quantitative and qualitative findings, demonstrating a consistent progression from acquiring TPACK knowledge to integrating that knowledge and subsequently applying it within teaching practice. The quantitative findings showed that the intervention group achieved an increase of 17.07 points, compared with an increase of 4.71 points in the control group. An independent-samples *t* test further demonstrated a 12.36-point difference in change between the groups, 95% CI [8.07, 16.64], $t(99.11) = 5.726$, $p < .001$, $d = 1.054$. Statistically significant differences in change scores were also identified across all seven TPACK domains, suggesting that the development involved more than technological knowledge and extended to the interconnected areas of professional knowledge.

The qualitative findings provided insight into how these quantitative improvements were experienced and incorporated into teaching. The increase in pedagogical confidence corresponded with the observed improvements in the pedagogical and integrated TPACK domains. Educators also described intentionally connecting nursing content, pedagogical approaches, technology, student activities and assessment, demonstrating how different knowledge domains were brought together during practice. Activities such as redesigning lessons, selecting technologies according to their purpose and using interactive teaching approaches reflected the practical utilisation of knowledge rather than acquisition alone.

The qualitative explanations in Table 3 further contributed to the quantitative results by identifying the contextual factors that influenced implementation. Available time, internet connectivity, technological preparedness, students' familiarity with digital tools, and ongoing support all affected whether newly acquired knowledge could be incorporated into consistent teaching practices. Educators' emphasis on additional training, preparedness for artificial intelligence and keeping their technological knowledge current also indicated that TPACK requires continuous renewal. Overall, the integrated findings suggest that TPACK-N can develop a professional knowledge asset at the educator level, although its long-term value depends on institutional mechanisms that facilitate its application, sharing and continued development.

Table 3. Joint display of integrated quantitative and qualitative findings

Knowledge process	Quantitative evidence	Qualitative explanation	Integrated interpretation
Knowledge acquisition	Intervention gain 17.07 vs. 4.71 in control; between-group change difference 12.36, 95% CI [8.07, 16.64], $p < .001$, $d = 1.054$.	Increased pedagogical confidence, awareness of teaching knowledge and recognition of multiple ways to teach nursing content.	TPACK-N developed measurable integrated professional knowledge.
Knowledge integration	All seven domain change differences were significant ($p < .001$; $d = .653-.883$).	Educators deliberately connected nursing content, pedagogy, technologies, learner activities and assessment.	Previously distinct knowledge domains were combined into purposeful teaching decisions.
Knowledge utilisation	Not directly measured by TPACK.xs.	Lesson redesign, purposeful technology selection, interactive learning, visualisation and assessment alignment were reported in practice.	Integrated knowledge was operationalised through digital teaching practice.
Contextual enablement	Not captured by the TPACK score.	Time, connectivity, technological readiness, student familiarity and continued support influenced implementation.	Possession of knowledge was insufficient without enabling contextual and organisational conditions.
Knowledge renewal	No long-term quantitative follow-up was undertaken.	Educators identified continued training, technological updating, AI readiness and broader	TPACK functions as a dynamic knowledge asset requiring continued renewal and institutional support.

Knowledge process	Quantitative evidence	Qualitative explanation	Integrated interpretation
		professional development needs.	

DISCUSSION

The combined findings suggest that TPACK should be understood as more than a measure of educational competency. The intervention generated a substantial difference in the development of integrated professional knowledge, while the educators' subsequent accounts demonstrated how this knowledge influenced their actual teaching decisions. The convergence of the mixed-methods findings therefore illustrates a progression from acquiring knowledge to integrating and applying it. This expands the relevance of TPACK within information and knowledge management by demonstrating that structured professional development can generate an educator-level knowledge asset, while lesson redesign and classroom implementation provide mechanisms through which this knowledge can produce practical value.

The findings at the individual domain level further support this interpretation, as statistically significant improvements were observed across all seven TPACK components rather than being restricted to technological knowledge. This finding corresponds with intervention research that identifies knowledge integration as a key process in TPACK development (Fabian et al., 2024; Schmid et al., 2024). Within nursing education, educators frequently possess considerable disciplinary and clinical expertise, meaning that the additional value of faculty development may involve transforming this existing expertise through pedagogical and technological decision-making. Educators' reports of increased confidence, intentional technology selection and stronger alignment between content, learning activities and assessment provide an explanation for how the quantitative improvements were translated into professional teaching practice.

These findings should, however, be interpreted in light of the baseline imbalance in teaching experience between the study groups (Table 1). Although participants were individually randomised and overall TPACK scores were comparable at baseline (106.12 vs. 105.37, $p = .793$), 39.0% of the intervention educators had more than 10 years of teaching experience compared with none of the control educators, and postgraduate qualifications were also more common in the intervention group. Teaching experience shapes pedagogical adaptability, classroom management and the capacity to translate a new framework into lesson design, and educators' professional backgrounds and experience have been associated with differing digital-competence profiles (Pajari et al., 2026). More experienced educators may therefore have been better positioned to absorb the TPACK-N content, redesign their lessons and apply the intervention during the 12-week implementation period, which may account for part of the 12.36-point between-group difference in change. It is also possible that educators with longer-established teaching routines found it more demanding to adopt new digital approaches; the direction and size of any influence therefore cannot be determined from the present data. Because the change-score comparison was not adjusted for teaching experience, the estimated size of the intervention effect may be biased and should be regarded as indicative rather than definitive. Nevertheless, the consistent improvements across all seven TPACK domains, together with educators' accounts of applying integrated knowledge in their teaching, provide convergent, though not conclusive, support for an effect of the TPACK-N intervention beyond differences in experience.

Additional findings also indicate that the usefulness of the developed knowledge asset was strongly influenced by contextual factors. Time availability, infrastructure, technological preparedness, students' familiarity with digital tools and access to continued support all influenced whether newly acquired knowledge could become established teaching practice. From a knowledge-management perspective, this suggests that institutions should not view faculty knowledge solely as an individual characteristic. Research in higher education similarly associates knowledge sharing and knowledge-management practices with innovation and the transformation of individual knowledge into organisational capability (Fan & Beh, 2024; Kim et al., 2025; Kumar et al., 2024; Rehman et al., 2024; Vyas, 2024). Strategies such as mentoring, peer review of lessons, communities of practice, shared repositories of reusable lesson designs and continuing

professional development could therefore support the retention and dissemination of integrated digital-pedagogical knowledge.

The future-focused qualitative findings additionally indicate that TPACK represents a renewable knowledge asset rather than a fixed competency. Educators acknowledged the importance of remaining current with artificial intelligence, emerging technologies and changing expectations among learners. This is consistent with recent nursing-education research highlighting the importance of digital competence, adaptability and ongoing faculty development (Asal et al., 2025; Pajari et al., 2024, 2026; Štemberger Kolnik et al., 2026). Consequently, the knowledge-management challenge is not simply to develop TPACK at one point in time, but to establish institutional conditions that allow this knowledge to be continuously updated, shared and adapted as technology and educational requirements change.

Implications for knowledge management in higher education in nursing

Three key implications can be identified. First, digital transformation initiatives should prioritise developing integrated nursing knowledge rather than relying primarily on training focused on individual platforms or technologies. Second, institutions should transform individual educator learning into collective organisational capability through mechanisms such as peer exchange, mentoring, reusable lesson-design resources, reflective teaching portfolios and communities of practice. Third, assessments of digital transformation should examine both the development of knowledge and evidence that this knowledge is being applied in the nursing faculty, since increased self-reported competence by itself does not demonstrate sustained utilisation. Together, these approaches reposition the nurse educator's knowledge development for an integrative, collaborative and contemporary acquisition which is practical and relevant to the discipline of nursing education.

Implications for digital transformation and faculty development

Within nursing education, TPACK-N provides a practical connection between digital-transformation objectives and their implementation within the classroom. Faculty-development programmes should therefore integrate conceptual understanding with authentic lesson redesign, guided practice and support following the training period. For institutions introducing artificial intelligence and other emerging technologies, TPACK may provide a useful framework for decision-making by encouraging educators to consider not only which technologies are available, but also whether they appropriately support disciplinary content, pedagogy, assessment, learner requirements and professional responsibilities.

Limitations and future research

The main quantitative outcome relied on educators' self-reported TPACK knowledge, and the correspondence between TPACK self-reports and actual teaching practice remains contested (Backfisch et al., 2025); the follow-up period also covered only one academic implementation period. Although participants were individually randomised, a marked imbalance in teaching experience occurred between the groups ($\chi^2(2) = 32.69$, $p < .001$, Cramér's $V = .526$): more than one-third of the intervention group, but none of the control group, had over 10 years of teaching experience, and postgraduate qualifications were also more common in the intervention group. Because teaching experience may influence educators' pedagogical adaptability and their ability to adopt and apply the intervention, this imbalance is a potential confounder, and the between-group change-score analysis was not adjusted for it. Part of the observed intervention effect may therefore reflect differences in experience rather than the TPACK-N module alone, even though overall TPACK scores were comparable at baseline. Future trials should use randomisation stratified by teaching experience and qualification (or minimisation) and apply covariate-adjusted analyses such as analysis of covariance. The qualitative sample consisted of educators from the intervention group, who may have been more likely to describe positive experiences. In addition, the study was undertaken

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within a single national nursing-education setting, while the conceptualisation of TPACK as a knowledge asset represents a theoretical interpretation rather than a direct assessment of organisational knowledge capital. Future studies should incorporate observed teaching practices, assessments of lesson plans and longer follow-up periods, and should examine whether gains in educator knowledge translate into student learning outcomes (Visscher et al., 2025). Further research should also investigate how leadership, workload, infrastructure, knowledge-sharing processes and organisational culture affect the retention, transfer and diffusion of TPACK-related knowledge.

CONCLUSION

The structured TPACK-N intervention was associated with considerable improvements in nurse educators' integrated technological, pedagogical and disciplinary knowledge, although the baseline imbalance in teaching experience means that the size of this effect should be interpreted with caution. The qualitative findings further demonstrated how educators applied this knowledge to develop purposeful digital teaching practices. When the quantitative and qualitative findings were considered together, they demonstrated a progression from knowledge acquisition to integration and utilisation, while also showing that implementation was influenced by factors including time, infrastructure, technological readiness and continued professional support.

Viewing TPACK-N as a professional knowledge asset broadens its significance to integrate technology, pedagogy and context of nursing. The prototype findings indicate that testing this in a real-time environment has enhanced nurse educators' knowledge acquisition. Additionally, it contributes to faculty-development interventions that can generate valuable professional knowledge among educators, but achieving sustainable digital transformation requires institutional support for the continued application, sharing and renewal of that knowledge. TPACK-N therefore offers an integrative knowledge-management perspective for examining how individual professional learning can contribute to wider institutional digital-teaching capability.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing commercial or financial interests associated with this study.

AUTHORS' CONTRIBUTIONS

The primary author, Aminath Rinzy, was responsible for conceptualisation, methodology, investigation, data collection, analysis and preparation of the original manuscript draft. Sharifah Shafinaz Sh Abdullah provided methodological guidance, interpretation, validation, supervision and critical review of the manuscript. Aminath Shiyama did the editing and prototype validation. In addition, Ibrahim Adam wrote the comments and revised the intellectual property used as the prototype in the manuscript. Husham Mohamed helped with research design, editing data tables and layout. All authors reviewed and approved the final version of the manuscript.

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