Heliyon 10 (2024) e37874

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Development of theoretical framework and digital competence assessment checklist (DCAC) for nursing students

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ARTICLE INFO

Keywords:
Digital competence
Nursing student
Instrument development
Scoping review
Modified delphi
Psychometric

ABSTRACT

Background: The rapid development of digital technology impacts all aspects, including nursing education. Nursing programs are tasked with equipping graduates with both clinical skills and digital competence. However, inconsistencies in the conceptual understanding of digital competence in nursing literature, underscore the need to refine the concept.
Design: This study involved two phases including a modified Delphi approach and psychometric testing. In Phase 1, the panel of experts in nursing was invited to evaluate the theoretical framework, domain, and item of assessment checklist. In Phase 2, the psychometric properties of the assessment checklist were tested using a quantitative survey.
Setting: The study was conducted in Taiwan, Indonesia, and Vietnam.
Participant: Participants included 12 nursing experts from Taiwan, Indonesia, and Vietnam during the development phase and 417 nursing students from these countries in the validation phase.
Methods: Phase 1 utilized a modified Delphi approach establishing a theoretical framework and assessment checklist. Experts provided feedback on a Likert scale, aiming for consensus. Phase 2 involved a quantitative survey where graduate nursing students rated the DCAC. The analysis process following the recommendation of the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN).
Results: The theoretical framework defined digital competence across four domains. In the first Delphi round, all items were rated above the consensus threshold. After two rounds, the CVI ranged from .8 to 1.0, suggesting strong agreement among experts. The second phase revealed high discriminant validity among survey items, with Cronbach's alpha indicating high internal consistency. The refined 22-item DCAC showed improved fit indices, confirming the assessment checklist's structure.
Conclusion: The developed 22-item DCAC is a valid and reliable tool for measuring digital competence among nursing students. Integration of digital competence into nursing education is essential for preparing students to excel in the healthcare environment.

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https://doi.org/10.1016/j.heliyon.2024.e37874
Received 10 June 2024; Received in revised form 12 August 2024; Accepted 11 September 2024
Available online 20 September 2024

1. Introduction

The swift development of information and communication technology has brought substantial societal transformation, affecting many sectors including nursing education. The transformation underscores the importance of skills related to digital utilization encapsulated by the concept of digital competence [1]. The significance of digital competence is emphasized by the transition towards proficient and accountable utilization of technology for information management and engagement in online communication and collaboration [2].

Acquiring digital competence in nursing education is essential for equipping students with the necessary capabilities to navigate digital healthcare environments and deliver excellent patient care [3–5]. This skill encompasses four fundamental domains: proficiency in utilizing digital media and resources, exhibiting proficiency in digital communication, enhancing cognitive capacities in digital learning, and ensuring safety in the digital realm [1]. In addition, digital competence promotes the ability to adapt and think critically, which are essential for managing the quickly changing technological environment in the healthcare setting [5].

Although digital competence is crucial, there is a lack of uniformity in its interpretation within the field of nursing education [6,7]. Leading nursing organizations, such as the American Nurses Credentialing Center and Quality and Safety Education for Nurses, address aspects of informatics competence but lack a comprehensive approach to digital competence. Digital competence refers to the basic skills or daily abilities required to engage with the digital world [8], whereas nursing informatics is a specialized field within the nursing profession that focuses on developing and using technology to improve patient care [9]. This distinction is crucial as digital competence serves as a foundation for all healthcare professionals, while informatics involves creating and managing healthcare technologies [10,11].

Many of the theoretical frameworks of digital competence have been developed in different fields [12–16], but in nursing education, there is still a dearth. Several existing frameworks, such as TIGER, ILCSN, and The Digital Competence Framework for Nursing: Humanizing Digital Learning Process, focus heavily on informatics and advanced digital skills, but they often lack applicability in general nursing education due to their limited emphasis on foundational digital skills and practical tool usage essential for clinical practice [6,17,18].

An ideal theoretical framework for digital competence in nursing education should encompass a precise and comprehensive definition of digital competence, elaborate descriptions of fundamental domains, development and validation of reliable assessment instruments, and harmonization with established professional standards [19]. Prior research has not thoroughly examined or

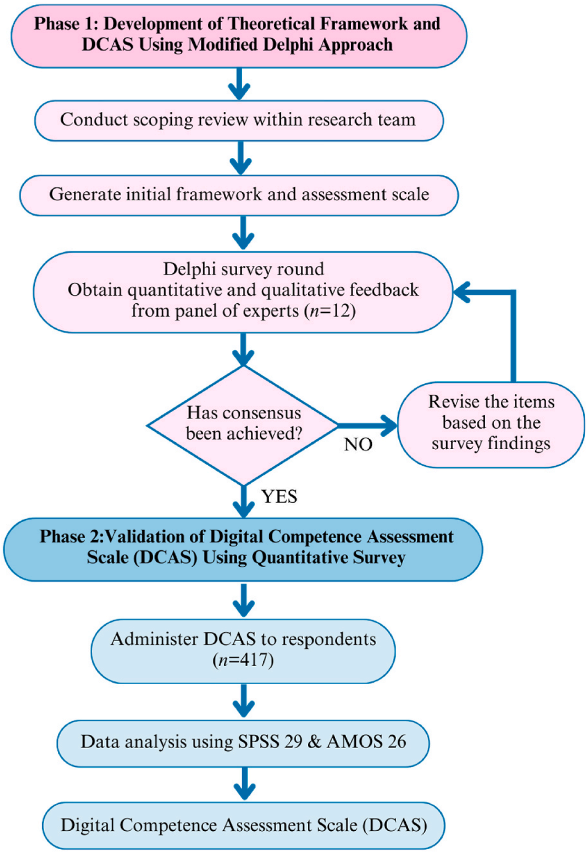

Fig. 1. Research design flowchart.

established these elements, underscoring the necessity for a complete theoretical framework that fills these gaps [7].

This gap highlights the need for a refined theoretical framework to ensure alignment with the evolving digital healthcare landscape. This study seeks to develop and validate a digital competence framework and Digital Competence Assessment Checklist (DCAC) specifically for nursing students. This study is crucial for nurse educators to adequately equip nursing students to fulfill the increasing need for digital proficiency in healthcare [20].

2. Methods and results

2.1. Aim

This study aimed to develop and validate a framework and Digital Competence Assessment Checklist (DCAC).

2.2. Design

The study involved two phases (Fig. 1). In Phase 1, a theoretical framework and Digital Competence Assessment Checklist (DCAC) were developed based on a scoping review as the basis of the modified Delphi method. In Phase 2, nursing students enrolled in a Master's program in Taiwan, Indonesia, and Vietnam were surveyed and asked to rate the DCAC.

2.3. Phase 1: development of theoretical framework and DCAC using modified delphi approach

The purpose of Phase 1 was to develop and gain consensus about the theoretical framework and assessment checklist using a modified Delphi approach. Phase 1 was developed based on a scoping review.

2.3.1. Sample

During the initial phase of the modified Delphi approach, the research team, acting as principal investigators, engaged in a scoping review to generate the theoretical framework and assessment checklist of digital competence. Each team member held a graduate degree with extensive experience in performing literature reviews. Following the establishment of the theoretical framework and the assessment checklist, the Delphi method was deployed to elicit in-depth insights and input from the experts.

A panel of experts representing Taiwan, Indonesia, and Vietnam were invited using purposive sampling to participate in the rounds of the Delphi approach through an online platform. Experts held a supervisory or faculty position within a nursing institution, held a minimum of a graduate degree, reported at least five years of teaching experience, and taught nursing informatics. Experts who could not commit to participating in both rounds of the Delphi study were excluded. To determine the appropriate sample size for the Delphi study, a formula commonly used in qualitative research to estimate proportions was employed. The calculation aimed to ensure a balance between achieving a reliable consensus and maintaining manageability in conducting multiple iterative rounds. The sample size formula used is:

$$n = \frac{Z^2 p(1-p)}{d^2}$$

The Z-value of 1.96 corresponds to a 95% confidence level, and the anticipated proportion of experts agreeing on critical issues was set at .5 to maximize variability, as recommended by Cochran [21]. This approach resulted in a margin of error of approximately 28.3%, which was deemed acceptable given the exploratory nature of our study.

Consequently, a purposive sample size of 12 experts was considered sufficient to capture a broad range of qualitative insights. This decision aligns with established guidelines suggesting that 10 to 30 experts are typically adequate for Delphi studies [22].

2.3.2. Procedure

The scoping review was guided by Arksey and O'Malley's stages [23], which aimed to locate existing digital competence frameworks. Systematic searches were performed in MEDLINE, PsycINFO, EMBASE, CINAHL, and ERIC for literature until June 2021, with search parameters refined by the researchers and a librarian. The review focused on peer-reviewed research papers written in English, Chinese, and Indonesian specifically addressing digital competence as a phenomenon of interest. Article forms such as comments, abstracts, editorials, and dissertations were excluded. Forty-nine data-based studies were analyzed.

2.3.3. Data analysis

Guided by the results of the scoping review, a total of 28 items over four domains of DCAC were formulated and assessed by a panel of nursing experts. The rating was based on a 7-point Likert scale, ranging from 1 (indicating highly inappropriate) to 7 (indicating highly appropriate). Experts were asked to provide feedback on items rated below 4. Consensus was defined as a rating of 4 or higher from at least 75% of the experts [24]. The item content validity index (I-CVI) and domain validity index (D-CVI) were set at a minimum threshold of .78 [25]. The suggestions from experts were integrated and the rating results were calculated. The process was iterative until the consensus was achieved. Descriptive statistics, percentages, and content validity index were used to summarize the results after data collection was finished. Adjustments for each item were made based on the qualitative feedback provided by the experts to improve the quality and appropriateness of the developed items. Each expert was given 4 weeks to evaluate and provide feedback for each round of the Delphi approach.

2.3.4. Results

Theoretical framework development. Based on the scoping review, the definition of digital competence was determined as the capacity to effectively use digital media and resources, engage in digital communication as technology evolves, participate actively in digital learning, and maintain safety within digital environments. The concept of digital competence includes four domains: utilization of digital media and resources, application of digital communication, cognition in digital learning, and safety in the digital environment. The domains provide a comprehensive view of the specific items of digital competence in nursing education. The framework is incorporated within four essential nursing paradigms—people, environment, health, and nursing (Fig. 2).

Within the digital competence framework, basic computer skills serve as the underlying foundational requirement. The definition of basic computer skills includes computer operationalization and general internet utilization. Researchers have measured basic computer skills as a fundamental domain through several assessment approaches such as multiple choice, observations, qualitative, or mixed methods [26–28]. Basic computer skills are fundamental skills to survive in the digital age.

Domain 1: Utilization of Digital Media and Resources. Utilization of digital media and resources is defined as the employment of digitized data, information, and content through machine-readable platforms. Domain 1 refers to the expansion of basic computer skills, including the ability to identify, examine, and analyze digital resources [28–30]. There are three subdomains: accessing digital resources through digital media, evaluating the eligibility and trustworthiness of digital resources, and analyzing the data using digital media. The domain requires that healthcare professionals distinguish useful information from a range of resources, use specific search strategies for systematic purposes, and utilize software analysis to interpret the data. The domain can be adapted for a specific purpose. For example, to improve the ability of students to conduct research, the search strategy must be tailored to locate relevant literature based on the research question. Software analysis ability should be able to do tasks ranging from determining sample sizes to conducting detailed statistical tests. For better patient care proficiency, search strategy abilities should assist in finding evidence to advance practice, while the software should aid in executing digital nursing documentation.

Domain 2: Application of Digital Communication. Applying digital communication refers to the exchange, sharing, and collaboration of digital information within the digital environment [31]. The management of digital communication was defined as active participation in digital networks to exchange and share information. The scope of this domain underlines the effort of media convergence, interaction, and collaboration as values of digital citizenship. Healthcare professionals are expected to be able to merge distinct health media technologies and platforms with the contemporary trends of digital information. The integration will create web-based health education including videos, interactive patient-provider chat platforms, or artificial intelligence-based interventions. Communications and collaborations require appropriate and responsible behavior when using technology. The four subdomains include: applying transmedia navigation for digital communication, interacting and sharing digital information, collaborating in digital environments, and maintaining digital identity with behavioral norms during digital communication.

Domain 3: Cognition in Digital Learning. Digital learning has been defined as an applied set of technology-based approaches to support learning processes [32]. The domain cognition in digital learning is defined as advanced cognitive ability and skills in learning and knowledge development facilitated by technology. The domain generally requires critical thinking and sequential reasoning to understand a situation, using a step-by-step approach. Cognition involves comprehending patterns or connections between situations, identifying the main issue, and adapting useful information to create new knowledge. For example, cognition in digital learning may involve the use of online clinical case studies. In this situation, the students are encouraged to engage with interactive digital case studies. Cognitive processes involve information processing, problem-solving, memory retention, critical thinking, and adaptability. The learning innovation process is made easier with the help of technology [26]. The subdomains include organizing digital content in healthcare, facilitating digital learning, and problem-solving. The domain supports the learning process in healthcare professional education, research, and evidence-based implementation.

Domain 4: Safety in Digital Environment. Safety in a digital environment is the effort to promote the safety and integrity of digital resource utilization. The subdomains refer to awareness of digital protection, application of digital protection, and promoting data integrity. In the healthcare systems, the domain plays a vital role in developing attitudes toward data resource management starting from the preservation of scientific integrity to the protection of patients' digital data and health information [7,33].

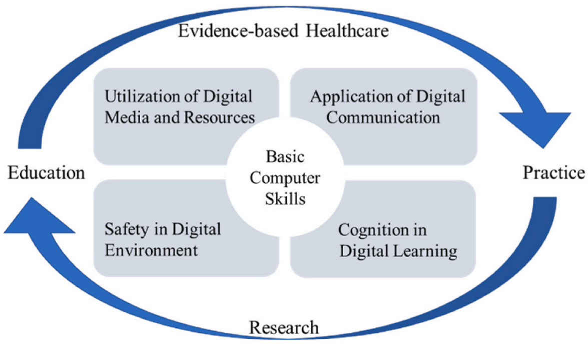

Fig. 2. Digital competence framework.

Modified Delphi approach. The modified Delphi approach was conducted in two rounds which spanned from February to May 2022. A panel of 12 nursing experts representing Taiwan ($n = 5$), Indonesia (n=4), and Vietnam (n=3) rated twenty-eight items provided in Round 1. The results of the four items of domain categories and 28 items of the assessment checklist were all rated above 4. The CVI values ranged from .8 to 1.0 and the desired threshold of convergence of 75% was attained, however, several recommendations from experts concerning phrasing and wording were important to enhance the clarity. Revisions of the 2 items were directed toward refining the wording to ensure better alignment between the digital competence assessment checklist. In the second round, all 28 items met the study criteria with a range of item ratings between 5.8 and 6.8. I-CVI and D-CVI from .8 to 1.0 (Appendix table S1). The Modified Delphi approach provides a robust method for establishing content validity by systematically involving a panel of experts in multiple rounds of evaluation.

2.4. Phase 2: psychometric testing of digital competence assessment checklist (DCAC) using quantitative survey

The aim of Phase 2 was to validate the psychometric properties of the DCAC in a quantitative survey of Master's students in nursing following the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) recommendations [34].

2.4.1. Sample

A convenience sampling approach was employed to recruit first and second-year nursing master's students from nursing schools in Taiwan, Indonesia, and Vietnam. Nursing students who were on leave of absence or those who had recently graduated were excluded from the study. The Levene's test was utilized to assess the homogeneity of variances [35]. When the heterogeneity of variance was found, an alternative to the classical approach using the Welch *t*-test statistic, was applied [36]. For the 28 learning objective items, a minimum of 280 completed responses were required to ensure adequate sample size following the rule of thumbs [37]. Nursing students were selected to address the generation gap in digital competence. Digital competence studies often aim at trainers or educators, rarely investigating learners' applicability [38].

2.4.2. Procedure

Participants were asked to assess each learning objective using a seven-point Likert scale that ranged from 1 for "strongly disagree" to 7 for "strongly agree". A higher score indicated higher agreement with the Delphi findings. The original version of the assessment checklist was drafted in English and then translated into Chinese, Indonesian, and Vietnamese, with back-translation to maintain meaning. Multilingual translation was undertaken to ensure that the material was understandable across different languages [39].

After obtaining Institutional Review Board approval to conduct the study, the four nursing departments distributed a request to complete an online questionnaire. By completing and submitting the questionnaire, students were considered to have provided their consent to participate in this research.

2.4.3. Data analysis

Sample adequacy and factorability were assessed to determine if the data were appropriate for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Sphericity test were employed. A KMO score above .9 and a significant Bartlett's test ($p < 0.05$) imply a homogenous sample suitable for factor analysis [40,41].

Item discriminant analysis was used to evaluate the ability of each item on Digital Competence Assessment Checklist (DCAC) to distinguish participants with high and low scores by comparing the item scores of the highest and lowest 113 (27%) participants. Discriminant analysis was performed using Cureton's [42] approach, and item-total correlations were determined with a .30 threshold for adequate discrimination [43].

Hypothesis Testing Analysis examined inter-item correlations, which should surpass .3 to show item discrimination. Additionally, corrected item-total correlations showed a moderate to strong relationship between each item and the overall test score.

Structural validity was tested using Confirmatory Factor Analysis. CFA is an essential test for confirming theoretical constructs and frameworks in studies, especially when there is robust theoretical grounding and empirical backing for the suggested factorial configuration [44]. Factor loading for each item was set at > .4 [45]. The indices of Chi-square χ^2/df lower than 3, root mean square error of approximation (RMSEA) lower than .08, incremental fit index (IFI), normed fit index (NFI), and comparative fit index (CFI) higher than .90 were employed as criteria to evaluate the model fit [46].

Internal consistency was assessed using Cronbach's alpha, with .7 suggesting reliability [47]. Data analysis employed SPSS (version 29.0) and AMOS (version 26.0).

2.4.4. Results

Assessment of Sample Adequacy and Factorability. During the period of April to May 2023, a total of 417 nursing students from Taiwan (n = 129), Indonesia (n = 150), and Vietnam (n = 138) participated in an online survey (Appendix table S2). Most of the participants were female, accounting for 81.8% (n = 341). Additionally, 39.3% (n = 164) of the participants were first-year students in a graduate program, and 63.1% (n = 263) reported an active interest in adult nursing. The mean age was 35.4 years with a standard deviation of 8.1. The KMO measure yielded a value of .96, indicating high adequacy for factor analysis. Additionally, Bartlett's test of Sphericity was significant ($\chi2 = 7818.84$; df = 378; $p < 0.001$), confirming that the sample size is sufficient, and the data are suitable for factor analysis.

Item Discriminant Analysis. A discriminant analysis was conducted to determine the ability of each question in the Digital Competence Assessment Checklist (DCAC) to successfully distinguish between participants with high and low scores. The findings indicated that the high-scores group achieved notably higher scores on every item in comparison to the low-scores group (Table 1).

Hypothesis Testing Analysis. All items had inter-item correlations exceeding .3, indicating a significant level of item discrimination. The revised item-total correlations ranged from .54 to .76, showing a moderate to high relationship between each item and the overall test score (Table 1). This suggests that the internal consistency of the test is adequate.

Table 1
Item analysis results of learning objectives.

Learning Objectives	Mean ± SD	Mean ± SD (27% of top group)	Mean ± SD (27% of low group)	Corrected-item total correlation
Domain 1: Utilization of Digital Media and Resources				
(1) Apply general browsing to capture relevant digital resources in health care context	5.84 ± 1.23	6.59 ± .99	4.97 ± 1.36	.54
(2) Perform Data Searching	6.12 ± .99	6.78 ± .66	5.46 ± 1.30	.63
(3) Utilize database to enter or to extract data and information for specific purpose	5.96 ± .96	6.58 ± .55	5.34 ± 1.24	.61
(4) Identify eligible digital resource that relate to practice and care	5.90 ± .95	6.54 ± .64	5.09 ± 1.22	.69
(5) Assess the trustworthiness and rigor of the accessed digital resources	5.76 ± 1.00	6.43 ± .68	4.85 ± 1.21	.72
(6) Conduct data/information interpretation accurately	5.74 ± 1.02	6.47 ± .65	4.83 ± 1.21	.70
(7) Use application to aggregate data in healthcare context	5.71 ± 1.08	6.46 ± .64	4.73 ± 1.24	.69
(8) Use application to record digital resources in healthcare context	5.84 ± .98	6.56 ± .56	4.98 ± 1.17	.69
(9) Use application to perform analysis of data, including data visualization, evaluation, and reporting	5.78 ± .99	6.53 ± .60	4.83 ± 1.16	.74
Domain 2: Application of Digital Media				
(10) Identify appropriate media for digital communication	5.98 ± .97	6.65 ± .64	5.20 ± 1.25	.67
(11) Understand the merge of different types of social media in digital communication	5.70 ± 1.05	6.43 ± .71	4.74 ± 1.19	.69
(12) Use transmedia format to communicate with user in health care context	5.70 ± .97	6.42 ± .59	4.79 ± 1.14	.72
(13) Able to focus and avoid getting lost while navigating in the digital environment	5.69 ± .97	6.35 ± .68	4.93 ± 1.07	.68
(14) Participate in digital environment to support and extend learning or practice/care	5.86 ± .98	6.54 ± .57	5.06 ± 1.19	.72
(15) Aware of behavior norm and regulation while using and interacting in digital environment	5.74 ± 1.05	6.49 ± .64	4.82 ± 1.24	.69
(16) Conduct collaboration through virtual platform	5.45 ± 1.21	6.20 ± .86	4.34 ± 2.38	.57
(17) Perform digital data sharing	5.71 ± 1.08	6.42 ± .67	4.79 ± 1.27	.66
(18) Apply accurate digital identity	5.59 ± 1.06	6.32 ± .67	4.65 ± 1.22	.62
Domain 3: Cognition in Digital Learning				
(19) Organize digital resources in learning	5.74 ± 1.00	6.47 ± .60	4.77 ± 1.22	.73
(20) Apply appropriate digital media and resources as strategic for health improvements	5.78 ± 1.00	6.45 ± .64	4.81 ± 1.22	.75
(21) Use appropriate learning platform through technology	5.92 ± .87	6.51 ± .60	5.21 ± 1.13	.70
(22) Synthesize digital content to professional knowledge	5.78 ± .96	6.50 ± .65	4.91 ± 1.15	.76
(23) Identify resources to solve technical problems	5.73 ± .98	6.43 ± .65	4.86 ± 1.21	.76
(24) Recognize technological features for practical application	5.64 ± .98	6.29 ± .70	4.75 ± 1.12	.71
Domain 4: Safety in Digital Environment				
(25) Understand personal data regulation and legislation	5.60 ± 1.13	6.36 ± .66	4.56 ± 1.31	.67
(26) Recognize the use of personal information	5.76 ± 1.04	6.40 ± .76	4.99 ± 1.23	.59
(27) Perform online data protection	5.74 ± 1.17	6.44 ± .76	4.79 ± 1.49	.63
(28) Apply the principle of intellectual properties of data integrity	5.77 ± 1.07	6.39 ± .77	5.02 ± 1.37	.60

**Notes*. Corrected Item-Total Correlation >.3; Factor loading >.4.

Structural Validity. Structural validity, also referred to as construct validity, pertains to the extent to which a measurement instrument accurately assesses the fundamental construct it purports to evaluate.

Model 1. The first model was subjected to confirmatory factor analysis (CFA) to validate the structural integrity of the DCAC. All of the elements were loaded with a factor more than .4, ranging from .59 to .79 (Fig. 3). However, the model fit indices did not fully meet the criteria, namely the test Chi-square value ($\chi2/df = 3.410$), as well as the IFI (.892), NFI (.854), and CFI (.891) were below the required thresholds. Nevertheless, the RMSEA value remained under the permissible threshold (<.08). It suggested the necessity of further developing the model.

Model Refinement. To improve the model's fit, the Modification Indices (MI) were examined to increase the accuracy of the model. We detected a total of six pairs of items with modification indices (MI) that exceeded 20. By closely examining the I-CVI (Item-Content Validity Index) item discriminant analysis, content meaning, and factor loadings, it was determined that six questions should be removed. This resulted in a final set of 22 items, which were then cross validated using CFA.

Model 2. In Model 2, the factor loadings consistently exceeded > .4 (Fig. 4). Additionally, there is a noticeable enhancement and substantial improvement in the fit values of all indices, including the Chi-square test value ($\chi2/df = 2.75$), IFI (.938), NFI (.906), CFI (.938), and RMSEA (.065). In addition, Model 2 has lower AIC values in comparison to Model 1, indicating a more accurate match in reducing the number of items. Table 2 displays this information. Therefore, this was the ultimate model specification of the DCAC (Table 3).

Internal Consistency. Internal consistency refers to the degree to which a measurement equipment or test demonstrates reliability. The degree of internal consistency of an instrument or test is determined by the level of agreement among the items in assessing a specific construct or characteristic. The reliability of the 22-item model was assessed using Cronbach's alpha coefficient. The overall scale demonstrated a good level of dependability, as evidenced by a Cronbach's alpha coefficient of .96. The reliability of each of the four domains was strong, with values of .893 for Domain 1, .885 for Domain 2, .895 for Domain 3, and .772 for Domain 4.

3. Discussion

This study presents a novel framework and Digital Competence Assessment Checklist (DCAC) tailored for nursing students, filling a significant void in the current body of research. The DCAC underwent a two-phase development and validation process to ensure its robustness and reliability in measuring digital competence in nursing education.

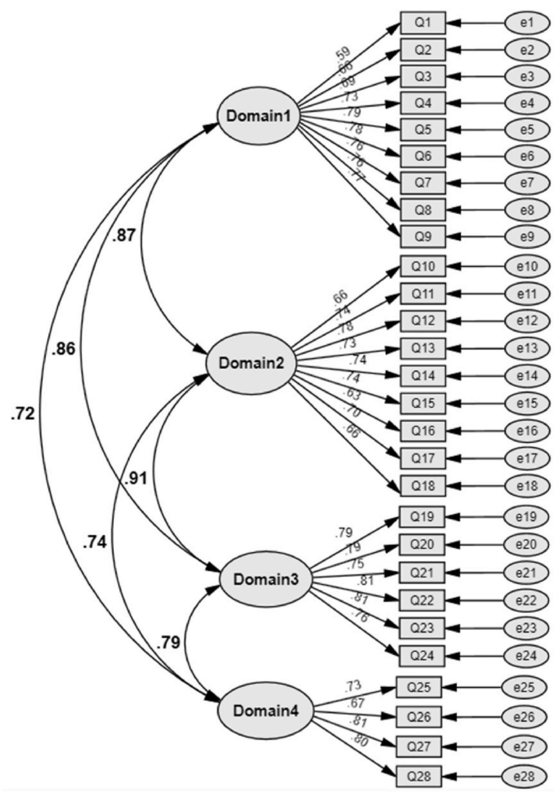

Fig. 3. Confirmatory factor analysis of Model 1 (28 items).

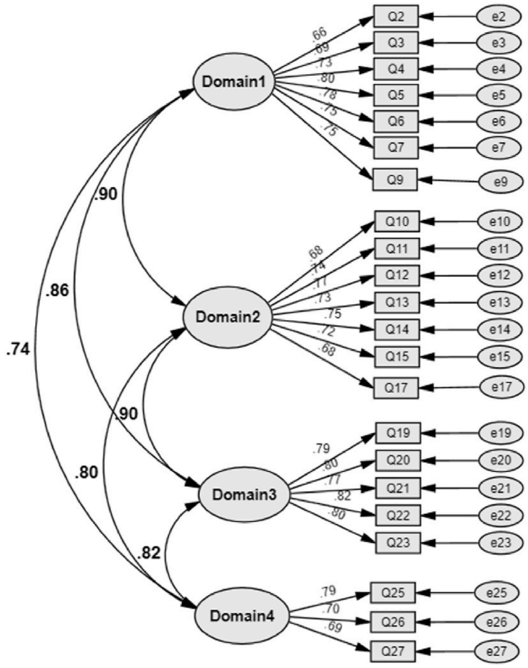

Fig. 4. Confirmatory factor analysis of Model 2 (22 items).

Table 2
Model fit indices calculated by Confirmatory Factor Analysis.

Model	χ^2/df	RMSEA	IFI	NFI	CFI	AIC
Model 1 (28-item)	3.410	.076	.892	.854	.891	1352.88
Model 2 (22-item)	2.751	.065	.938	.906	.938	702.41

*Notes. Chi-square x^2/df < 3; RMSEA = root mean square of approximation <.08; IFI = incremental fit index.
NFI = normed fit index; CFI = comparative fit index; IFI/NFI/CFI >.90; AIC = Akaike information criterion.

3.1. Phase 1: development of theoretical framework and DCAC

The initial phase of the project primarily involved establishing a robust theoretical framework for the DCAC. The process commenced with a thorough Scoping Review, which served as the foundation for a modified Delphi approach. The method attained expert consensus within a mere two rounds, emphasizing the lucidity and pertinence of the framework's elements. The swift consensus reflects the results of extensive study on digital competence in several domains, as demonstrated by studies conducted by Ferrari [12], Brečko and Ferrari [16], and Napal et al. [15]. These studies emphasize the widespread applicability of essential components of digital competence, such as digital literacy, information literacy, and ICT literacy, which are also pertinent in nursing education. The linkage with known frameworks enhances the theoretical basis of the DCAC.

Furthermore, this phase integrated knowledge from existing literature on several terminology and frameworks associated with digital competency. Feerrar [48], Ilomäki [49], and Nazeha et al. [7] have examined the concept of digital competence, which encompasses digital literacy, computer literacy, information literacy, and nursing informatics. Collectively, these components offer a thorough comprehension of digital proficiency, which is crucial for nursing students as they navigate the digital requirements of modern healthcare.

3.2. Phase 2: validation of DCAC

The second phase entailed validating the DCAC to ascertain its dependability and suitability in nursing education. The validity and reliability of the DCAC tool have been established by rigorous psychometric testing, in accordance with the COSMIN requirements. The Confirmatory Factor Analysis (CFA) yielded robust proof of the framework's structural soundness, aligning with the validation procedures employed in other digital competency tools across many domains [13,14]. This phase is particularly important because there was no previously existing digital competency assessment tool expressly designed for nursing students that was both valid and trustworthy.

The validation procedure was guided by preexisting frameworks such as TIGER and ILCSN. The TIGER framework, as described by

Table 3
The final 22-item of learning objectives in digital competence among nursing students.

Item Number	Item
Domain 1: Utilization of Digital Media and Resources	
1	Perform Data Searching
2	Utilize database to enter or to extract data and information for specific purpose
3	Identify eligible digital resource that relate to practice and care
4	Assess the trustworthiness and rigor of the accessed digital resources
5	Conduct Data/Information interpretation accurately
6	Use application to aggregate data in healthcare context
7	Use application to perform analysis of data, including data visualization, evaluation, and reporting
Domain 2: Application of Digital Communication	
8	Identify appropriate media for digital communication (Ex: smartphone, e-books, News Website …)
9	Understand the merge of different types of social media in digital communication
10	Use transmedia format to communicate with user in health care context
11	Perform adequate navigation in digital environment
12	Participate in digital environment to support and extend learning or practice/care
13	Identify behavior norm and regulation while using and interacting in digital world
14	Performs digital data sharing
Domain 3: Cognition in Digital Learning	
15	Organize digital resources in learning
16	Apply appropriate digital media and resources as strategic for health improvements
17	Use appropriate learning platform through technology
18	Synthesize digital content to professional knowledge
19	Identify resources to solve technical problems
Domain 4: Safety in Digital Environment	
20	Understand personal data regulation and legislation
21	Recognize the use of personal information
22	Perform online data protection

Hubner et al. [6], effectively combines technology and informatics. However, its intricate nature and emphasis on specific healthcare environments may limit its practicality for nursing students in general. On the other hand, the ILCSN paradigm, although successful in improving information literacy, may overlook wider elements of digital competence, such as safety, ethics, and communication [17]. The verified Digital Competence Assessment and Certification (DCAC) overcomes these deficiencies by offering a well-rounded and user-friendly tool that encompasses both technical and humanistic aspects of digital competence.

Additionally, the study was informed by the Digital Competence Framework for Nursing: Humanizing Digital Learning Process [18], which placed emphasis on adopting a human-centered approach. Nevertheless, the absence of explicit recommendations and evaluation criteria in these frameworks highlights the significance of this study's contribution. The DCAC provides a systematic and pragmatic evaluation tool, as well as a flexible framework that can be adjusted to meet the varied requirements of nursing students.

3.3. Strengths and limitations

This study contributes a novel and validated checklist for assessing digital competence among nursing students. The Digital Competence Assessment Checklist (DCAC) has undergone rigorous evaluation, including content validity through a Delphi approach, item discriminant analysis, and confirmatory factor analysis for structural validity. The instrument demonstrates strong internal consistency, providing a solid foundation for future research.

While the study offers significant insights, it does not encompass all stages of the COSMIN checklist. Specifically, the evaluation did not include test-retest reliability, measurement error, face validity, or responsiveness, which are critical components of a comprehensive psychometric assessment.

Additionally, validation testing was provided by graduate students in three Asian countries and results may vary in other regions, levels of education, and availability of digital infrastructure. The dynamic nature of digital technology requires ongoing evaluation of the digital competence framework and checklist.

3.4. Future recommendations

To further strengthen the DCAC and ensure its broader applicability, future studies should aim to complete the COSMIN checklist by addressing the remaining aspects, including test-retest reliability, measurement error, face validity, and responsiveness. This will enhance the reliability of DCAC and ensure its effectiveness across diverse populations and settings.

3.5. Implications for nursing education and clinical practice

Digital competence is widely acknowledged as a fundamental aspect of continuing education in higher learning institutions and has a vital role in enhancing educational achievements [50]. Future nursing students will probably face a healthcare setting that demands extensive involvement with digital technologies, encompassing its use, application, and collaboration within the digital domain [51].

Anticipated technology advancements are expected to modify the duties of nurses and impact how they perceive and engage with digital technologies in their daily tasks. Presently, the integration of digital proficiency into nursing education via curricula or dedicated training programs is inadequate. The lack of digital integration can result in technostress, which is a type of stress associated with the implementation of new technologies [52,53]. In order to combat technostress, it is essential to develop digital competence through educational programs, with a specific focus on nursing.

The study resulted in the development of a framework and assessment checklist for digital competence. This framework serves as a foundation for incorporating digital skills into nursing education programs. The results of this study are positioned to enhance the preparedness of nursing students to confront the digital obstacles encountered in healthcare environments, ultimately resulting in improved patient care and outcomes.

4. Conclusion

The Digital Competence Assessment Checklist (DCAC) developed is an initial step in addressing the scope of digital competence among nursing students. The 22-item DCAC is a valid and reliable tool to measure digital competence. Digital-related competence preparation is crucial to enable nursing students to achieve learning outcomes. By integrating digital competence into the education curricula, students will be empowered to thrive in an ever-involving healthcare setting and effectively meet the demands posed by the emerging digital era.

Ethical approval

Permission to conduct the study was obtained from the National Cheng Kung University Human Research Ethics Committee (Approval No. NCKU HREC-E−110-124-2).

Funding statement

This research has been funded by the National Science and Technology Council, Taiwan, with grant number: MOST 110-2511-H-006-005-MY3.

CRediT authorship contribution statement

Shannastaniar Aisya Adif: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Dhea Natashia:** Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Wei-Hung Lin:** Writing – review & editing, Validation, Supervision. **Muhammad Hadi:** Writing – review & editing, Supervision. **Mei-Feng Lin:** Writing – review & editing, Supervision. **Yu-Yun Hsu:** Writing – review & editing, Supervision. **Miaofen Yen:** Writing – review & editing, Visualization, Supervision, Methodology, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) utilized CHATGPT to assist with language writing refinement. The author(s) carefully reviewed and edited the content following the use of this tool and take(s) full responsibility for the content of the publication.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Miaofen Yen, PhD, RN, FAAN reports financial support was provided by National Science and Technology Council. Other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We extend our sincere gratitude to Professor Emerita Susan Jane Fetzer, from the University of New Hampshire and National Cheng Kung University, for her thorough review and invaluable feedback on this manuscript. Her insightful suggestions have greatly enhanced the scientific rigor and clarity of this work.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e37874.

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