Jurnal Ilmiah Profesi Pendidikan
Volume 11, Nomor 2, Mei 2026
ISSN (Print): 2502-7069; ISSN (*Online*): 2620-8326

Validation of Instrument to Measure Pre-Service Science Teachers Digital Skills: Rasch Model

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Article History
Received : April 07th, 2026
Revised : April 27th, 2026
Accepted : May 16th, 2026

Abstract: This study aimed to validate an instrument for measuring digital skills among pre-service science teachers using the Rasch model framework. A total of 349 Generation Z participants were surveyed from three year levels. Data were collected through Google Forms and analyzed using Winsteps 3.7.3. The Rasch model provided insights into item reliability, person reliability, separation indices, unidimensionality, item fit statistics, and differential item functioning (DIF). Results demonstrated strong psychometric robustness, with person reliability of 0.95, item reliability of 0.98, and Cronbach's alpha of 0.97. Wright Map analysis indicated appropriate alignment between item difficulty and respondents' abilities. Item fit statistics fell within the acceptable range, supporting internal validity. Unidimensionality analysis confirmed that the instrument measured a single construct, while DIF analysis showed no significant bias across gender or year of study. Overall, the instrument proved reliable, valid, and equitable in assessing digital skills among science pre-service teachers, offering a valuable tool for teacher education and digital competence assessment.

Keywords: digital skill; instrument; pre-service teachers; rasch model; validation

INTRODUCTION

The rapid advancement of digital technologies has transformed education globally, requiring both students and educators to adapt to new modes of learning, teaching, and knowledge production. Classrooms today are no longer limited to physical spaces; instead, they are increasingly shaped by online platforms, digital resources, and interactive technologies (Chugh, Turnbull, Cowling, Vanderburg & Vanderburg, 2023). This transformation demands a shift in pedagogical practices, as teachers are expected not only to deliver content but also to facilitate learning experiences that are meaningful, engaging, and relevant to the digital age. Within this context, the role of teachers extends far beyond traditional instruction, encompassing skills in digital literacy, critical evaluation of resources, and creative use of technology to enhance learning outcomes (Jiang, 2025; Zakharov, Komarova, Baranova & Gulk, 2021).

In particular, pre-service teachers—future educators currently undertaking their training—must develop adequate digital skills not only for academic purposes but also to ensure effective integration of technology into their future classrooms (Chang, Annisa & Chen, 2025). Unlike previous generations, today's learners are growing up in a digital society where information is readily accessible, communication occurs instantly, and knowledge is produced collaboratively through digital platforms. Therefore, teachers entering the profession must be capable of meeting these demands, ensuring that their students are prepared to navigate and contribute to an increasingly digitalized world (Aslan, Alanoğlu & Karabatak, 2025).

Digital skills for pre-service teachers include more than the ability to operate devices or use software applications. They encompass a broader set of competencies such as accessing, evaluating, creating, and sharing digital content responsibly and effectively. Additionally, pre-service teachers must understand how to design inclusive digital learning environments, promote responsible online behavior, and integrate technology in ways that support diverse learners

(Li & Yu, 2022). For instance, they should be able to select digital tools that align with pedagogical goals, adapt resources for students with different learning needs, and foster collaboration through technology-enhanced methods. Mastery of these competencies allows teachers to move beyond passive use of technology toward active, critical, and innovative applications in education (Kasperski, Blau & Ben-Yehudah, 2022; Potyrała & Tomczyk, 2021).

As teacher education shifts toward digital learning environments, assessing pre-service teachers' digital competencies becomes increasingly crucial. Without systematic evaluation, it is difficult to determine whether pre-service teachers possess the readiness required to integrate technology meaningfully into their future practice (Haşlaman, Uslu & Mumcu, 2023). Reliable assessment not only provides insights into their current levels of digital competence but also highlights areas where additional training and support may be necessary. Moreover, validated instruments for measuring digital skills can guide teacher education programs in refining curricula, ensuring that they address essential competencies while responding to evolving educational demands (Alnasib, 2023; Althubyani, 2024).

In essence, the integration of technology in education is not optional but a necessity in the 21st century. Preparing pre-service teachers with strong digital skills is a fundamental step toward ensuring that schools remain responsive to the challenges and opportunities of the digital era (Dolezal, Motschnig & Ambros, 2025). By assessing and nurturing these skills during teacher training, institutions can contribute to the development of educators who are confident, competent, and capable of shaping learning environments that empower students to thrive in an interconnected, technology-driven world (Çebi & Reisoğlu, 2020; Niyazova, et. al., 2023).).

Digital skills encompass multiple dimensions, including the ability to access, manage, and evaluate information; utilize digital media for communication and learning; engage in creative and collaborative tasks; and ensure ethical and responsible use of technology. For Generation Z pre-service teachers, who have grown up with pervasive access to digital tools, expectations of proficiency are high. However, their digital engagement is often uneven, with strong informal use (e.g., social media, entertainment) but varying mastery of academic or pedagogical applications. Therefore, measuring their digital skills through a validated, psychometrically sound instrument is both timely and essential (Galindo-Domínguez & Bezanilla, 2021; McGarr & McDonagh, 2021).

The Rasch model, rooted in Item Response Theory (IRT), offers a robust approach to validation. Unlike classical test theory, Rasch analysis examines the interaction between person ability and item difficulty on a common logit scale, providing precise insights into the functioning of test items and respondents (Adam, Qudratuddarsi, Ningthias, Rahmadhani & Noviana, 2025; Ayçiçek, 2025). It enables the identification of misfitting items, assesses unidimensionality, ensures fair functioning across subgroups (through Differential Item Functioning analysis), and confirms scale reliability. For digital skills assessment, Rasch modeling is particularly advantageous, as it helps ensure that the instrument captures varying levels of ability, from basic operational tasks to higher-order creative and evaluative skills (Jumriani, Qudratuddarsi, Rahmah, Ningthias & Indriyanti, 2025). This research sought to validate an instrument for measuring the digital skills of pre-service science teachers using the Rasch model. Specifically, it aimed to: 1) Examine the reliability and separation indices of the instrument. 2) Analyze item fit statistics to ensure psychometric soundness. 3) Test unidimensionality to confirm that the instrument measures a single underlying construct. 4) Evaluate Differential Item Functioning (DIF) across gender and year of study to ensure fairness.

METHOD

Research Design

This study employed a quantitative survey method, focusing on gathering and analyzing numerical data derived from structured responses provided by participants. As a survey-based investigation, it sought to evaluate pre-service science teachers' digital skills at a particular moment in time, without introducing interventions or manipulating the participant group (Ramadhana & Qudratuddarsi, 2024). The researchers applied a cross-sectional design, which allowed them to capture participants' digital skills in a single snapshot, thus avoiding typical challenges associated with longitudinal studies, such as participant attrition or changing external factors that may influence perceptions over time (Wang & Cheng, 2020). The use of quantitative analysis ensured objectivity and data

reliability, enabling statistical exploration of trends and response patterns (Qudratuddarsi, Meivawati & Saputra, 2024).

Research Subject

A total of 349 Generation Z pre-service science teachers participated in this study. They were selected through convenience sampling, which provided quick and accessible participant recruitment, although it may slightly limit the generalizability of the findings (Qudratuddarsi, Ramadhana, Indriyanti & Ismail, 2024). Despite this, the sample was highly relevant because of their uses of technology in their daily life and their education journey. Based on gender, 28.30% were male and 71.70% were female, indicating that the majority of the participants were female. In terms of specialization, 27.99% of participants specialized in chemistry, 20.75% in physics, 22.96% in biology, and 28.30% in general science. This distribution shows a balanced representation across the different science disciplines, which provides diverse perspectives relevant to the study's focus.

Instrument

This instrument, adapted from Fan and Wang (2022), is designed to evaluate students' digital competencies and has been translated and culturally validated for the Indonesian context through the back-translation procedure. It comprises six key dimensions: Access to and Management of Digital Content (AMDC), which measures the ability to locate, organize, and critically assess digital information; Use of Digital Means (UDC), which pertains to the operation of technological devices and applications; Communication of Digital Content (CS), which examines the capacity to exchange information and adjust communication strategies in digital settings; Creation of Digital Content (CrS), which relates to producing and adapting digital materials in a responsible manner; Digital Safety (DSS), which highlights awareness of cybersecurity and data protection; and Digital Empathy (DES), which represents ethical conduct and respect in online interactions.

Data Collection

Data collection was conducted through Google Forms, supporting sustainable, paperless research practices while also improving efficiency and minimizing data entry errors (Qudratuddarsi, Rahmah & Indriyanti, 2025). The digital format allowed for real-time access to responses. To further ensure clarity and accurate understanding of the survey items, the researcher was present during data collection, offering immediate assistance to participants if needed. This presence also helped create a supportive environment that encouraged participants to respond sincerely. Participation in the study was voluntary, with clear assurances that their responses would remain confidential and would not influence their academic evaluations. These ethical safeguards were crucial in maintaining the credibility and integrity of the collected data (Chen, at. al., 2025; Hamdoun, Hussein, Almaaly, & Jawad, 2024).

Data Analysis

After the data collection process, responses were organized and tabulated using Microsoft Excel 2019, which facilitated further analysis with Winsteps 2018 version 3.7.3. The Rasch analysis framework was applied to examine each sub-construct of digital skill independently. The analysis evaluated several key aspects, including reliability, separation, item fit statistics, unidimensionality, and rating scale calibration. Reliability testing assessed the consistency of the measurement instrument, while separation statistics provided evidence of the scale's ability to differentiate participants across varying levels of digital skills. Item fit statistics were used to identify any misfitting items that did not adequately represent the construct, thereby supporting the validity of the scale (Qudratuddarsi, Ramadhana, Indriyanti & Ismail, 2024). Unidimensionality was tested to ensure that the instrument measured a single underlying trait, which is a core assumption of the Rasch model. In addition, rating scale calibration verified that the response categories functioned as intended, producing meaningful distinctions across levels of the construct. By applying this comprehensive analytical approach, the study ensured robust and reliable findings, which are essential for drawing valid conclusions regarding the measurement of digital skills (Hope, Kluth, Homer, Dewar, Goddard-Fuller, Jaap & Cameron, 2025).

RESULT AND DISCUSSION

Wright Map

The Wright Map analysis shows a good alignment between the distribution of respondents' abilities and item difficulty levels. Most science pre-service teachers were clustered

around the logit values of 0 to +1, suggesting that the majority demonstrate moderate levels of digital skills. The easier items, such as AMDC3, DSS1, and UDM1, were positioned at the lower end of the scale, reflecting basic skills that were widely mastered by the respondents. In contrast, items related to creative skills (CrS1–CrS3), advanced use of digital media (UDM2), and higher-order content management (AMDC5) appeared at the upper levels, indicating greater difficulty. This distribution demonstrates that the instrument is well-targeted, with items appropriately spanning from easier to more complex digital skills, thereby supporting its validity in assessing the diverse skill levels of science pre-service teachers.

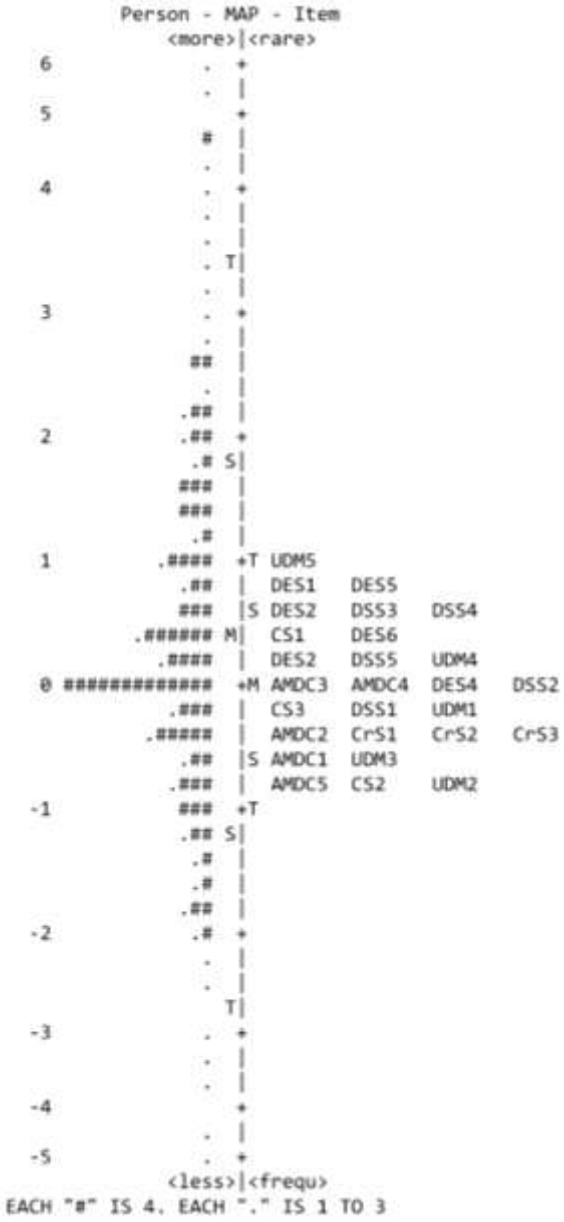

Figure 1. Wright Map

Reliability and Separation

Findings from the reliability and separation analysis provide compelling evidence that the instrument developed to measure science pre-service teachers' digital skills is highly robust psychometrically. The person reliability value of 0.95 shows that the instrument can consistently distinguish respondents with varying levels of digital skills, while the item reliability of 0.98 demonstrates that the items are stable and well-constructed across different samples. The Cronbach's Alpha of 0.97 further confirms the

strong internal consistency of the instrument, ensuring that the items measure the same construct. The person separation index of 4.31 suggests that the instrument can classify respondents into at least five to six distinct ability levels, and the item separation index of 6.39 reflects a wide range of item difficulty, covering both basic and advanced digital skills. Finally, the chi-square value (18732.73, d.f. 8915, $p < .01$) indicates a significant model fit, which is acceptable given the large sample size and item pool. Overall, these results confirm that the instrument is highly reliable and valid for assessing digital skills among science pre-service teachers.

Table 2. Reliability and Separation

Indicator	Value
Person Reliability	0.95
Item Reliability	0.98
Cronbach Alpha	0.97
Person Separation	4.31
Item Separation	6.39
Chi-square	18732.73** (d.f. 8915)

Item fit statistics

The item fit statistics demonstrate that all items of the digital skills instrument exhibit acceptable fit to the Rasch model. The infit and outfit mean square (MNSQ) values ranged from 0.68 to 1.48, which falls within the recommended range of 0.5 to 1.5, indicating that the items function consistently in measuring their respective dimensions. A few items, such as CS1 (1.45/1.48) and UDM5 (1.35/1.33), showed slightly higher values, suggesting greater response variability, while items like CrS3 (0.68) and DES3 (0.70) presented lower values, reflecting more predictable responses. However, all remain within acceptable thresholds. In addition, the point-measure correlations, which ranged from 0.65 to 0.78, were positive and strong, confirming that each item contributes meaningfully to the construct it represents. These findings indicate that the 27 items across the six dimensions—AMDC, UDM, CS, CrS, DSS, and DES—are psychometrically sound and valid for assessing science pre-service teachers' digital skills.

Table 3. Item Fit Statistics of digital skill instrument

Item	MNSQ		Pt Mea Corr
	Infit	Outfit	0.73
AMDC1	0.89	1.03	0.75
AMDC2	0.82	0.83	0.72
AMDC3	0.99	1.02	0.76
AMDC4	0.84	0.90	0.65
AMDC5	1.35	1.34	0.72
UDM1	0.89	0.91	0.71
UDM2	0.90	0.90	0.72
UDM3	0.98	1.04	0.66
UDM4	1.20	1.18	0.67
UDM5	1.35	1.33	0.72
CS1	1.45	1.48	0.69
CS2	1.18	1.21	0.66
CS3	0.92	0.95	0.77
CrS1	0.96	0.95	0.77
CrS2	1.09	1.14	0.74
CrS3	0.68	0.67	0.71
DSS1	0.72	0.71	0.70
DSS2	0.84	0.85	0.71
DSS3	1.18	1.15	0.70
DSS4	1.07	1.12	0.76
DSS5	0.83	0.83	0.74
DES1	0.96	0.96	0.72
DES2	1.06	1.07	0.72
DES3	0.70	0.70	0.78
DES4	0.75	0.73	0.78
DES5	1.00	1.01	0.74
DES6	0.88	0.87	0.76

Unidimensionality

The results of the unidimensionality test support the validity of the digital skills instrument. The raw variance explained by measures reached 53.5%, exceeding the minimum requirement of 40% and indicating that the majority of variance is explained by the main construct being measured. Specifically, the variance explained by persons (32.2%) and items (21.3%) confirms that both respondents' ability and item characteristics contribute meaningfully to the construct. Meanwhile, the unexplained variance in the first contrast was 1.8 eigenvalue units or 7.1%, which is below the threshold of 15%, suggesting that there are no substantial secondary dimensions interfering with the measurement. These findings indicate that the instrument demonstrates unidimensionality, meaning it consistently measures a single underlying construct—science pre-service teachers' digital skills.

Table 4. Unidimensionality of digital skill instrument

	Value
Raw variance explained by persons	32.2%
Raw variance explained by items	21.3%
Raw variance explained by measures	53.5%
Unexplained variance in 1st contrast (eigenvalue)	1.8
Unexplained variance in 1st contrast (percentage)	7.1%

DIF based on gender

The DIF analysis based on gender shows that the digital skills instrument functions equivalently for male and female pre-service teachers. Across the 27 items, the differences in item difficulty between genders were generally small, with most values ranging between –0.5 and +0.5 logits, well within acceptable limits. A few items, such as UDM4 and UDM5, showed slightly higher difficulty for female respondents, while CS1 appeared somewhat more difficult for males. However, these differences did not exceed the critical threshold of ±1.5 logits, indicating no substantial gender-related bias. Overall, the results confirm that the instrument is gender-fair and can reliably measure digital skills across both male and female science pre-service teachers.

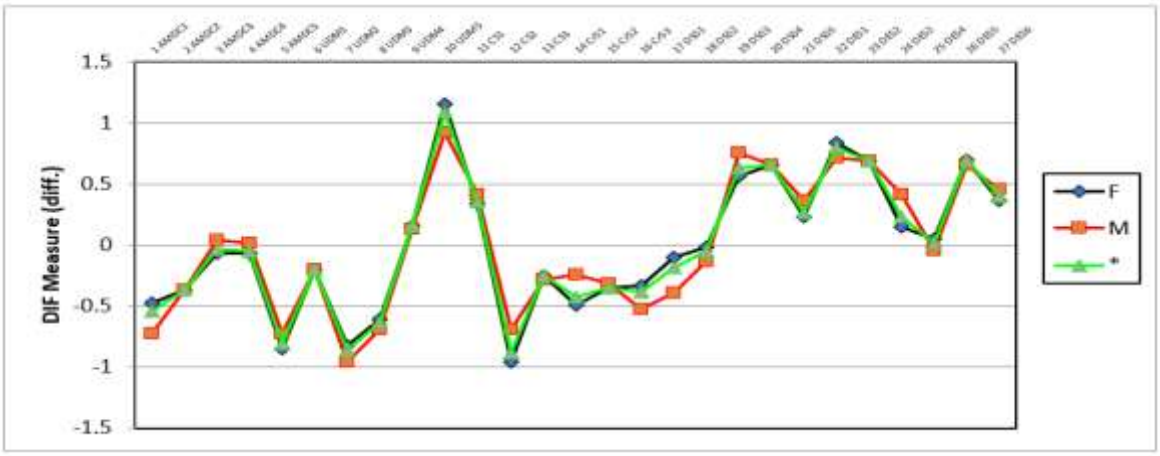

Figure 2. DIF based on gender

DIF based on year of study

The DIF analysis by year of study (Figure 3) indicates that the digital skills instrument functions consistently across first-, second-, and third-year science pre-service teachers. The overall patterns of item difficulty were highly similar among the three groups, with most DIF values within ±0.5 logits, demonstrating minimal year-related bias. A few items, such as UDM4 and UDM5, showed slightly higher difficulty for second-year students, while CS1 appeared somewhat more difficult for first-year students. However, these differences did not exceed the critical threshold of ±1.5 logits, suggesting that they do not threaten the validity of the instrument. Overall, the results confirm that the instrument provides a fair and reliable measurement of digital skills across different year levels.

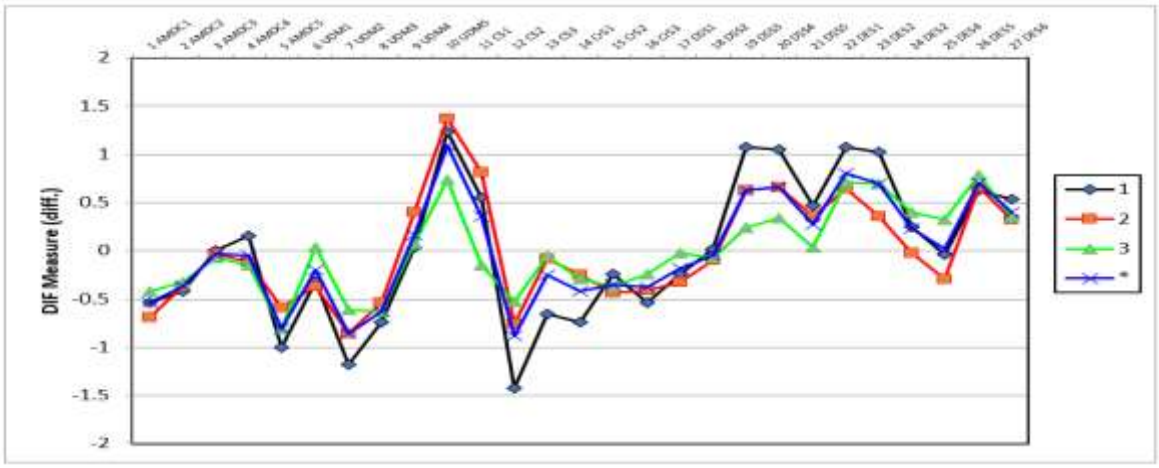

Figure 3. DIF based on year of study

Discussion

The findings of this study provide strong empirical evidence supporting the validity and reliability of the digital skills instrument for Generation Z pre-service science teachers. Overall, the results align with the growing emphasis in teacher education on developing robust digital competencies that enable future educators to design and facilitate technology-enhanced learning environments (Gallego, Merchán, & Barrera, 2025). The Wright Map, reliability coefficients, item fit statistics, unidimensionality test, and DIF analyses collectively confirm that the adapted instrument functions effectively in measuring a wide range of digital skills, from basic operational abilities to higher-order creative and evaluative competencies. These results reinforce theoretical and empirical perspectives outlined in the introduction, which emphasize the necessity of equipping pre-service teachers with digital skills that match the demands of the 21st-century classroom (Aslan, Alanoğlu & Karabatak, 2025; Dolezal, Motschnig & Ambros, 2025).

First, the Wright Map analysis reveals that the distribution of item difficulty aligns well with the abilities of the participants. This pattern is consistent with previous studies suggesting that Generation Z pre-service teachers generally possess moderate to high levels of functional digital literacy due to their daily exposure to digital technologies (Galindo-Domínguez & Bezanilla, 2021; McGarr & McDonagh, 2021). The clustering of respondents around moderate logit values and the adequate spread of item difficulties indicate that the scale successfully captures both foundational and advanced aspects of digital competence. More difficult items related to digital content creation and higher-order management reflect competencies that require not only technological familiarity but also critical thinking, creativity, and pedagogical application—skills that many pre-service teachers may not yet fully master (Kasperski, Blau & Ben-Yehudah, 2022). This finding highlights a common global trend: although young learners are surrounded by digital tools, their academic and pedagogical digital skills are often less developed than their informal digital engagement.

Second, the high person and item reliability coefficients (0.95 and 0.98, respectively) and the strong Cronbach's Alpha (0.97) demonstrate that the instrument yields consistent and stable measurements. These reliability values surpass the thresholds commonly recommended in Rasch modeling, indicating that the instrument not only functions well statistically but also possesses meaningful interpretive value in practical educational settings. The person separation index (4.31) suggests the ability to differentiate individuals across multiple proficiency levels, supporting its use in identifying students who require additional training or intervention. This is crucial for teacher education programs aiming to design targeted digital literacy curricula or professional development opportunities (Haşlaman, Uslu & Mumcu, 2023; Alnasib, 2023).

Third, the item fit statistics further support the psychometric robustness of the instrument. All items fell within the acceptable MNSQ range of 0.5–1.5, indicating strong alignment with Rasch model expectations. While a few items (e.g., CS1, UDM5) demonstrated slightly higher values, these remain within tolerable limits and may reflect genuine variability in how pre-service teachers engage with more complex forms of digital communication and media usage. High

creativity- and communication-related item difficulties have also been reported in recent studies assessing educators' digital competencies, suggesting that these skills are typically more advanced and require intentional instructional support (Potyrała & Tomczyk, 2021; Li & Yu, 2022). Conversely, items showing lower MNSQ values, such as CrS3 and DES3, indicate predictable responses and may reflect foundational competencies widely shared among participants.

Fourth, the unidimensionality results indicate that the instrument measures a single underlying construct: digital skills. The raw variance explained (53.5%) exceeds recommended thresholds and aligns with the structure of digital competence frameworks, which conceptualize digital skills as a coherent, integrated construct despite comprising multiple interrelated dimensions (communication, safety, creation, access, etc.). The low unexplained variance in the first contrast further suggests that no secondary dimensions distort the measurement. These findings validate the conceptual clarity and coherence of the scale, supporting its use as a unified measure of digital competence among science pre-service teachers.

Finally, the DIF analysis confirms that the instrument operates fairly across gender and year of study. This is an important finding, given that prior research has sometimes reported gendered or cohort-based differences in digital skill development (Ayçiçek, 2025). The absence of DIF indicates that variations in performance reflect true differences in ability rather than measurement bias, reinforcing the instrument's credibility for diverse student populations. The minor differences observed in specific items (e.g., CS1, UDM4, UDM5) do not exceed the bias threshold, suggesting that any observed disparities may be attributable to natural variations in learning experiences rather than flaws in item construction.

The validated instrument provides a reliable foundation for teacher education institutions to systematically assess and monitor the digital competencies of pre-service teachers, enabling the development of targeted interventions and competency-based training programs. In practice, the instrument can guide curriculum designers in identifying areas where digital skills—particularly creative content development, digital communication, and higher-order evaluative skills—require further instructional emphasis. This evidence-based approach supports more intentional integration of digital pedagogy across coursework and practicum experiences. At the policy level, the findings highlight the importance of institutional frameworks that promote continuous digital capacity-building, ensuring that teacher preparation programs align with national digital transformation agendas in education. Policies that mandate regular digital skills assessment, provide professional development resources, and ensure equitable access to digital tools can strengthen the readiness of future teachers to navigate and lead technology-enhanced learning environments.

Despite the strong psychometric results, this study has several limitations that should be acknowledged. The use of convenience sampling and the focus on pre-service science teachers limit the generalizability of the findings to other disciplines and broader populations of teacher candidates. Additionally, the cross-sectional design captures digital skills at a single point in time, preventing insights into developmental trajectories or the effects of instructional interventions. Future research should employ longitudinal designs to examine how digital competencies evolve over the course of teacher education and practicum experiences. Expanding the sample to include diverse subject areas, institutions, and cultural contexts would further strengthen the instrument's external validity. Moreover, integrating qualitative approaches—such as interviews or classroom observations—could provide deeper insights into how pre-service teachers apply their digital skills in real pedagogical settings, contributing to more comprehensive understanding and refinement of digital competence frameworks.

CONCLUSION

This study validated an instrument designed to measure digital skills among pre-service science teachers using the Rasch model. Results confirmed excellent psychometric properties, with high reliability, strong separation indices, acceptable item fit, and robust unidimensionality. Differential Item Functioning analysis further demonstrated that the instrument functions equitably across gender and year of study. Collectively, these findings establish the instrument as a valid and reliable tool for assessing digital skills in teacher education contexts. The instrument provides teacher educators and policymakers with an evidence-based means to evaluate digital competence,

guide curriculum development, and support targeted interventions. By ensuring fairness and accuracy, the validated instrument not only enhances the assessment of current cohorts but also contributes to preparing future science teachers to integrate digital technologies effectively in their teaching practices. As digital skills remain central to 21st-century education, such validated tools are essential for bridging the gap between technological potential and pedagogical implementation.

ACKNOWLEDGMENT

This section displays authors appreciation to sponsors, fund donors, resource persons, or parties who have an important role in conducting research.

REFERENCES

Adam, W., Qudratuddarsi, H., Ningthias, D. P., Rahmadhani, A., & Noviana, E. (2025). Validation of Pre-Service Science Teacher Artificial Intelligence Competence Self-Efficacy (AICS): Rasch Model Analysis. *Jurnal Ilmiah Profesi Pendidikan*, *10*(2), 1985-1995.

Alnasib, B. N. (2023). Digital Competencies: Are Pre-Service Teachers Qualified for Digital Education?. *International Journal of Education in Mathematics, Science and Technology*, *11*(1), 96-114.

Althubyani, A. R. (2024). Digital competence of teachers and the factors affecting their competence level: A nationwide mixed-methods study. *Sustainability*, *16*(7), 2796.

Aslan, S., Alanoğlu, M., & Karabatak, S. (2025). Enhancing 21st-century teaching competencies: The key role of digital literacy in connecting pre-service teachers' TPACK. *Information Development*, 02666669251315841.

Ayçiçek, B. (2025). Peer Assessment Analysis via the Many-Facet Rasch Model. *Mersin Üniversitesi Eğitim Fakültesi Dergisi*, *21*(2), 631-646.

Çebi, A., & Reisoğlu, İ. (2020). Digital competence: A study from the perspective of pre-service teachers in Turkey. *Journal of New Approaches in Educational Research*, *9*(2), 294-308.

Chang, C. F., Annisa, N., & Chen, K. Z. (2025). Pre-service teacher professional education program (PPG) and Indonesian science teachers' TPACK development: A career-path comparative study. *Education and Information Technologies*, *30*(7), 8689-8711.

Chen, Y., Jarecka, D., Abraham, S. A., Gau, R., Ng, E., Low, D. M., ... & Ghosh, S. S. (2025). Standardizing survey data collection to enhance reproducibility: Development and comparative evaluation of the ReproSchema ecosystem. *Journal of medical Internet research*, *27*, e63343.

Chugh, R., Turnbull, D., Cowling, M. A., Vanderburg, R., & Vanderburg, M. A. (2023). Implementing educational technology in Higher Education Institutions: A review of technologies, stakeholder perceptions, frameworks and metrics. *Education and Information Technologies*, *28*(12), 16403-16429.

Dolezal, D., Motschnig, R., & Ambros, R. (2025). Pre-service teachers' digital competence: A call for action. *Education Sciences*, *15*(2), 160.

Fan, C., & Wang, J. (2022). Development and validation of a questionnaire to measure digital skills of Chinese undergraduates. *Sustainability*, *14*(6), 3539.

Galindo-Domínguez, H., & Bezanilla, M. J. (2021). Digital competence in the training of pre-service teachers: Perceptions of students in the degrees of early childhood education and primary education. *Journal of Digital Learning in Teacher Education*, *37*(4), 262-278.

Gallego Joya, L., & Merchán, M. MA, & López Barrera, EA (2025). Development and strengthening of teachers' digital competence: Systematic review. *Contemporary Educational Technology*, *17*(1).

Hamdoun, S. H., Hussein, R. A., Almaaly, A. M. J., & Jawad, A. S. N. M. (2024). Evaluating the efficacy of emerging techniques: innovations in survey methodology. *Journal of Ecohumanism*, *3*(5), 322-334.

Haşlaman, T., Uslu, N. A., & Mumcu, F. (2023). Development and in-depth investigation of pre-service teachers' digital competencies based on DigCompEdu: a case study. *Quality & Quantity*, 1.

Hope, D., Kluth, D., Homer, M., Dewar, A., Goddard-Fuller, R., Jaap, A., & Cameron, H. (2025). Exploring the use of Rasch

modelling in "common content" items for multi-site and multi-year assessment. *Advances in Health Sciences Education*, *30*(2), 427-438.

Jiang, B. (2025). Enhancing digital literacy in foreign language teaching in Chinese universities: Insights from a systematic review. *Teaching and Teacher Education*, *154*, 104845.

Jumriani, J., Qudratuddarsi, H., Rahmah, N., Ningthias, D. P., & Indriyanti, N. (2025). Validation Of Instrument to Measure Gen-Z Pre-Service Teacher Chemistry Virtual Lab Acceptance and Use. *Chemistry Education Practice*, *8*(1), 128-136.

Kasperski, R., Blau, I., & Ben-Yehudah, G. (2022). Teaching digital literacy: are teachers' perspectives consistent with actual pedagogy?. *Technology, Pedagogy and Education*, *31*(5), 615-635.

Li, M., & Yu, Z. (2022). Teachers' satisfaction, role, and digital literacy during the COVID-19 pandemic. *Sustainability*, *14*(3), 1121.

McGarr, O., & McDonagh, A. (2021). Exploring the digital competence of pre-service teachers on entry onto an initial teacher education programme in Ireland. *Irish Educational Studies*, *40*(1), 115-128.

Niyazova, A. Y., Chistyakov, A. A., Volosova, N. Y., Krokhina, J. A., Sokolova, N. L., & Chirkina, S. E. (2023). Evaluation of pre-service teachers' digital skills and ICT competencies in context of the demands of the 21st century. *Online Journal of Communication and Media Technologies*, *13*(3), e202337.

Potyrała, K., & Tomczyk, Ł. (2021). Teachers in the lifelong learning process: examples of digital literacy. *Journal of Education for Teaching*, *47*(2), 255-273.

Qudratuddarsi, H., Rahmah, N., & Indriyanti, N. (2025). Analysis of the attitudes of generation z prospective science teachers toward the chemistry virtual laboratory. *Arfak Chem: Chemistry Education Journal*, *8*(1), 651-665.

Qudratuddarsi, H., Ramadhana, N., Indriyanti, N., & Ismail, A. I. (2024). Using Item Option Characteristics Curve (IOCC) to unfold misconception on chemical reaction. *Journal of Tropical Chemistry Research and Education*, *6*(2), 105-118.

Zakharov, K., Komarova, A., Baranova, T., & Gulk, E. (2021). Information literacy and digital competence of teachers in the age of digital transformation. In *XIV International Scientific Conference "INTERAGROMASH 2021" Precision Agriculture and Agricultural Machinery Industry, Volume 2* (pp. 857-868). Cham: Springer International Publishing.