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Beyond Area Scores: Digital Competence Analysis Of Pre-Service Elementary Teachers In Mathematics Learning Based On Digcompedu

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ABSTRACT

Digital competence studies grounded in the DigCompEdu framework typically report scores only at the area level, concealing which of the twenty underlying items are genuinely strong or weak and limiting the precision of subsequent training design, including for mathematics teaching. This descriptive quantitative study analyzes item-level scores from a DigCompEdu-adapted questionnaire administered to pre-service elementary teacher education students preparing to teach mathematics at Universitas Negeri Surabaya. Data collection has reached 37 respondents, exceeding the planned sample of 30. Composite digital competence reached a high category (M = 4.18, SD = 0.50). Item-level ranking shows that discussing teaching strategies through digital platforms is the strongest item (M = 4.57, SD = 0.64), while designing learning activities that integrate digital tools in a meaningful, non-decorative way is the weakest item (M = 3.97, SD = 0.72), together with analyzing digital assessment results (M = 4.00, SD = 0.84), two capacities central to technology-integrated mathematics teaching. An exploratory one-way ANOVA comparing composite scores across six regional-origin clusters found no statistically significant difference, F(5, 31) = 0.64, p = .675, partial eta-squared = .09, suggesting no strong link to region of origin. These item-level findings are intended to inform a more precisely targeted digital-competence strengthening program for pre-service elementary mathematics teachers, prioritizing meaningful pedagogical integration and digital assessment analysis over basic technical skills already well mastered. Limitations include the convenience sampling technique

and the uneven size of regional subgroups, which restrict the regional comparison to an exploratory status.

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INTRODUCTION

Digital competence has become one of the main prerequisites for elementary school teachers, including pre-service teachers still completing their initial teacher education, to design instruction that remains relevant to present-day demands, including the growing presence of artificial intelligence in classroom practice (Putri, 2026b). The European Framework for the Digital Competence of Educators (DigCompEdu) maps educators' digital competence into six areas and twenty-two sub-competencies arranged from the newcomer to the pioneer level (Redecker, 2017), and it has been widely adapted to pre-service teacher contexts in many countries, including Indonesia (Cáceres-Reche, Ramos-Navas-Parejo, & Rodríguez-García, 2025).

Most studies that adapt the DigCompEdu framework report their results at the area level, that is, the combined average of three to four items grouped within a single competence area. This reporting approach is practical for comparing general profiles across groups, as done in a comparative study of pre-service and in-service teachers in Lebanon (Momdjian, Manegre, & Gutiérrez-Colón, 2024) and an in-depth case study of pre-service teachers in Turkey (Haşlaman, Atman Uslu, & Mumcu, 2024), yet it risks masking variation in achievement across items within the same area. An area can appear to fall into a high category on average while one of its constituent items actually lags far behind the other items in the same area, so a training program designed from area scores alone risks missing its target.

The need for item-level analysis is supported by evidence that pre-service teachers' weaknesses in digital competence are often specific to particular kinds of activity rather than spread evenly across an entire area. A

study of pre-service English teachers in Indonesia found that the most pronounced weaknesses lay in reflective practice and the ability to analyze assessment results, two specific activities located in different areas of the DigCompEdu framework (Sumarni, Iskandar, & Santosa, 2023), indicating that area-level mapping alone is not sufficient to reveal this kind of weakness pattern. The differing degree of complexity across items can also be explained through the Technological Pedagogical Content Knowledge framework, which holds that activities requiring the simultaneous integration of technological, pedagogical, and content knowledge are considerably more complex than activities that merely require the technical skill of operating an application (Mishra & Koehler, 2006), so it is unsurprising that items within the same area achieve different levels of attainment.

The link between digital competence and mathematics learning in particular has drawn growing research attention through the Technological Pedagogical Content Knowledge (TPACK) framework, which is essentially a content-specific version of the technology-integration idea underlying DigCompEdu. A systematic review of TPACK research in elementary mathematics education found that the ability to design pedagogically meaningful technology integration, rather than mere technical mastery of an application, remains the most difficult achievement for pre-service teachers to attain across countries (Li, Vale, Tan, & Blannin, 2025). A similar pattern was reported among pre-service mathematics teachers learning to design polygon lessons with GeoGebra, where technical mastery of the application developed faster than the ability to design mathematical tasks that used the application meaningfully (Kartal & Çınar, 2024). A study in the elementary teacher education program at Universitas Negeri Padang further showed that a TPACK-based hybrid learning model can improve pre-service elementary teachers' computational thinking skills in mathematics learning, an indication that digital competence and mathematical mastery among pre-service

elementary teachers are closely related and can be developed together (Helsa, Turmudi, & Juandi, 2023).

The digital competence data used in this study come from the same data collection instrument as a companion article that discusses the relationship between digital competence and pre-service teachers' ethnomathematics understanding and practice at the area level. This manuscript specifically deepens that discussion by focusing on item-level analysis and an exploration of achievement differences based on respondents' region of origin, an angle not presented in the companion article, so the two manuscripts complement each other without overlapping in focus.

Based on this background, the present study aims to (1) describe pre-service elementary teachers' digital competence achievement at the item level, not only the area level, according to the DigCompEdu framework, (2) identify the items with the highest and lowest achievement as a basis for prioritizing a digital competence strengthening program in mathematics learning, and (3) explore whether digital competence achievement differs according to respondents' region of origin. The findings are expected to serve as an empirical basis for designing a more precise and well-targeted digital competence strengthening program or module for pre-service elementary mathematics teachers.

METHODS

This study uses a quantitative descriptive approach in the form of a need analysis that focuses solely on pre-service elementary teachers' digital competence.. The digital competence data in both manuscripts come from the same data collection instrument, but this manuscript analyzes it with a different focus and depth, namely at the item level and through an exploration of region of origin, rather than at the area level as part of a cross-variable relationship study.

Population and Sample

The population of this study consists of active students in the Elementary Teacher Education Program who have taken the elementary mathematics learning course and/or the Field Experience Program. As future homeroom teachers at the elementary level, the respondents in this study will be responsible for teaching mathematics in an integrated manner with other subjects, so their digital competence is directly relevant to their readiness to teach technology-assisted mathematics, in line with the finding that digital competence and mastery of mathematical TPACK among pre-service elementary teachers develop in a related manner (Helsa, Turmudi, & Juandi, 2023). As of the writing of this manuscript, the questionnaire had been completed by 37 respondents from various regions, covering East Java (including the Bojonegoro cluster), East Nusa Tenggara (the Soe/South Central Timor cluster), Sulawesi (including the Toraja cluster), and several other regions in Sumatra and Java, exceeding the initial target of 30 respondents calculated using the Slovin formula/Krejcie-Morgan table. Data collection continues in order to strengthen the representativeness of the population, particularly for regional groups whose respondent numbers remain small.

Instrument

Data were collected through a digital competence questionnaire adapted from the DigCompEdu framework, consisting of 20 statement items on a 1-5 Likert scale covering six areas: professional engagement (3 items), digital resources (4 items), teaching and learning (4 items), assessment (3 items), empowering learners (3 items), and facilitating learners' digital competence (3 items).

Data Analysis Technique

Data were analyzed using descriptive statistics (mean and standard deviation) at the item level to answer the first and second research objectives, with achievement categorized using the intervals Very Low (1.00-1.79), Low (1.80-

2.59), Moderate (2.60-3.39), High (3.40-4.19), and Very High (4.20-5.00). To answer the third research objective, each respondent's composite score was grouped by region of origin into six clusters and tested using a one-way analysis of variance (ANOVA) to determine whether a statistically significant mean difference existed between clusters, following the standard procedure for difference testing in descriptive quantitative research (Creswell & Creswell, 2018). Given the uneven cluster sizes and the small size of some clusters, this test result was treated as a preliminary exploration rather than a confirmatory hypothesis test.

Instrument Validity and Reliability

The content validity of the questionnaire was tested through expert judgment by lecturers specializing in instructional media and lecturers specializing in elementary mathematics education, calculated using the Content Validity Ratio (CVR) or Aiken's V. The instrument was then piloted on respondents outside the research sample to test item validity (item-total correlation) and reliability using Cronbach's Alpha coefficient, with items considered valid and reliable if they met the threshold set before being used on the actual research sample.

RESULTS AND DISCUSSION

This section presents the results of the digital competence analysis of 37 pre-service elementary teachers, beginning with a general profile at the area level, followed by a detailed analysis at the item level, and closing with an exploration of achievement differences based on respondents' region of origin.

General Profile of Digital Competence at the Area Level

The composite digital competence score of the 37 respondents fell into the high category (M = 4.18, SD = 0.50). Table 1 presents the mean and standard deviation for each area as a general picture before moving to the item-level analysis that is the main focus of this manuscript.

Table 1. Digital Competence Scores of Pre-Service Teachers by DigCompEdu Area (N = 37)

DigCompEdu Area	M	SD	Category
Professional Engagement	4.29	0.49	Very High
Digital Resources	4.20	0.56	Very High
Empowering Learners	4.19	0.54	High
Assessment	4.14	0.62	High
Facilitating Learners' Digital Competence	4.14	0.56	High
Teaching and Learning	4.11	0.60	High
Overall Mean	4.18	0.50	High

Source: primary data, processed (2026).

The gap between areas is narrow, ranging from 4.11 to 4.29, which at first glance gives the impression that all six digital competence areas have developed evenly. That impression is precisely the main reason the item-level analysis in the following subsection is needed, because an area average that looks even can conceal a particular item whose achievement differs greatly from other items in the same area, a pattern that has been conceptually flagged in the literature on the risk of over-generalization in area-level reporting (Sumarni, Iskandar, & Santosa, 2023).

Analysis of Achievement Across Digital Competence Items

Table 2 presents the achievement of all twenty digital competence items, ordered from highest to lowest, along with the area each item belongs to. The area codes used are PE (Professional Engagement), DR (Digital Resources), TL (Teaching and Learning), AS (Assessment), EL (Empowering Learners), and FL (Facilitating Learners' Digital Competence).

Table 2. Ranking of Pre-Service Teachers' Digital Competence Item Achievement (N = 37)

Item Statement (Abbreviated)	Area	M	SD
Discussing teaching strategies through digital platforms	PE	4.57	0.64
Creating simple digital learning media	DR	4.32	0.81
Facilitating collaboration among learners	TL	4.27	0.60
Developing and administering digital assessment	AS	4.27	0.72
Using online learning resources for self-development	PE	4.24	0.63
Modifying existing digital learning resources	DR	4.22	0.70
Actively engaging learners in learning	EL	4.22	0.62
Searching for and selecting relevant digital learning resources	DR	4.19	0.56
Accommodating learners' diverse learning needs	EL	4.19	0.65
Encouraging learners' learning independence	EL	4.16	0.59
Guiding safe use of digital devices	FL	4.16	0.59
Encouraging creative use of digital technology	FL	4.16	0.59
Selecting platforms suited to learners' characteristics	TL	4.14	0.78
Providing fast, personalized digital feedback	AS	4.14	0.74
Teaching critical evaluation of digital information	FL	4.11	0.69
Understanding and applying ethics in the use of digital resources	DR	4.08	0.71
Documenting/sharing teaching experience digitally	PE	4.05	0.70
Managing digital learning and technical obstacles	TL	4.05	0.70
Analyzing digital assessment results for learning needs	AS	4.00	0.84
Designing learning activities with meaningful digital integration	TL	3.97	0.72

Source: primary data, processed (2026). Area codes: PE = Professional Engagement; DR = Digital Resources; TL = Teaching and Learning; AS = Assessment; EL = Empowering Learners; FL = Facilitating Learners' Digital Competence.

The item with the highest achievement is the ability to discuss teaching strategies through digital platforms (M = 4.57, SD = 0.64), well above the overall average. This finding is consistent with the pattern that professional communication through digital media is the form of technology use most familiar to the current generation of pre-service teachers, who as members of Generation Z have grown up embedded in digital communication environments (Putri, 2024), in line with the professional engagement area being consistently reported as the strongest area across studies of pre-service teachers' digital competence (Zhang, Yang, & Zheng, 2026). The second-strongest item, creating simple digital learning media (M = 4.32, SD = 0.81), points in the same direction, echoing prior work showing that pre-service teachers readily adopt interactive digital media once basic design principles are modeled explicitly during instruction (Putri, 2025).

Two items occupy the weakest positions: designing learning activities that integrate digital tools in a meaningful, non-decorative way (M = 3.97, SD = 0.72), and analyzing digital assessment results to identify learners' learning needs (M = 4.00, SD = 0.84). These two items share a fundamental similarity in that they demand a high level of integration among technological mastery, pedagogical understanding, and the interpretation of learning data, rather than merely the technical ability to operate an application, a distinction made explicit in the Technological Pedagogical Content Knowledge framework (Mishra & Koehler, 2006). This gap mirrors evidence that elementary teachers often struggle to move fluidly between lower-order and higher-order thinking demands when integrating technology into their lessons, a navigation problem central to translating technical skill into pedagogically meaningful practice (Putri, 2026a).

This pattern of weakness in the pedagogical-integration and assessment-analysis items reinforces findings among pre-service English teachers in Indonesia, who likewise found reflective practice and assessment analysis to be

weak points despite an overall achievement level considered adequate (Sumarni, Iskandar, & Santosa, 2023). The same pattern has also been reported in a systematic review spanning a decade of research on pre-service teachers' digital competence, which concluded that the most consistent weakness among pre-service teacher populations across countries lies not in basic technical skills but in the ability to create digital content and integrate it pedagogically into learning activities (Zhang, Yang, & Zheng, 2026). The consistency of this pattern across different contexts, whether by country, teacher education level, or subject taught, indicates that the gap in the pedagogical-integration item is fairly universal and not specific to any single study program, making it a relevant priority for digital competence strengthening programs across teacher education institutions, including the elementary teacher education program that is the context of this study.

More specifically within the context of mathematics, the same weakness pattern has consistently been found in research on pre-service mathematics teachers across countries. A study of pre-service mathematics teachers taking a TPACK-based teaching practicum course found that designing lessons that genuinely integrate technology into students' mathematical reasoning is far more challenging than merely operating mathematical software (Bueno & Niess, 2023). A similar difficulty has been reported among novice mathematics teachers, who tend to use digital technology only as an administrative aid rather than as a tool for developing students' mathematical reasoning (Stein, Gurevich, & Gorev, 2019). In the area of digital assessment, a TPACK observation instrument for mathematics teachers showed that the ability to interpret technology-assisted assessment data to adjust mathematics teaching strategies is consistently the lowest-scoring TPACK component compared with other components (Njiku, 2024), consistent with the weakest-item finding in this study.

Exploring Differences in Achievement Based on Respondents' Region of Origin

The distribution of respondents' regions of origin in this study is far more diverse than in the previous data collection stage, covering the Bojonegoro and surrounding area cluster (n = 9), other parts of East Java (n = 7), East Nusa Tenggara/Soe-South Central Timor (n = 8), Toraja (n = 4), other parts of Sulawesi (n = 4), and other regions outside these four clusters (n = 5). Table 3 presents the mean composite score for each cluster.

Table 3. Composite Digital Competence Scores by Regional Cluster of Origin (N = 37)

Regional Cluster of Origin	n	M	SD
East Nusa Tenggara (Soe/SCT)	8	4.34	0.52
Bojonegoro	9	4.24	0.56
Other East Java	7	4.21	0.37
Other Sulawesi	4	4.19	0.52
Other Regions	5	3.98	0.49
Toraja	4	3.86	0.17

Source: primary data, processed (2026).

The highest composite score was found in the East Nusa Tenggara cluster (M = 4.34) and the lowest in the Toraja cluster (M = 3.86), a gap that appears fairly large at first glance. A one-way ANOVA across the six clusters found no statistically significant difference, $F(5, 31) = 0.64$, $p = .675$, with a partial eta-squared of .09, classified as a small-to-medium effect according to common effect-size conventions for ANOVA (Creswell & Creswell, 2018). This result means that the variation in achievement between regional clusters in this sample still falls within a range explainable by random variation between individuals rather than by a systematic difference related to region of origin. The Toraja and Other Regions clusters have small sample sizes (n = 4 and n =

5), so the averages for these two clusters remain sensitive to the influence of particular individual scores and should be read with caution. This exploration should be repeated once the number of respondents in each regional cluster increases, so that a conclusion about whether a regional difference exists can be drawn more convincingly.

Implications for Designing a Digital Competence Strengthening Program in Mathematics Learning

The item-level findings provide more precise direction than findings at the area level alone. The strong foundation seen in the professional-communication and simple-media-creation items shows that a strengthening program does not need to allocate much time to these basic technical skills, and can instead focus directly on the two weakest items, namely designing meaningful digitally integrated learning activities and analyzing digital assessment results. This recommendation aligns with the suggestion that developing teachers' digital competence needs to involve authentic activities that give direct opportunities to design and practice technology integration, rather than mere application-use training separated from pedagogical context (Momdjian, Manegre, & Gutiérrez-Colón, 2024).

For the elementary teacher education program, these findings can be translated concretely into the elementary mathematics learning course. Designing meaningful digitally integrated learning activities, for instance, can be practiced through assignments that require designing GeoGebra-assisted explorations of geometry or number patterns in which students must explain the pedagogical reasoning behind their choice of digital representation, as recommended in research on pre-service mathematics teachers learning to design polygon lessons with GeoGebra (Kartal & Çınar, 2024) and in a study of students' digital literacy in GeoGebra-based mathematics learning in the Indonesian context (Wahyuni, Fauzan, Yerizon, & Musdi, 2022). The ability to analyze digital assessment results can be practiced through assignments that

require interpreting real digital numeracy assessment data to plan instructional follow-up, rather than merely reading score reports, in line with the finding that interpreting technology-assisted assessment data is the mathematical TPACK component most in need of strengthening (Njiku, 2024) and that strengthening pre-service mathematics teachers' self-efficacy in technology integration contributes to the quality of their pedagogical decisions (Li, 2024). Contextual teaching materials with digital content developed for a pre-service teacher contextual mathematics course (Fiangga, Kohar, Palupi, Ekawati, & Setianingsih, 2022) can serve as one reference model for this kind of assignment.

CONCLUSION

Data from 37 pre-service elementary teachers in the Elementary Teacher Education Program at Universitas Negeri Surabaya, a number that has exceeded the sample target of 30, show that overall digital competence falls into the high category (M = 4.18, SD = 0.50). The item-level analysis reveals that the item on discussing teaching strategies through digital platforms has the highest achievement, while the items on designing meaningful digitally integrated learning activities and analyzing digital assessment results are the two weakest items. An exploration of differences between respondents' regions of origin through a one-way ANOVA found no statistically significant difference, so digital competence in this sample cannot be said to be strongly related to respondents' region of origin.

The main recommendation from this study is that digital competence strengthening programs for pre-service elementary mathematics teachers should prioritize activities that train meaningful pedagogical integration in mathematics learning, such as designing GeoGebra-assisted explorations, and the analysis of digital numeracy assessment results, rather than focusing on basic technical skills that are already well mastered. For future researchers, it is recommended to increase the size of each regional cluster so that the

exploration of regional differences can be tested more convincingly, and to complement this quantitative data with in-depth interviews of respondents with the lowest achievement on the two weakest items to understand the specific causes behind these difficulties.

This study has limitations in its convenience sampling technique, which restricts the generalization of the findings, the uneven size of regional subgroups, which makes the ANOVA result exploratory rather than confirmatory, and its reliance on self-report data, which carries a risk of social desirability bias. Further research is advised to consider triangulation through direct observation of teaching practice or analysis of the lesson plan documents prepared by respondents, particularly to verify achievement on the two lowest-scoring items.

Declarations

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