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SCIENCE LEARNING IN ANSWERING DIGITAL COMPETENCY NEEDS OF PRE-SERVICE MATH AND SCIENCE TEACHERS IN THE STEM CONTEXT

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ABSTRACT

These study purposes are to map the digital competency of pre-service math and science teachers and investigate how science learning can answer the challenge of digital competencies (DigComp) needs. This research used Rasch Model analysis to make knowledgeability mapping of the subject and analyzed using Wright map output by Winsteps 5.3.4. Data was gathered from a survey of 328 pre-service teachers of science majors, e.g., Biology, Chemistry, Geography, or Math, using the DigComp Framework-Based Questionnaire (DFBQ). The responses were based on respondents' diverse demographic profiles (gender, region, living area, and field of study). The findings identify several differences in teacher training students' knowledgeability of digital competencies that the Wright map in the Rasch model can map. Knowledgeability mapping is essential to determine which part of DigComp still needs to be strengthened with science education in the context of Science, Technology, Engineering, and Mathematics (STEM) implementation. The study yields two main conclusions: 1) The mapping study of pre-service math and science teachers' knowledgeability in the DigComp framework shows *Logit Value Person* (0.31<LVP<1.11) and *Logit Value Item* (LVI > 0.66 logits); (0 ≥ LVI ≥ 0.66) that are reflecting a middle to lower level of competency, and 2) Science learning has high potential to address this challenge through its learning strategy implementations. The findings can be recommendations for future research of knowledgeability mapping and policy development and discuss implications for digital competency framework practices.

Keywords: decision-making; digital competency; mapping; pre-service teachers; Rasch analysis

INTRODUCTION

A close relationship exists between science learning and digital technology toward 21st-century skills mastery. Science learning is prominent to STEM-based learning (Science, Technology, Engineering, and Mathematics), an enormous worldwide education program in recent years (Aldahmash et al., 2019; Nugroho et al., 2019). Therefore, the current education, in addition to emphasizing ethics and manners, also emphasizes the mastery of STEM. STEM, as a global 21st-century education agenda, cannot be separated from the quality of teacher training education. It is because the graduates from this institution will educate the younger generation to be more prepared and responsive to the challenges of 21st-century life.

Accordingly, science teacher education is an integral part of the flourishing of future generations through STEM learning and digital-based education (Larkin & Miller, 2020; Yordanova et al., 2020). As a result, many nations are developing national and international policies to enhance and promote their citizens' digital competencies at every level and field (Ferrari, 2013;

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Carretero et al., 2017). Especially for pre-service teachers in mathematics and science, graduates are expected to be able to apply STEM-based education and be digitally competent (Yordanova et al., 2020; Mystakidis, 2021).

Therefore, applying a digital competency framework has become a critical concern in national and international policies in European Union countries nowadays (Ilomäki et al., 2016). However, some research on pre-service teachers' digital progress shows insufficient integration of digital technology with learning-teaching processes (Instefjord & Munthe, 2015). These future teachers will teach students who are the "native technology" and the generation that grew up with disrupted conditions in the use of technology due to a pandemic that has changed the way of teaching and learning (Thomas & Rogers, 2020; Awaludin et al., 2023). To this end, pre-service teachers must receive digital literacy training to elevate their skills in this important part of the future education challenge (Cano et al., 2018).

Exploring further into the implementation of the DigComp framework at educational institutions, to the best of our knowledge, there have been limited studies that map the potential digital competencies of pre-service teachers at a national level with diverse respondents and significant sample size. Previous research on digital competency has been more focused on partial aspects, such as the application of specific digital competencies in a particular field (Blaženka, 2022), measuring the application of DigComp areas for teachers and students (Kuzminska et al., 2018), or examining the correlation factors between DigComp areas (Falloon, 2020). Therefore, further investigation is still required to measure the level of digital competency among pre-service teachers (in the teacher preparation phase) from various academic departments (STEM context) with a broader scope of research subjects at the national level, considering different demographic factors, to enable quantitative generalization of the findings.

Therefore, the level requires stages from initial preparation to implementation. According to Benavides et al. (2020), at least five stages are needed to carry out digital transformation in an institution, starting from planning, application, developing human resource competencies, integration, and transformation. This study is an early stage of digital transformation in a private university network environment with 14 Muhammadiyah universities to map the potential that can be encouraged and the weaknesses that need to be found for improvement solutions.

An investigation is severely needed to map the knowledge and practices of thousands of pre-service teachers in many provinces in Indonesia with diverse demographic backgrounds. From this standpoint, the investigation aims to gain a brief map of competency among pre-service math and science teachers within private universities as a pre-requisite for developing a program to improve the digital competency of pre-service teachers. This research projection results in a model for the potential mapping of pre-service math and science teachers and the basis for decision-making in developing digital competency programs for pre-service teachers in other countries.

This study highlights mapping the undergraduate pre-service science teacher's knowledge and practice of digital competency in diverse demographic backgrounds and how science learning could cope with the challenges of the digital competency requirements. It adds fresh insights to fundamental knowledge, which may be utilized to design policies and programs for teacher training institutions to allow graduates to acquire the elements of digital competency. The study's recommendations will assist teacher training institutes that intend to strengthen their graduates' digital competencies in terms of utilizing STEM in pre-service teacher education.

The terminology of digital competency is increasingly becoming the subject of research and discussions (Nouri et al., 2020). Because of the rapid growth and implementation of digital technology in numerous industries, the term is developing and frequently interchanged with other notions such as digital, technology, or media literacy (Ilomäki et al., 2011). Therefore, Ilomäki et al. (2016) emphasize that digital competencies are more than skills; the term competence refers to not just knowledge and abilities, but also the social and emotional aspects of utilizing and comprehending digital technology. Everyone agrees that having access to and using technology is no longer as important as using it in meaningful ways for life, work, and learning (Al-Abdullatif & Gameil, 2020).

According to Falloon (2020) and Carretero et al. (2017), the framework for these digital competencies continues to be developed for specific segments of European Union citizens, which are: a) Digital competence for citizens (Carretero et al., 2017), b) Digital competence framework for educators (DigCompEdu) (Redecker, 2017), c) DigComp for educational organizations (DigCompOrg), and d) DigComp for consumers (DigCompConsumers) (Carretero et al., 2017). DigComp and DigCompEdu are frameworks that serve as this study's theoretical foundation and further implementation. DigComp for citizen's framework is being developed to assist in shaping policies to promote the digital skills of persons of all ages (Hazar, 2019).

The framework is divided into five competencies: (1) data and information literacy, (2) communication and collaboration, (3) digital content production, (4) safety, and (5) problem-solving (Ferrari, 2013). Due to the growing rate of demand change, educators now require a broader and more sophisticated range of competences than in the past (Redecker, 2017). Because pre-service teachers' digital skills are the most essential aspect of this study, the training and data analysis parts do not focus on "facilitating learners" or how to help students enhance their digital skills. DigCompEdu, on the other hand, categorizes educators' digital skills and presents explanations and areas for pedagogical and professional practices related to integrating technology in teaching and professional careers (Ghomi & Redecker, 2019). DigCompEdu also recommends six digital skills areas for educators at all levels, from preschool to college: professional engagement, teaching and learning, digital resource teaching, evaluation, empowering learners, and enabling learners' digital competence (Ghomi & Redecker, 2019).

Pre-service teachers' digital competencies differ from those of other people since their primary focus is on how digital technology can be used for teaching (Røkenes & Krumsvik, 2014). Krumsvik (2014) describe digital competence for pre-service teachers as "proficiency of applying digital technologies with sound pedagogic-didactic judgments and awareness of the implications of these technologies for learning strategies and the digital culture of students." Thus, expertise is required. Digital competences involve facilitating the student's learning process and engaging in all procedures that lead to information configuration in the definitions (Instefjord & Munthe, 2017).

There are differences between the digital skills pre-service teachers learn in school and the digital skills they may need in their careers (Krumsvik, 2014). According to studies on how pre-service teachers improve their digital skills, they need to be adequate in integrating digital tools with learning and teaching (Instefjord & Munthe, 2017). According to Voogt et al. (2013), the digital competencies pre-service teachers gain through their teacher education programs impact how they use digital technology in their classrooms. Therefore, experts argue that teacher preparation programs should emphasize generic digital abilities more (DigComp) than the one for educators (DigCompEdu) as a framework (Gudmundsdottir & Hatlevik, 2018). So, in this study, the DFBQ is developed based on the DigComp for citizen framework instead of the DigCompEdu.

Meanwhile, according to Setyaningsih et al. (2022), STEM-based education in its application can collaborate with learning models such as Problem-Based Learning (PBL) and Project-Based Learning (PjBL), thus giving rise to innovative learning methods. Huang et al. (2022) emphasize the relevance of STEM Literacy in higher education by categorizing it into three dimensions: STEM knowledge, STEM abilities, and STEM skills. These three dimensions are elaborated as the definition of STEM literacy as sustaining 21st-century skills such as problem-solving competency, social communication skills, technology and engineering skills, system skills, and knowledge management skills as critical competencies for STEM workers (Huang, 2022).

The fundamental concept of the STEM application intersects with the key framework of Digital competency, such as digital content creation skills, digital communication and collaboration, and problem-solving. The result shows a close correlation between STEM and Digital competency, which is becoming a trend in graduate professionalism programs in higher education institutions (Toto et al., 2021).

There are few previous studies on Digital competency mapping or related sub-topics of STEM. Adams et al. (2018) investigate student readiness to implement e-learning at private campuses in Malaysia using the Rasch model analysis. Adams et al. (2021) also map students' readiness at a state campus in Malaysia for applying Blended learning as well as with the Rasch Model analysis. Meanwhile, Karunaweera (2021) conducts an exploratory study to map digital competency among pre-service English teachers in Sri Lanka.

However, to our knowledge, previous studies have yet to map these studies for cross-university digital competency of pre-service teachers from various science departments in 14 different provinces in Southeast Asia's largest archipelago country with high diversity, like this study. Therefore, this study investigates how science learning can answer the challenge of digital competencies (DigComp) needs for pre-service math and science teachers.

METHODS

This study conducted the Rasch Model Analysis, a quantitative approach to evaluate the instrument's ability to mimic the characteristics of basic measurement (invariance and uni-dimensionality) and function as a tool for quantifying non-observable human conditions and interaction between research measurement instruments and humans (Boone et al., 2014; Khine, 2020) to map the pre-service Mathematics and Science teachers' knowledgeability of digital competencies. The following subsections describe the details of the study through the questionnaire survey method.

A cross-sectional quantitative survey method was used in this part. A sample came from 333 undergraduate pre-service Math and Science teachers from various fields of study from teacher training faculties in private Universities/Higher Education Institutions (HEI) on five big islands in Indonesia (Java, Sumatera, Kalimantan, Nusa Tenggara, and Sulawesi) during the academic year 2021-2022. A convenience sampling technique was used with digital form questionnaires. Concerning ethical considerations, prior to completing the questionnaire, the students' consent to participate in this study was obtained. Participation was entirely voluntary and confidential.

The Digital Competency Framework-based Questionnaire (DFBQ) was used to collect data via an online questionnaire (Hidayat et al., 2023). The DFBQ was created primarily with the DigComp framework for people and the digital literacy framework provided by the Indonesian Minister of Information and Communications (Syarifudin et al., 2021). The DFBQ included four basic demographic questions (gender, year of study, field of study, and region) as well as 36 items divided into five categories that addressed various aspects of pre-service teachers' digital abilities, as shown in Table 1. Area I consists of five items, area II seven items, area III six, area IV nine, and area V nine items.

Table 1. General Description of Competence Areas for Digital Competency (Carretero et al., 2017)

Areas	General description
Data and Information Literacy	Find and identify the relevant data, information, and digital assets. Information, data, and digital material can be filtered, analyzed, evaluated, interpreted, organized, and stored.
Communication and Collaboration	Work with others and share information, data, and material utilizing digital technologies. Utilize public and private digital services to interact and participate in communities, comprehend social norms connected to digital technology, and build and maintain various digital identities.
Digital content creation	Create and edit novel digital material in various forms, include and revise earlier works, comprehend the use of intellectual property rights and licenses, and address issues through writing computer system programs.
Safety	Recognize risks and threats in digital settings, secure digital tools and content, safeguard personal information and privacy, prevent physical and psychological risks when using digital technologies, and be aware of the environmental implications of such use.
Problem-solving	Use digital resources to locate and fix problems by applying innovative methods. The process of producing commodities and data uses digital tools and technology. Determine and enhance the need for digital competency.

All obtained data was converted to an Excel sheet file and validated and cleaned using WINSTEPS version 5.3.4, a Rasch measurement model program. Outlier replies (all maximum or minimum scores) were submitted by 33 respondents. Following that, data cleaning was undertaken to identify respondents' consistency in answering, and five deviating responses were received from the respondents. After the outliers were removed from the data, the final number of responders was 328. Table 2 shows the demographic profile of the respondents.

Table 2. Demographic Profile of Respondents (N= 328) after Data Cleaning

Variable		Freq.	%
Gender	Male	55	16.5
	Female	273	83.5
	N	328	100
Department of Education	Mathematics	94	28.7
	Biology	80	24.4
	Chemistry	18	5.4
	Geography	7	2.1
	Science for Primary School	118	35.8
	Science for Secondary School	12	3.6
	N	328	100
Living Area	Village	202	61.6
	Sub-urban	30	9.1
	City	96	29.3
	N	328	100
Origin of Region	Java	249	75.9
	Kalimantan	4	1.2
	Sumatera	33	10.1
	Sulawesi	10	3.1
	Nusa Tenggara	29	8.8
	Papua	3	0.9
	N	328	100

The Rasch model analysis is appropriate for analyzing human opinions, perceptions, and attitudes by measuring latent qualities (Rusland et al., 2020). It offers numerous statistical analyses, including descriptive analysis, Chi-square (χ^2), unidimensionality of rating scale, person and item reliability, and Cronbach Alpha.

The Rasch model's descriptive analysis revealed participants' perceptions of knowledge and practice. Chi-square (X2) identified the significance level among the questionnaire statements in DFBQ. The unidimensionality rating scale was performed to evaluate the capability of the instrument being developed and whether it can be measured. The person reliability index indicated the consistency of personal responses, and item reliability indicated whether the instrument could define the latent variable well. Lastly, Cronbach Alpha described the interaction quality between the persons and the items (Bond & Fox, 2007).

The Rasch measurement model analyzed the data using WINSTEPS software (this study used the 5.3.4 version). By calibrating item difficulty and personal abilities, the WINSTEPS software mathematically processed raw ordinal (Likert-type) data. The transformation was based on the frequency of response, which presented as probability, to logit (log odd unit) via the logarithm function, which assessed overall instrument and person fit (Adams et al., 2018). Later, using the same unit scale, scaled logit (logarithm odd unit), a measurement model was calibrated using conjoint measurement to assess the correlation between the item difficulty level and the person's ability (Linacre, 2011). The results and outcomes are discussed in the following section.

Table 3. Reliability of Person and Item (*p < 0.01)

N	Person	Item
	328	36
Mean	1.42	0.00
SD	1.11	0.66
SE	0.06	0.11
Separation	3.74	7.83
Reliability	0.93	0.98
Cronbach's Alpha	0.94	
Raw variance	43.8%	
Chi-Square (X^2)	84137.13	

RESULTS AND DISCUSSION

The section consists of two parts: results and analysis of this study, which are presented in three tables, and a discussion that tries to solve DigComp's need through science learning implementation in teacher training institutions.

First, Table 3 describes the results of the statistical summary of the Rasch analysis for persons and items. Table 4 depicts the item difficulty levels obtained from mapping using the Wright item map, which divides the difficulty levels into four levels from the hardest to the easiest. Meanwhile, Table 5 provides an overview of the level of knowledgeability (in logit units) of respondents (person) through the Wright map for persons in the Rasch Model. This person map divides all respondents again into four categories based on the mean and standard deviation ranges from Table 3.

Table 3 lists the person reliability index (0.93), which indicates the consistency of person responses is 'very good' and implies that the scale discriminates very well between persons. The same interpretation logic applies to the Item Reliability measures of 0.98, also classified as 'very good.' It suggests that the probability of persons responding to items is likely high. High item reliability estimation indicates that the items define the latent variable very well (Bond & Fox, 2007). The DFBQ may be regarded as a reliable instrument for use with different groups of respondents.

Table 3 shows the high value of the Cronbach Alpha coefficient = 0.94, describing the interaction between the 328 persons and the 36 items. A reliability score of 1.00 is classified as 'Excellent' as defined under the instrument quality criteria (Sumintono, 2018). This score suggests a high level of interaction between the persons and items. An instrument with good psychometric internal consistency is considered highly reliable.

The person separation index in Table 3 estimates how well the DFBQ can distinguish between 'Person abilities' in the latent trait. The bigger the separation index, the more likely the respondents will respond correctly to the items. On the other hand, the item separation index indicates how widespread the items are in defining both the easy and hard items (Boone, 2016). The wider the spread means, the better the fit. In this study, the Person Separation index = 3.74 and the Item Separation index =7.81, as shown in Table 3, clearly indicate the DFBQ's good spread across respondents and the items. These criteria endorse the DFBQ as a fit and reliable instrument for identifying pre-service teachers' knowledge perception with the digital competency framework.

The items are classified according to their difficulty level or *Logit Value of the Item* (LVI). The classification of the items is split into four difficulty levels by dividing the distribution of the item logit scores based on mean and standard deviation values. Table 4 lists that there are 7 items (19.4%) in the category of very hard level with respondents (LVI > 0.66 logits). In the second category, which is hard level with (0 ≥ LVI ≥ 0.66), there are 17 items (47.3%); in the following category, which is medium difficulty with by respondents (-0.66 ≥ LVI ≥ 0.0), there are also 12 items (33.3%), and lastly, 0 item (0%) falls into the difficult category which is easy with the respondents (LVI < - 0.66 logit).

Table 4. Item Classification According to the Difficulty Level (LVI)

	Construct/ Dimension					
Difficulty Level	**Data and Information Literacy**	**Communication and collaboration**	**Content Creation**	**Safety**	**Problem-solving**	**N**
Very hard		B4, B6	C4, C5, C6	D4	E7	7
Hard	A1, A2	B3, B5	C2, C3	D8, D9, D5	E2, E3, E5, E6, E9, E1, E4, E8	17
Medium	A3, A4, A5	B1, B2, B7	C1	D3, D1, D6, D7		12
Easy						0

Based on the mean and standard deviation of the person logit from the Rasch measurement (see Table 3), the students can be categorized into four levels of knowledgeability in DigComp (from very high to low level) by the demographic profile of students and its *Logit value of person* (LVP) (Bond & Fox, 2012). The categorization of LVP into these four categories is based on constraints formed from five Likert scale treatments based on the Rasch Model. For instance, the 'very hard level' LVP category is formed by the upper limit of Mean: 1.42 logits, the 'hard level' category is formed between 1.11 logits (SD) and 1.42 logits (mean). Therefore, LVP is categorized into four levels: very hard-level LVP $\geq$ 1.42 logit, hard level 1.11<LVP<1.42 logit, medium level 0.31<LVP<1.11 logit, and Low-level LVP$\leq$ 0.31 logit.

At the beginning of the discussion, one of the research's objectives is to map the competency of pre-service science teachers from the Department of Mathematics, Biology, Chemistry, Geography, and Science for primary and secondary school in teacher training institutions in Indonesia. Each department has specific characteristics, even those in a similar science cluster. The mapping study also considers the respondents' knowledgeability in digital competency based on gender, region, and living area. This mapping is essential because it can be a big picture for consideration in decision-making to improve the digital skills of these pre-service science teachers (Biedermann et al., 2019). It is considered that digital competence and STEM correlate, and it is a priority on the agenda of various international organizations, including higher education institutions (HEI) (Lucas, 2019).

This study's result shows that pre-service math and science teachers at these teacher training institutions have a medium level of knowledge about Digital Competency. This summary finding is related to a study by Dintoe (2018), which states that even though the average age of these students is between 19 and 23 (the age of Z generation, who are daily surrounded by digital technology), the ability to use proper digital technology tend to vary because of the differences in demographics factors, e.g., those who live in rural areas, the difference of economic condition of families who are at the lower middle level, and the availability of infrastructure affecting students' access and knowledgeability with learning technology (Adams et al., 2018). However, some details are interesting to discuss in the following paragraphs.

According to the first competency in the DigCom framework: Data and information literacy, the study shows that these pre-service teachers find it easy to recognize the truth of the information in cyberspace (mean logit score: -0.352). They are used to compare various sources of information to decide whether the information is valid. This finding aligns with the report by Nielsen et al. (2015) that the science learning curriculum at the university is initially designed to make students learn about methods of taking valid and credible reference sources. The skill of taking valid and relevant resources in science learning could support the skill of the first competency of the Digital Competency. However, adjusting the search engine filter to identify relevant digital content by date recency, source validity (website or author), multimedia type, file format, or modifiability still needs to be improved for the respondents (A2). This 'search engine filtering' skill needs attention in process-based science learning designs, such as assignments and individual projects, so each pre-service teacher has more learning experience.

This survey analysis also shows results of a discrepancy regarding skills related to understanding copyright rules through search engine use (A5). The copyright rules are applied to digital resources they will use for lectures or personal purposes (images, text, audio, and film). This understanding of copyright still needs to be improved in Indonesia. This view is supported by Sudjana (2022), who reports on Indonesia's high piracy rate of works of art and intellectual property.

One of the reasons that can be seen from the results of this study is that pre-service teachers still need to gain knowledge about intellectual property (e.g., creative commons, copyright, copyleft, name credit, or trademark) from digital content they upload or download on the internet. The phenomenon regarding the importance of awareness of legal issues in the context of intellectual property among pre-service teachers is investigated by Kutsyuruba et al. (2019). Kutsyuruba's (2019) study on pre-service teachers in Canada states that it is determinant to design a curriculum or learning strategy for pre-service teachers so that they are concerned about the problem of violations of legality in the world of education. Literacy in legal issues, for instance, copyright, will provide reasonable provisions with respect for creativity, achievement, and honesty when they work as a teacher in the real world later.

Table 5. Respondents' Knowledgeability Level of DigComp based on Gender, Departments, Living Area, and Region (N= 328)

Variable	Separation factor	Very high LVP ≥ 1.42	High 1.11<LVP<1.42	Medium 0.31<LVP<1.11	Low LVP≤ 0.31	∑
Gender	Female	38 (11.59%)	84 (25.61%)	117 (35.67%)	34 (10.37%)	273
	Male	11 (3.35%)	14 (4.27%)	21 (6.40%)	9 (2.74%)	55
Department of Education	Mathematics	17 (5.18%)	23 (7.01%)	38 (11.59%)	16 (4.88%)	94
	Biology	12 (3.66%)	25 (7.62%)	39 (11.89%)	4 (1.22%)	80
	Chemistry	4 (1.22%)	7 (2.13%)	5 (1.52%)	2 (0.61%)	18
	Geography	-	3 (0.91%)	2 (0.61%)	2 (0.61%)	7
	Science for primary school	20 (6.10%)	37 (11.28%)	46 (14.02%)	15 (4.57%)	118
	Science for secondary school	5 (1.52%)	1 (0.30%)	6 (1.83%)	-	12
Living Area	Village	28 (8.54%)	66 (20.12%)	87 (26.52%)	21 (6.4%)	202
	Sub-urban	4 (1.22%)	11 (3.35%)	14 (4.27%)	3 (0.91%)	30
	City	15 (4.57%)	24 (7.32%)	39 (11.89%)	18 (5.49%)	96
Region	Java	35 (10.67%)	83 (25.30%)	104 (31.71%)	27 (8.23%)	249
	Kalimantan	-	2 (0.61%)	1 (0.30%)	1 (0.30%)	4
	Sumatera	4 (1.22%)	10 (3.05%)	16 (4.88%)	3 (0.91%)	33
	Sulawesi	1 (0.30%)	2 (0.61%)	2 (0.61%)	5 (1.52%)	10
	Nusa Tenggara	8 (2.44%)	4 (1.22%)	13 (3.96%)	4 (1.22%)	29
	Papua	-	1 (0.30%)	1 (0.30%)	1 (0.30%)	3

In science learning, the act of respect for this creativity is studied in the competence of scientific methodology (Ata & Yıldırım, 2019). Scientific methods in science learning can be integrated with digital competencies, including literacy regarding digital copyright awareness. In science learning, students learn to collect data, analyze information, and build arguments based on valid evidence. In this process, students must also understand how to access information ethically and responsibly (Leoste et al., 2022)

Information is easily found and accessed via the internet in the digital era. However, information found on the internet may only sometimes be reliable or may not be copyrighted. Therefore, students must be trained to understand digital copyright literacy, such as valid copyrights, licenses, and resources, to avoid copyright infringement (Wallan, 2020). Through digital technology in science learning, students can acquire skills and knowledge about digital copyright literacy more interestingly and interactively. Students can use digital resources, such as e-books or scientific articles in e-journals, to learn scientific concepts and understand how to respect copyright (Paragarino et al., 2014)

Secondly, the students view the communication and collaboration area competency as hard-level competencies. Competencies such as expressing thoughts and opinions through relevant social media by commenting on news articles, writing blogs, sharing social media posts, or actively participating in specific community/group networks (item B4) are at a hard level, according to pre-service teachers' perceptions.

How does science learning look at this challenge? In the science learning element, some learning strategies aim to improve students' ability to carry out digital communication and collaboration. For example, teachers can utilize Learning Management Systems (LMS), e-learning, collaboration with cloud documents, and interactive learning videos in science learning (Rubio-Hurtado et al., 2022). With digital collaboration-based learning with science material, students will get used to discussing, giving comments to each other, or working synchronously in the same media. It is similar to a study conducted by Hidayat et al. (2022), who ask science teachers to collaborate live remotely with cloud documents. The study finds that the research subjects gain new and practical collaboration experiences.

The following competency categorized as the very hard level is knowledgeability in Netiquette (B6). Netiquette refers to the rules and ethics that govern human behavior and interaction in the online world. Netiquette covers various aspects, such as using polite language, respecting the privacy of others, avoiding spamming and trolling, and complying with copyrights and intellectual property rights (Bartolomé & Garaizar, 2022). According to Soler-Costa et al. (2021), this netiquette is a fundamental pillar of social interaction in the digital world. It must be prepared for internet users, especially students, at personal, social, and professional levels.

Various aspects of science education can be incorporated with netiquette, including communication between teachers and students and inter-students in online activities such as discussion forums and research. It is essential to communicate with integrity and courtesy and to avoid cyberbullying and copyright infringement that need to be integrated into the learning curriculum, in this context, mathematics and science. It corroborates with a study by Iqbal et al. (2021), concluding that accrediting bodies and medical institutions should develop a policy regarding online etiquette. The time has come to incorporate netiquette practices into the undergraduate curriculum.

Thirdly, the content creation competency area needs more attention because students consider this area 'very hard' and 'hard' (only one item, C1, is categorized as a medium difficulty level) in the Digital Competency framework. Competency related to copyright is again some of the issues that arise. The pre-service teachers feel that when they upload or download digital content that is a type of intellectual property (e.g., creative commons, copyright, copyleft, name credit, or trademark), they need to understand the meaning and consequences of its use. Therefore, the respondents feel they need to be used to asking the copyright owner's permission before duplicating or distributing their work, whether for commercial purposes or not. This perception needs to be changed with education and training in the curriculum of teacher training institutions so that these competencies can be mastered (Ebner & Braun, 2020).

In contrast, some things can be understood related to the difficulties in digital content creation competencies, namely programming skills (item C6). Basic programming skills such as Macro, Excel, Java, Python, or PHP to solve a problem in a digital environment are mostly learned by pre-service teachers in the vocational or engineering departments (Informatics and engineering education).

Do pre-service teachers of mathematics and science need to learn programming? According to Heintz et al. (2017), programming learning can support science learning at teacher training institutions or tertiary institutions that offer teacher education programs. Programming learning can help them to learn science concepts more interactively and practically with activities such as developing applications, performing simulations and data analysis, and developing scientific models. Those activities can help students understand and apply science concepts more concretely and acquire the skills needed to apply science concepts in real situations (Kong et al., 2020).

Therefore, in the Safety dimension, based on item analysis with person (Table 3), the pre-service teachers perceive that they do not understand cyberbullying and know how to overcome or fight it if it happens to them or their students later (item D8). Knowledge about cyberbullying and how to deal with it needs to be understood by Generation "Z" because this incident is very vulnerable to anyone in the digital era. This finding corroborates the results of another study by Falloon (2020) that cyberbullying is a vulnerability in socializing in a digital environment (e.g., social media) because it can endanger the mental and physical health of the victim.

Another challenge for these respondents is that they need to understand the risks of cyberattacks on their devices (item D2). For example, they do not know the working principle of ransomware attacks, malware, adware, phishing, or privacy violations. These results reflect that information about security risks in the digital world needs to be understood by students who will use internet devices or media to teach their students in the future. This knowledge of the risks of cyberattacks can be beneficial for themselves and their future students. Finally, no less important, it turns out that this student still lacks an understanding of physical health guidelines when doing activities in a digital environment using their devices (D9)—for example, practicing duration restrictions, posture comfort, and screen position when using the device, and ergonomic factors.

These findings follow what Kusumaningrum and Raharya (2022) state that the readiness of universities, schools, and educational institutions in Indonesia still needs to improve in dealing with this cyber-attack or crime. Kusumaningrum and Raharya (2022) utilize the Multi-Criteria Decision Analysis (MCDA) analysis to study the risk management of this cyber-attack among students and the Cybersecurity Vulnerability Behavior Scale Model to measure the level of this vulnerability. The result shows that student ratings are still vulnerable, with a scale of 3.3 out of 5. The study suggests that students are more concerned and consistent in maintaining their security and the digital environment from cyber-attacks, mainly because the habit of interacting, studying, and working online will still be intense after the pandemic.

Therefore, based on the results, the problem-solving competency area is the most challenging for all the pre-service math and science teachers in this digital environment. This is evidenced by the tendency of students to answer that these items are classified as hard and very hard. Tenacity and patience to solve problems that arise in software or hardware are challenging skills for them (item E2). Application settings on gadgets and the use of hotkeys to find efficient solutions in working in a digital environment, e.g., back (undo), search, screenshot, bold text, navigation, or zoom, are also less knowledgeable among pre-service teachers (item E3), who are demographically percentage of 83.5% of respondents are female. This finding is consistent with a report by Charlesworth et al. (2019). Their study on the gender gap in intent to major in STEM and non-STEM fields among U.S. colleges reveals that in the fields of Engineering and Computer science, men (20%) are more dominant than women (4%).

On the other hand, in the education sector, the ratio is 3%: 8% for men and women. However, what needs to be appreciated by these respondents is the willingness to improve and update their digital pedagogical competencies, for example, by trying tutorials from the internet independently or gaining knowledge from more skilled colleagues. However, in contrast, their willingness and ability to provide advice or tutorials through social media regarding the practice of learning innovation still need to be improved.

Lastly, the most unfamiliar skill of pre-service teachers in the problem-solving dimension is the ability to detect and abandon plagiarism (item E7). The results of this study also indicate that plagiarism still needs attention from stakeholders in Teacher Training Institutions because, once again, when they graduate and teach in schools, understanding and skills to detect plagiarism in the school environment, more specifically in science learning, are crucial. This finding is consistent with a study by Akbar & Picard (2019) that plagiarism inhibits creativity and innovation in Indonesia. Adiningrum (2015) adds that plagiarism occurs at the level of students and academics, ranging from ignorance and lack of skills related to problems to more severe behavior involving counterfeiting, financial rewards, and intentional cheating. Simultaneous action needs to be taken as a step to prevent and fight plagiarism. According to Adiningrum (2015), three recommendations are needed: strengthening detection, preventing plagiarism, and strengthening the university's anti-plagiarism system.

Regarding students' demographics, as shown in Table 3, the knowledgeability level of the respondents is at the 'medium' level or below the 'high' level. The result shows that most respondents still do not feel they understand and can apply competencies in the DigComp area. These results occur evenly across all variables: gender, department, living area, and region. If added up, the percentage is evenly distributed at the medium level ($0.31<LVP<1.11$), and low ($LVP<0.31$) always tends to be greater than the sum of the percentage levels of 'very high' ($LVP \geq 1.42$ logit) and 'high' ($1.11<LVP<1.42$).

CONCLUSION

The conclusions drawn from mapping the knowledgeability of digital competence among pre-service math and science teachers in Indonesia are as follows: 1) In broad terms, Rasch model analysis has successfully mapped the digital competence of the study subjects, namely pre-service math and science teachers, based on demographics and specific areas of digital competence; 2) The digital competence of the study subjects remains at a medium level, indicating the need for further enhancement through integrative teaching strategies and curricula; 3) Theoretical models and strategies commonly employed in science education can theoretically address the challenge of improving digital competence through integrative learning strategies between the Digital competency and science and math subjects; also 4) generating policies from stakeholders of educational institutions so that the implementation has a legal basis, including reward or sanction policy. However, this study has limitations in the uneven number of samples in each province and improvement in the questionnaire sampling technique so that the number of respondents is more evenly distributed with a more extensive and vast number.

REFERENCES

Adams, D., Sumintono, B., Mohamed, A., & Noor, N. S. M. (2018). E-learning readiness among students of diverse backgrounds in a leading Malaysian higher education institution. *Malaysian Journal of Learning and Instruction*, *15*(2), 227–256.

Adams, D., Tan, M. H. J., & Sumintono, B. (2021). Students' readiness for blended learning in a leading Malaysian private higher education institution. *Interactive Technology and Smart Education*, *18*(4), 515–534.

Adiningrum, T. S. (2015). Reviewing Plagiarism: An Input for Indonesian Higher Education. *Journal of Academic Ethics*, *13*(1), 107–120.

Akbar, A., & Picard, M. (2019). Understanding plagiarism in Indonesia from the lens of plagiarism policy: Lessons for universities. *International Journal for Educational Integrity*, *15*(1).

Al-Abdullatif, A., & Gameil, A. (2020). Exploring students' knowledge and practice of digital citizenship in higher education. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(19), 122-142.

Aldahmash, A. H., Alamri, N. M., Aljallal, M. A., & Bevins, S. (2019). Saudi Arabian science and mathematics teachers' attitudes toward integrating STEM in teaching before and after participating in a professional development program. *Cogent Education*, *6*(1).

Ata, R., & Yıldırım, K. (2019). Exploring Turkish Pre-Service Teachers' Perceptions and Views of Digital Literacy. *Education Sciences*, *9*(1), 40.

Bartolomé, J., & Garaizar, P. (2022). Design and Validation of a Novel Tool to Assess Citizens' Netiquette and Information and Data Literacy Using Interactive Simulations. *Sustainability (Switzerland)*, *14*(6).

Benavides, L. M. C., Arias, J. A. T., Serna, M. D. A., Bedoya, J. W. B., & Burgos, D. (2020). Digital transformation in higher education institutions: A systematic literature review. *Sensors (Switzerland)*, *20*(11), 1–23.

Biedermann, D., Kalbfell, L., Schneider, J., & Drachsler, H. (2019). Stakeholder attitudes towards digitalization in higher education institutions. *Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft Fur Informatik (GI)*, *P-297*.

Blaženka, B. S., & Martina, M. P. (2022). Digital Competencies in the Context of Preschool Music Education. *International Journal of Cognitive Research in Science, Engineering and Education*, *10*(2), 77-87.

Bond, T. G., & Fox, C. M. (2007). *Applying the Rasch Model: Fundamental Measurement in the Human Sciences Second Edition University of Toledo*.

Boone, W. J. (2016). Rasch Analysis for Instrument Development: Why, When, and How? *CBE Life Sciences Education*, *15*(4).

Boone, W. J., Yale, M. S., & Staver, J. R. (2014). Rasch analysis in the human sciences. In *Rasch Analysis in the Human Sciences*.

Cano, J., Domínguez, A., & Ricardo, C. (2018). Strengthen of digital competence of higher education students in virtual learning environments. *Espacios*, *39*(25), 35-44.

Carretero, S., Vuorikari, R., & Punie, Y. (2017). DigComp 2.1: The Digital Competence Framework for Citizens. With eight proficiency levels and examples of use. In *Publications Office of the European Union*.

Charlesworth, T. E.S., & Banaji, M. R. (2019). Gender in Science, Technology, Engineering, and Mathematics: Issues, Causes, Solutions. *The Journal of Neuroscience*, *39*(37).

Dintoe, S. S. (2018). Information and communication technology use in higher education : Perspectives from faculty Seitebaleng Susan Dintoe Memorial University of Newfoundland, Canada. *International Journal of Education and Development Using Information and Communication Technology*, *14*(2), 121–166.

Ebner, M., & Braun, C. (2020). *Emerging Technologies and Pedagogies in the Curriculum* (Issue January). Springer Singapore.

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*.

Ferrari, A. (2013). *DIGCOMP : A Framework for Developing and Understanding Digital Competence in Europe.*

Ghomi, M., & Redecker, C. (2019). Digital competence of educators (DigCompedu): Development and evaluation of a self-assessment instrument for teachers' digital competence. *CSEDU 2019 - Proceedings of the 11th International Conference on Computer Supported Education*, *1*.

Gudmundsdottir, G. B., & Hatlevik, O. E. (2018). Newly qualified teachers' professional digital competence: implications for teacher education. *European Journal of Teacher Education*, *41*(2), 214–231.

Hazar, E. (2019). A comparison between European digital competence framework and the Turkish ICT curriculum. *Universal Journal of Educational Research*, *7*(4), 954–962.

Heintz, F., Mannila, L., Nordén, L.-A., Parnes, P., & Regnell, B. (2017). Informatics in Schools: Focus on Learning Programming. *Informatics in Schools: Focus on Learning Programming. ISSEP 2017. Lecture Notes in Computer Science, Vol*

10696, *4*, 117–128.

Hidayat, M. L., Astuti, D. S., Hariyatmi, H., Prayitno, H. J., & Anif, S. (2022). Digital Collaboration Skills Training for Middle School Science Teachers in Central Java. *Warta LPM*, *25*(2), 263–274.

Hidayat, M. L., Hariyatmi, Astuti, D. S., Sumintono, B., Meccawy, M., & Khanzada, T. J. S. (2023). Digital competency mapping dataset of pre-service teachers in Indonesia. *Data in Brief*, *49*.

Huang, X., Erduran, S., Zhang, P., Luo, K., & Li, C. (2022). Enhancing teachers' STEM understanding through observation, discussion and reflection. *Journal of Education for Teaching*, *48*(5), 576–591.

Ilomäki, L., Kantosalo, A., & Lakkala, M. (2011). What is digital competence ? In *European Schoolnet* (Issue 2008).

Ilomäki, L., Paavola, S., Lakkala, M., & Kantosalo, A. (2016). Digital competence – an emergent boundary concept for policy and educational research. *Education and Information Technologies*, *21*(3), 655–679.

Instefjord, E. J., & Munthe, E. (2017). Educating digitally competent teachers: A study of integration of professional digital competence in teacher education. *Teaching and Teacher Education*, *67*, 37–45.

Instefjord, E., & Munthe, E. (2015). Preparing pre-service teachers to integrate technology : an analysis of the emphasis on digital competence in teacher education curricula. *European Journal of Teacher Education ISSN: October*.

Iqbal, S., Hanif, R., Ali, F., Tahir, M., Minhas, R., Yasmeen, R., Khokhar, A., & Laique, T. (2021). Teachers' Perceptions of Netiquette Practices by Undergraduate Dental Students During Online Classes in Covid-19 Pandemic. *Pakistan Journal of Medical and Health Sciences*, *15*(12), 3498–3500.

Karunaweera, A. S. (2021). Measuring digital competence: an exploratory study mapping digital competence profiles of Sri Lankan English language teachers. *Asia Pacific Journal of Educators and Education*, *36*(1), 93–112.

Khine, M. S. (2020). Rasch measurement: Applications in quantitative educational research. In *Rasch Measurement: Applications in Quantitative Educational Research*.

Kong, S. C., Lai, M., & Sun, D. (2020). Teacher development in computational thinking: Design and learning outcomes of programming concepts, practices and pedagogy. *Computers and Education*, *151*(March), 103872.

Krumsvik, R. J. (2014). Teacher educators' digital competence. *Scandinavian Journal of Educational Research*, *58*(3), 269–280.

Kutsyuruba, B., Murray, J., & Hogenkamp, S. (2019). *Understanding Pre-Service Teachers' Legal Literacy and Experiences with Legal Issues in Practicum Settings: An Exploratory Study*.

Larkin, K., & Miller, J. (2020). STEM Education Across the Learning Continuum. In *STEM Education Across the Learning Continuum*. Springer Singapore.

Leoste, J., Lavicza, Z., Fenyvesi, K., Tuul, M., & Õun, T. (2022). Enhancing Digital Skills of Early Childhood Teachers Through Online Science, Technology, Engineering, Art, Math Training Programs in Estonia. *Frontiers in education*, *7*.

Linacre, J. M. (2011). *Winsteps Help for Rasch Analysis*.

Lucas, M. (2019). Facilitating Students' Digital Competence: Did They Do It?. In *Transforming Learning with Meaningful Technologies: 14th European Conference on Technology Enhanced Learning, EC-TEL 2019, Delft, The Netherlands, September 16–19, 2019, Proceedings 14* (pp. 3-14). Springer International Publishing.

Mystakidis, S. (2021). A systematic mapping review of augmented reality applications to support STEM learning in higher education. *Education and Information Technologies*.

Nouri, J., Zhang, L., Mannila, L., & Norén, E. (2020). Development of computational thinking, digital competence and 21st century skills when learning programming in K-9. *Education Inquiry*, *11*(1), 1–17.

Nugroho, O. F., Permanasari, A., & Firman, H. (2019). The movement of stem education in Indonesia: Science teachers' perspectives. *Jurnal Pendidikan IPA Indonesia*, *8*(3), 417–425.

Paragarino, V. R., Barujel, A. G., & Nistal, M. L. (2014). Use of repositories of digital educational resources in higher education. *ACM International Conference Proceeding Series*, *10-12-September-2014*.

Redecker, C. (2017). *European Framework for the Digital Competence: DigComEdu*. https://moodle.ktu.edu/pluginfile.php/428841/mod_resource/content/1/pdf_digcomedu_a4_final.pdf

Røkenes, F. M., & Krumsvik, R. J. (2014). Development of student teachers' digital competence in teacher education. *Nordic Journal of Digital Literacy*, *2014*(4), 250–280.

Rubio-Hurtado, M. J., Fuertes-Alpiste, M., Martínez-Olmo, F., & Quintana, J. (2022). Youths' Posting Practices on Social Media for Digital Storytelling. *Journal of New Approaches in Educational Research*, *11*(1), 97–113.

Rusland, S. L., Jaafar, N. I., & Sumintono, B. (2020). Evaluating knowledge creation processes in the Royal Malaysian Navy (RMN) fleet: Personnel conceptualization, participation and differences. *Cogent Business and Management*, *7*(1), 0–25.

Setyaningsih, E., Agustina, P., Anif, S., Ahmad, C. N. C., Sofyan, I., Saputra, A., Salleh, W. N. W. M., Shodiq, D. E., Rahayu, S., & Hidayat, M. L. (2022). PBL-STEM Modul Feasibility Test for Pre-service Biology Teacher. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, *4*(2), 118–127.

Soler-Costa, R., Lafarga-Ostáriz, P., Mauri-Medrano, M., & Moreno-Guerrero, A. J. (2021). Netiquette: Ethic, education, and behavior on internet—a systematic literature review. *International Journal of Environmental Research and Public Health*, *18*(3), 1–15.

Sorokova, M. G. (2020). E-course as blended learning digital educational resource in university. *Psychological Science and Education*, *25*(1), 36–50.

Sudjana, S. (2022). The Effectiveness of Combating Piracy of Copyright In The Perspective Of The Legal System. *Res Nullius Law Journal*, *4*(1), 77–99.

Sumintono, B. (2018). *Rasch Model Measurements as Tools in Assessment for Learning*. *173*(Icei 2017), 38–42.

Thomas, M. S. C., & Rogers, C. (2020). Education, the science of learning, and the COVID-19 crisis. *Prospects*, *0123456789*, 1–4.

Toto, T., Yulisma, L., & Amam, A. (2021). Improving teachers' understanding and readiness in implementing stem through science learning simulation. *Jurnal Pendidikan IPA Indonesia*, *10*(2), 303–310.

Voogt, J., Erstad, O., Dede, C., & Mishra, P. (2013). Challenges to learning and schooling in the digital networked world of the 21st century. *Journal of Computer Assisted Learning*, *29*(5), 403–413.

Yordanova, M., Eited, K., & Krumova, M. (2020). *STEM and Digital Competences of New Millennium Learners*.