Adoption of Digital Technology among Pre-Service Teachers : Bibliometric Analysis

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Abstract. One of the agendas to be achieved by the SDGs is the fourth agenda, namely quality education-ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Adopting digital technology development by prospective teachers is one of the efforts that can be taken to achieve this goal. This study aims to review research in the field of Technology Knowledge (TK) following the development of digitalization, the adoption of digital technology and efforts that have been made in improving the digital technology adoption capabilities of prospective teachers as well as future research agendas in the field of Technology Knowledge (TK) for prospective teacher education. The research method uses bibliometric analysis based on datasets in the Scopus database from 2014-2024. The results of the analysis show that there are studies that describe the digital literacy of prospective teacher students, efforts to integrate learning related to student digital technology adoption through various learning strategies and models are carried out but not all can increase digital technology adoption and increase student meaning of technology utilization because it is also determined by internal factors from prospective teacher students including motivation and self-efficacy. An interesting finding from this literature study is the inclusion of cyber ethics element in the integration of digital technology-based learning. The next research agenda based on the analysis that has been done leads to the development of learning models according to the needs of the current generation and the importance of cyber ethics.

Keywords: quality education, technology knowledge, digital literacy

1 Introduction

The 2030 Sustainable Development Goals (SDGs) agenda of the United Nations adopted by world leaders in 2015 including eradicating poverty, mitigating climate change, and universal access to education is currently being prepared in stages. One of

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the agendas to be achieved is the fourth agenda, namely quality education-ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. To achieve this goal, everyone can play their role, including the government, individual sectors, communities, and citizens. Education has a very important role in global development (1,2). Therefore, a fundamental shift in the way we think about the role of education in global development is needed. This is because education has a catalytic impact on individual well-being and the future of the world. Today, education must be responsive to the challenges and aspirations of the 21st century and foster the right kind of values and skills to achieve sustainable and inclusive growth and peaceful living together. In this regard, education can contribute to a new vision of sustainable global development. Therefore, we must empower the education system to meet the demands of today by preparing the next generation of high quality (3). One of the things that can support the achievement of the SDGs agenda in the field of education is the adoption of technological developments.

The rapid development of technology in various fields including in the field of education is a challenge that must be faced rather than avoided (4,5). The entire educational process has begun to improve in preparing various elements in the education system so that they can adopt the development of existing digital technology. Teachers as an element in the educational process are prepared early to have the knowledge, attitudes and skills to adopt and utilize digital technology developments since taking teacher education (6–8).

Digital technology adoption in prospective teachers is one of the elements related to Technological Knowledge (TK) which is part of Technological Pedagogical Content Knowledge (TPACK), which is the mastery of teachers in using technology in teaching (9). This knowledge is important as a basis for developing learning methods according to the development of the 21st century and harmonizing with the rapid development of technology. Technological mastery of prospective teachers can be supported by digital critical competence.

Digital critical competence as one of the important elements in digital adoption is currently a concern among learning design developers for prospective teachers (10). Digital critical competence includes the ability to critique information sources found on the internet and use a norm-critical approach in school teaching (11). Prospective teachers are expected to learn appropriate ways of evaluating the veracity of information from online sources and how to apply them effectively in the learning environment so that students will be trained to think logically and analytically when searching for information or conducting research online. More experienced teacher candidates tend to have a more reflective and critical approach to understanding digital content, so they can relate digital critical competence to the teaching profession as well as the school context (10).

Contextual factors such as prospective teachers' self-efficacy, motivation, and technology acceptance and their intention to use digital media are also widely studied as variables that influence digital technology adoption (12,13). Self-efficacy can influence pre-service teachers' TPACK if it is supported by a specific competency framework and measuring instruments to design pre-service teachers' digital learning situations (13).

Motivation and technology acceptance are closely related to each other, so training for teachers should focus on motivation and technology acceptance (14).

In addition to contextual factors affecting pre-service teachers' digital technology adoption, research and findings related to the importance of cyber ethics are interesting to explore. Ethical issues arising from the use of digital technology in learning, what type of knowledge teachers need to deal with these issues are research questions that remain unanswered in previous studies (15). Cyber ethics is important for prospective teachers to master so that teachers can maintain cyber ethics when doing online activities such as on social media (11).

Various learning methods are used in an effort to integrate digital technology into prospective teachers' learning with the aim of increasing prospective teachers' Technology Knowledge (TK) (4,14,16–18). Not only that, some studies also focus on assessment instruments to measure the extent of mastery of TPACK of prospective teacher students, especially in the element of mastery of technology (15). The methods tested varied greatly according to the needs of each research object and produced different results. Developments related to digital adoption of prospective teachers are interesting to study, therefore this paper tries to examine several specific things as mentioned in the research questions below:

What research has been conducted in the field of Technology Knowledge (TK) according to the development of digitalization, digital technology adoption and efforts that have been made in improving the digital technology adoption capabilities of prospective teachers in terms of research themes, methodologies and research settings?

What is the future research agenda in the field of Technology Knowledge (TK) for prospective teacher education?

This study aims to investigate the development of research in the field of TPACK, especially the element of Technology Knowledge (TK) in the context, theme, method, and research setting.

2 Literature Review

2.1 SDGs

Sustainable Development Goals (SDGs) is a development program while maintaining a balance between the economy, social life, and the quality of the community's environment which contains 17 goals and 3 objectives (19). The sustainable development goals (SDGs) are designed as a continuation of the millennium development goals (MDGs) that have not yet achieved their goals by the end of 2015 (20). SDGs is a global action plan designed by UNDP as an effort to achieve shared prosperity, balance life in nature, and encourage awareness of environmentally friendly behavior (19).

2.2 Technology Adoption

Technology is something that can help all humans around the world to help become a means to carry out daily activities carried out by humans at work and in education (21). In the development of a more modern era, technology is also getting more sophisticated

and more advanced, such as more media supporting workers and students or students in doing assignments. The existence of this new technology makes it easier for all workers and students to facilitate their work and school, but several problems exist in using this media. In education, the internet is utilized as a support in learning media. The world of education needs to improve the progress of schools and education by making positive innovations. Schools are expected not to miss the news about the sophistication of technology by providing electronic devices that support the learning process. Good and complete facilities and infrastructure will make learning activities run effectively and efficiently.

2.3 The Integration of Digital Technologies within the Educational Process

The incorporation of information and communication technology (ICT) into education has presented notable challenges for both academic researchers and training institutions. These difficulties necessitate alterations not only in the substance of what must be learned, but also in the manner in which learning occurs (22). To advance transformative learning, it is vital to emphasize the significance of transdisciplinary thinking and contemporary technologies in shaping innovative teaching methodologies that are appropriate for the modern era. By embracing these principles, educators can cultivate an atmosphere that fosters ingenuity while inspiring students to actively participate in their own educational progression (23).

2.4 Pre-Service Teacher

A teacher who is still learning is called a pre-service teacher. Pre-service teachers need a lot of knowledge before performing their duties at school. The process of being placed in a class that contains students who are studying the subject is based on their qualifications. They can also be matched with the age group they want to work with such as; Primary, Secondary and Pre-school. Usually they will get a microteaching class before implementing what they have learned. Microteaching is known as a method used in mini teaching simulations between pre-service teachers supervised by lecturers. A pre-service teacher is a university student who is preparing to carry out Teaching Practice Activities (PPL) in schools recommended by the government. This is very important because of the activities that pre-service teachers will be able to do to improve their teaching, implementation skills strategies, as well as the proficiency to be developed (24).

3 Method

This research uses bibliometric analysis based on datasets in the Scopus database. A total of 64 articles were published in the period 2014-2024. This study uses systematic data to reveal the development of digital technology adoption in the Technology

Knowledge (TK) element in students who take teacher education and qualitative inductive analysis to determine relevant themes in the topic and use the results of data analysis from VOSviewer software.

Keywords used in data search are technology AND knowledge, AND digital, AND pre AND service AND teacher. The dataset used from the Scopus database is limited to subject areas in social sciences, Computer Sciences, Psychology, Arts and Humanities, Business, Management and Accounting, Document type Article, Language English, Source type Journal. The procedure in analyzing data consists of five stages, including: 1) determining the purpose of writing; 2) identifying search topics and databases; 3) processing data for writing and reducing search results according to scientific principles; 4) findings and conclusions.

4 Results and Analysis

One of the agendas to be achieved in the SDGs is the fourth agenda of quality education (3). Quality education cannot be achieved on its own, it requires a collective effort in defining a vision of future sustainability, by "translating" what it means to achieve the SDGs. This process should involve the active participation of local civil society, and engage students, educators and stakeholders (2). Educators are one of the elements in education that can guide students in adopting and adapting to various developments and changes that occur (25,26). Technological development as an inevitable thing today is one of the competencies needed by educators in supporting the achievement of sustainable education.

Digital competence is one of the eight key competencies for lifelong learning and is a requirement for achieving personal goals and self-development, active citizenship, social inclusion, and employment in a knowledge-based society (27). To assist students in developing these competencies and ensure optimal implementation of information and communication technology (ICT), teachers must also be ICT literate and adopt digital technology developments well. Therefore, a program is needed for prospective teachers who can improve their digital literacy and have the knowledge to integrate their knowledge in the teaching and learning process that will be carried out after becoming a teacher (4).

Technology mastery is part of the TPACK framework which acts as a framework for teachers to integrate technology in their learning (28,29). Mastery of technology in teaching is not an instant process but requires time, strategies, and habituation that can be instilled since a person undergoes prospective teacher education. Prospective teacher education with its various learning curriculum designs seeks to provide learning that aims to equip knowledge of digital technology. Various strategies are carried out in order to find effective ways of learning that aim to equip prospective teachers with technological knowledge and skills (30–33).

Various studies related to the field of Technology Knowledge (TK) in accordance with the development of digitalization, digital technology adoption and efforts that have been made in improving the ability to adopt digital technology for prospective teachers in terms of research themes, methodology and research arrangements as well as future

research agendas in the field of Technology Knowledge (TK) for prospective teacher education are the research objectives in this article which are answered through bibliometric analysis of various literature reviewed. The literature review was conducted on 64 articles published in the Scopus dataset with a time span of 2014-2024. The data was then selected based on the suitability of the themes discussed in this article. A more specific discussion of the results of the literature review is described below. 21 articles were selected from 64 articles as articles that met the criteria according to the research objectives, namely discussing the adoption of digital technology for prospective teachers.

4.1 Overall Analysis Results

The results of the article analysis related to the Adoption of Digital Technology among Pre-Service Teachers are presented in Table 1.

Table 1. Combinations of Article Used in the Literature Review

Journal Database	Related Article
Elsevier	3
Springer	3
Taylor & Francis	4
Frontiers Media	3
ERIC	1
EBSCO	1
JSTOR	1
DergiPark	1
ASCILITE	1
Other	3
Total	21

The inclusion and exclusion criteria that we apply to select articles can be seen from Table 2.

Table 2. Inclusion and Exclusion Criteria

Criteria	
Inclusion	– Publications in peer-reviewed journals. – The article discusses about technology. knowledge, digital, and pre-service teacher, TPACK. – Written in the English Language. – Derived from the scopus dataset.
Exclusion	– Theses, books, and book titles. – White papers, technical reports, and non-peer reviewed research publications.

	– An editorial, an abstract, or a brief paper (four pages or fewer).

Articles that have been restricted by the above criteria are then identified based on their ranking which is presented in the following data :

Table 3. List Article Distribution

Publication Media	Number of Articles
Periodical Journal Q1	10
Periodical Journal Q2	9
Periodical Journal Q3	1
Periodical Journal Q4	1

Based on the review, several findings related to technology adoption by prospective teacher students include several studies on the digital literacy of prospective teacher students have been conducted (33–35), efforts to integrate learning related to student digital technology adoption through various learning strategies and models (14,17,18,36) have been carried out but not all can increase digital technology adoption and increase student meaning of technology utilization because it is also determined by internal factors from prospective teacher students including motivation, self-efficacy (13,37). An interesting finding from this literature study is the inclusion of cyber ethics elements in learning integration with the aim that students can sort and use digital technology wisely (34,38).

A more detailed discussion will be presented in a table containing each of the findings from this literature review.

4.2 Technological Knowledge (TK) of Pre-Service Teachers and Factors Influencing Digital Technology Adoption

Some studies that discuss the technological knowledge of prospective teachers are presented in Table 4.

Table 4. Technological Knowledge (TK) of Prospective Teacher Students and Factors Influencing the Adoption of Digital Technology

Literature Study Findings	Observed Technology Knowledge Elements	Researchers
Research: TK knowledge and TPACK were measured by a survey. The results showed low competence in using digital technology for teaching and learning.	Aspects observed in this study include: TPACK integration practices in learning Students' competence in using digital technology	Ahlam Mohammed Al-Abdullatif (2019) (35)

	Technological Knowledge of students observed based on gender	
This study shows the importance of integrating digital critical competencies into Norwegian teacher training programs to improve education quality. More experienced teacher candidates have a norm-critical approach and can relate digital critical competencies to the teaching profession as well as the school context.	The research was conducted by comparing the experiences of	Tove Leming and Lisbeth Bergum Johanson (2023)(39)
The research shows that prospective mathematics teachers in the Upper East Region of Ghana have positive perceptions of technology integration in algebra education, unaffected by age. Factors influencing their perceptions were the teacher education program, self-efficacy, previous experience, and their attitude towards technology.	Aspects observed in the study: students' beliefs, attitudes, self-efficacy and experiences related to technology integration in algebra learning, as well as the benefits and challenges they face when implementing it.	Essuman, S A, Wilmot, E M (2024)(40)
Participants had different digital skills depending on technology and cyber ethics knowledge.	The study used an online survey that included the level of digital skills and knowledge of cyber ethics and digital technology.	Oliver McGarr & Adrian McDonagh (2021) (34)
The results showed that technology self-efficacy was only moderately correlated with subject-specific self-efficacy when using digital data acquisition systems.	2 studies conducted: Identified 15 subject-specific abilities to operate digital data acquisition systems in the lab based on literature review and verbal thinking. Developed a brief self-efficacy scale as a valid measurement tool in operating a digital data acquisition system.	Gregor Benz and Tobias Ludwig (2023)(13)
The TPACK framework is used to explore how specific digital competencies relevant to	Contextual factors such as technology self-efficacy, motivation, and technology	Anna-Lisa Max, Holger Weitzel1

prospective teachers can be developed through a pedagogical makerspace project. Perception of its usefulness and intention to use ICT are strongly influenced by TPACK. Providing a low threshold entry point at the beginning of the study is significant in establishing a strong foundation for further TPACK development. Motivation and technology acceptance are closely related, so teacher training should focus on both.	acceptance influence the TPACK development of pre-service teachers as well as their intention to use digital media.	and Sarah Lukas (2023)(42)

Technological Knowledge (TK) describes the knowledge of the importance of technology integration in learning (35). Technology can be utilized in the communication process, processing learner data, and supporting teacher productivity. Technology integration is an important aspect of modern education, but this cannot be achieved without proper training and support for teachers. Teacher education programs should prioritize the development of pedagogical skills, subject matter expertise, practical experience with educational technology, and continuous professional development to prepare educators for success in the digital age and in achieving sustainable education (1).

4.3 Strategies and Models of Technology-Integrated Learning that have been Tested to Increase the Digital Technology Adoption of Prospective Teacher Students

The digital technology adoption of pre-service teachers can be improved through the application of learning strategies and models that are following the needs and initial conditions of pre-service teachers towards technology (43). The following presents findings from the analysis of strategies and models that have been used in learning for pre-service teachers in increasing technology adoption in Table 5.

Table 5. Strategies and Models that have been Used in Learning for Pre-Service Teachers in Increasing Technology Adoption

Literature Study Findings	The Learning Strategy or Model Used	Researchers
Using the Technology Integration Planning Cycle (TIPC) with pre-service	Technology Integration Planning Cycle for Pre service Teachers with a	Kristi Bergeson, Beth Beschorner (2020) (44)

teachers (PSTs) showed PSTs were overwhelmed by the selection of digital tools that would support their literacy goals and had difficulty knowing how to overcome obstacles and had a difficult time using technology effectively to improve their literacy goals.	cycle of observing TIPC modeling in practice, participating in group work, and discussing meaningful technology integration.	
This study showed that mixed methods with SRS improved the academic achievement of history elementary teacher candidates. The results are better than traditional lecture-based teaching and SRS scores can predict final exam scores for male students, but not for female students.	Inquiry-Based Learning and a student response system-based formative assessment in teacher training	Sergio Tirado-Olivares, Ramón Cózar-Gutiérrez, Rebeca García-Olivares, José Antonio González Calero (2021) (45)
Teacher training is based on flexible approaches and active strategies to develop skills, including digital. The participants were able to integrate digital technologies in their teaching and support the future development of online education.	The active teacher training model by adopting Structuring Principles of Active Teacher Training from Rodrigues (2017) which consists of 5 principles.	Ana Luísa Rodrigues (2020) (22)
The praxilogy approach is effective in instructional technology teacher training for digital transformation in early childhood education students.	Praxeological approach with the advantage that participants can define the way to advance themselves, take responsibility for their actions, stimulate collaborative learning, respond to questions regarding implementation, have transparent ethics and values.	Kulaksız, T, Toran, M (2022) (46)

4.4 Research on Cyber Ethics in Pre-Service Teachers' Technology-Based Learning

A review of the research results on digital technology adoption among pre-service teachers shows new findings, namely research that discusses cyber ethics in technology-based learning and pre-service teachers' introduction to technology. Knowledge about cyber ethics is considered important for prospective teachers so that they can limit their activities in utilizing technology without violating applicable ethics such as maintaining data confidentiality, not easily disseminating information in cyberspace and using technology in learning following learning objectives (47).

The following presents the results of research that discusses cyber ethics in technology-based learning for prospective teacher students presented in Table 6.

Table 6. Research on Cyber Ethics in Technology-Based Learning of Prospective Teacher Students

Literature Study Findings	Focus of discussion Cyber Ethics	Researchers
The new conceptual framework of TPCEK includes ethical knowledge in the TPACK framework for teaching with digital technology.	Ethical issues arising from the use of digital technologies in learning and what kind of knowledge teachers need to deal with such issues.	Guomin Deng, Jinyun Zhang (2023) (15)
Digital competence must be carefully exercised so that teachers have autonomy in the utilization of technology. Student teachers must be wise in using technology and maintain cyber ethics on social media.	Knowledge of cyber-ethics in Irish teacher education students who are active users of technology and use social media very frequently, but report lower levels of skills in the use of other digital technologies.	Oliver McGarr & Adrian McDonagh (2021) (34)

The findings above show that research conducted in 2021-2023 includes ethics as a matter to be considered in the adoption of digital technology by prospective teachers. This suggests that future research on the adoption of digital technology by prospective teachers requires a more in-depth study to obtain more comprehensive data related to cyber ethics. Efforts are needed to understand the implications and impacts of using digital technology in an educational context, especially in terms of cyber ethics (34). Therefore, larger and broader studies need to be conducted to provide a better understanding of this issue. We need to consider important aspects such as privacy, security and responsibility when using digital technology in an educational context. All these factors should be carefully considered in designing teacher training programs and educational curricula to ensure that teachers are ready and able to face future technological challenges appropriately and responsibly.

5 Conclusion

The adoption of digital technology is inevitable today in realizing quality learning. Student teachers as prospective educators who spearhead education must be equipped with mastery of technology so that they can meet the demands of 21st century learning. Various studies identifying digital literacy have been conducted and show different abilities. Various learning strategies and models have also been developed including Technology Integration Planning Cycle for Pre service Teachers, Praxeological approach, The active teacher training model is done to increase technology adoption in prospective teachers. Currently, cyber ethics is also a topic of concern to be integrated in the learning of prospective teachers.

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