A case study of how digital competencies affect Pre-Service Physics Teachers’ Professional growth: Realizing SDG 4

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Abstract. This study unveils the level of digital competencies among prospective teachers, their correlation with professional development, and relevant university programs. The research was conducted at a public educational university in East Java, Indonesia, and involved seven four-year undergraduate students who were interviewed in a semi-structured manner. The results indicate that the participants possess intermediate-level digital competencies, including information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving. It is crucial for PSPTs to have digital competency as it can enhance the quality of learning activities and create an interactive physics learning environment. Additionally, universities that specialize in education can offer programs, such as digital competency-based courses, seminars, workshops, or internships, to help aspiring teachers improve their digital competencies. This research contributes to informing teacher education programs and guiding the integration of targeted training modules to enhance technological proficiency and professional development in realizing SDG 4.

1. Introduction

Since 2015 all countries of the United Nations have joined in a grand program intended to the transformation of the world, namely Sustainable Development Goals (SDG). The main objectives of this program are to end poverty and inequality, protect the planet and ensure that all people enjoy health, justice, and prosperity. Both developed and developing countries are adopting this program with the expectation of achieving all the goals by 2030. Among the 17 goals set by the United Nations, SDG number 4, Quality Education, specifically needs to be emphasized as the major key to achieving other goals and targets. A country must pay attention to its quality of education to have a considerable impact on the global realm. An ineffective education system will also produce low-quality human resources that are incapable of pushing the country to compete in the worldwide era [1]. Actualization of SDG 4 can be obtained by elaborating on the aspect of the professional competence of pre-service teachers. As one of the developing countries currently participating in this global program,
Indonesia has already considered this matter. The latest education system in Indonesia, *Kurikulum Merdeka*, developed by the Ministry of Education, has declared the importance of teachers' professional development. A teacher's professional development is defined as a continuous process of reflection, learning, and action to further a teacher's knowledge and skills, leading to enhanced teaching practices that positively impact students’ learning [2].

Education is a dynamic sector, so teachers must keep developing their professional competencies to find the most compatible method of teaching a subject by utilizing learning resources. This also aligns with one of the indicators of SDG 4: The percentage of teachers who meet qualifications according to national standards corresponding to each education level. There are several essential teacher competencies to support the learning process. In Indonesia, these competencies are grouped into four main competencies. Based on Peraturan Menteri Pendidikan Nasional No. 16 Tahun 2007, about teachers’ academic qualification standards and competency, those four competencies are pedagogical competence, character competence, professional competence, and social competence. The Ministry of Education then also explained specified indicators for each competence.

The process of developing professional competencies should be started before becoming an experienced teacher, through undergraduate studies as pre-service teachers. While the specific level of pre-service teachers' professional development is not explicitly addressed, studies prove that various learning experiences and communities could enhance their professional competencies [3]. The role of universities in producing competent teacher graduates is vital. Multiple subjects are combined in the campus curriculum to prepare for the professional growth of pre-service teachers. With the rising importance of communication and technology at the beginning of this modern era, educational policies also shifted to prioritize more collaboration with information and communication technologies in learning progress, whether inside the class or outside [4-6]. It becomes important for pre-service teachers to master digital competence as well. Adapting information and communication technologies in the learning process has also been added as one of the indicators of pedagogical competence by the Ministry of Education. By learning digital competence, pre-service teachers are going to be able to easily access and operate the newest educational technology or even serve as the ones who construct sustainable learning resources to be used by fellow graduates [7]. Digital training is necessary for pre-service teachers to establish a digitally competent future teachers’ line [8]. Pre-service teachers should be given abundant experience in integrating with digital technologies provided by the university [9]. Specifically, pre-service physics teachers (PSPTs) should have digital competencies because they can facilitate learning activities by utilizing various digital technologies such as virtual laboratory, virtual reality, augmented reality, and mobile learning. These technologies can create physics learning that is interactive, immersive, and provides visualization of abstract and microscopic concepts, leading to a better students' concepts understanding and learning outcomes.

Several studies related to this topic have been published [7, 10-14]. All studies agreed on the importance of digital competence for pre-service or in-service teachers. Some stated that personal factors that could influence the professional growth of pre-service teachers in digital competency are gender, age, and academic qualification. These factors also affect teachers' perspectives about digital competence. However, the respondents come from similar cultural backgrounds, meaning the survey results are limited and generalized [7,10]. Other studies researched the best strategies to develop digital competency for pre-service teachers with Synthesis of Qualitative Evidence model research [11]. It was found that strategies such as Role Models, Instructional Design and Authentic Experiences are clearly the most important in digital competency training for pre-service teachers [12]. Another study highlighted the necessity to evaluate pre-service teachers' training programs to produce graduates with the cognitive, teaching, and digital competencies required in the era of technology [13].
However, this study did not take the threshold of participants’ digital competency, so the data provided by the participants might be insincere. This may also affect the stability of the data calculation process. A study on the influence of digital transformation on inclusive education stated that raising awareness and improving teacher competencies can help actualize SDG 4 in Indonesia [14].

The purpose of this study is to explore the influence of digital competence on the professional growth of pre-service physics teachers based on training programs provided by the university to prepare pre-service physics teachers to actualize SDG 4. This study contributes to culturalizing awareness of the importance of digital competence for pre-service teachers as assets to set up learning resources and comprehend the best programs from the university to implement digital competence for graduate candidates of educational departments. In this regard, the research questions proposed in this study are:

1. To what extent PSPTs mastered digital competence?
2. How does the digital competence of pre-service teachers affect their professional development?
3. What kind of programs are provided by universities to prepare pre-service teachers’ professional competence?

2. Method

2.1 Research design

This study used a qualitative design to explore PSPTs’ perceptions of digital competencies and their relationship with their professional development. Qualitative research aims to provide a rich, contextualized understanding of some aspect of PSPTs experience through intensive study of individual cases [15]. In this context, since the qualitative case study design aims to describe a limited experience or activity in a finite amount of time, it was the most suitable choice. The case study was conducted at the Department of Physics Education, Universitas Negeri Surabaya, which is recognized as one of Indonesia's top teacher training colleges. The first author is a former student of the institution, while the second author is a lecturer and teacher there. The third author validated the data and analysis. The first and second authors have experience with all the teaching activities, facilities, and infrastructure available at the institution, assuring their fieldwork.

2.2 Data collection

Data collection used semi-structured interviews to explore participants' experiences, attitudes, and beliefs. It allows for discovery, exploration, and meaning-making so that the investigation does not overlook intricacy and nuance [16]. The interview protocol consisted of 12 open-ended questions to explore the influence of digital competencies on PSPTs' professional development. The digital competence framework was adapted from "The Digital Competence Framework for Citizens (DigComp 2.1)" which consists of 5 competence areas: information and data literacy; communication and collaboration; digital content creation; safety; and problem-solving [17]. The interview process was conducted for approximately 30 minutes per interviewee and was conducted face-to-face, either in person or online. The participants were seven fourth-year undergraduate students of physics education (3 males and 4 females). They are generally 20-22 years old and have Indonesian citizenship. The interview process was conducted in Indonesian.
2.3 Data analysis

Personal narratives or conversations from the interview process were the data types used in this study. The interview data was transcribed and then coded based on the most frequent themes. Moreover, the transcription results were used to classify participants' proficiency based on DigComp 2.1 levels, namely: foundation (1-2), intermediate (3-4), advanced (5-6), and highly specialized (7-8) [17]. The themes in this study include (1) the digital competency profile of PSPTs, (2) the influence of digital competency on PSPTs' professional development, (3) university programs that can help improve PSPTs' digital competency. To increase the trustworthiness of the findings, the researcher cross-checked with the track record of university activities and educational curriculum.

2.4 Ethical considerations

The participants have declared their willingness to participate in this study voluntarily. By having participants speak consent declaration, the authors could get their voluntary informed consent. It indicated that the participants were aware of the nature and goal of the study. The researcher also kept the participants' identities confidential by applying an Indonesian general pseudonym: Alif (male), Bowo (male), Joko (male), Dian (female), Elsa (female), Maharani (female), and Sari (female).

3 Results and Discussion

3.1 PSPTs’ digital competencies

3.1.1 Information and data literacy

The average score for participants in this competence is 5, which means the participants have advanced knowledge and skills in Information and data literacy. Whenever asked how they searched for references for their paper task, all of the participants answered that they mainly used Google Scholar and checked the SINTA (Science and Technology Index), the Website of the Ministry of Education, or Scopus for international journals for the reference credibility. Some of the participants manually manage the references they use. One of them used digital folders to group the references by topic, and the other half used Mendeley for auto citation.

3.1.2 Communication and collaboration

In collaborative tasks, participants mostly used common applications like WhatsApp, Zoom or Google Meet to communicate. In production, the participants used integrated applications like Canva, Google Docs, Spreadsheets, and others for easy access and real-time collaboration. This increases the effectiveness in time when finishing the task. The participants have advanced skills in communication and collaboration competence, with an average score of 6. All participants are used to using digital technology to support completing the task given, such as Grammarly and AI generator for paper, Microsoft Powerpoint, and Canva for presentation.
3.1.3 Digital content creation

The participants were asked how they did the presentation task. Most of the participants answered that they mostly used Canva or Microsoft PowerPoint and maximized the free templates available on those platforms. When creating a media for presentation, they stated that writing the material in points without excessive phrases will help fellow students be more interested and help them understand. Adding multimedia sources like videos or pictures also helps. Two of the participants notably answered that they prefer using Prezi over Canva or PPT because this application is more interactive and more accessible by sharing links. The participants have used other programs in producing media for Physics learning: Numerade, Python, and PhET. With all these mastery, the participants were once again graded in advanced level with an average score of 6 in digital content creation competence.

3.1.4 Safety

In terms of safety, as in device safety from viruses, all of the participants stated that they only used the antivirus provided in the device and only tried to clear the virus or service the device when they got a notification from the application. In terms of personal data safety or privacy, most of the participants know how to protect their personal information by using two-factor authentication from Google, using professional email without personal data to log in to high-risk websites, and periodically changing their passwords. Participants also take caution with only logging into their accounts on their trusted devices. The average score for this competence is 5, which assigns the participants to the advanced level.

3.1.5 Problem-solving

During their final year of college, when participants complete an internship, they demonstrate advanced skills in implementing digital technology into the learning process. No changes in content have been made. The participants reported using PowerPoint, Canva, or Prezi for presentations, introducing PhET to students for the first time, and utilizing interactive evaluation methods such as Quizizz or Google Forms. However, participants noted that the implementation of digital technology in education is influenced by the availability of tools and the school's culture. Some participants reported that their schools did not prioritize digital learning and instead favored traditional methods, while others reported that their internship schools provided tools and programs for augmented and virtual reality to enhance students' learning experiences.

Regrettably, none of the participants possessed the necessary skills to rectify issues with their device's software or hardware. They all admitted to seeking solutions on YouTube or consulting friends with greater expertise when encountering software problems, and taking their device to a service center when faced with hardware issues. As a result, the average score for this competency area has decreased to 4, placing the participants at an intermediate level.

3.2 Effect of digital competencies on PSPTs' professional development

All PSPTs considered digital competency a crucial aspect of their professional development. Essentially, digital competencies are closely linked to the ability to utilize technology, with technology serving as one framework for understanding and describing the knowledge required by teachers, commonly referred to as Technological, Pedagogical, and Content Knowledge (TPACK) [18]. Consequently, integrating digital competencies into teacher training programs enhances PSPTs' digital teaching competence and their capacity to utilize
digital technologies in physics educational practices effectively. In relation to this, some participants noted that digital competencies can enhance physics learning activities, making them more engaging and interactive, facilitating students' understanding of concepts taught by teachers, and also fortifying information security against cyber-attacks.

**Digital competencies can make learning activities more interesting and can protect personal data from cybercrime (Elsa).**

Mastering digital technology is very important because technology itself was created to streamline our work. Inevitably, we need to have digital competence because if we do not follow the development of digital technology today, we will be left behind everything because this technology develops very quickly. The use of digital technology is very influential on physics learning, for example earlier about VR, if there is no VR, students have difficulty visualizing. Therefore, technology makes physics learning activities easier (Bowo).

**Digital competences are very supportive of teacher professional development because it is related to how we teach physics to students. So when we understand technology, we can apply it in education, it is very supportive, it makes it very easy for us to teach them, makes it easier for them to understand the concept (Maharani).**

Researchers confirmed that teachers with digital competencies can implement digital pedagogy strategies that promote active and participatory learning. In other words, digital competencies also enable teachers to incorporate digital tools and instructional technology into their teaching, enhancing the delivery of content and promoting student engagement [19]. For instance, Bowo stated that their competence makes him able to operate VR technology, making it easier for students to understand physics material. These competencies also help create a constructive digital learning environment, fostering flexible and activity-oriented learning. Apart from pedagogical knowledge, digital competencies include understanding and implementing information security measures, and ensuring the protection of digital data and information [20].

Furthermore, one PSPT revealed that digital competence can improve his pedagogical art when teaching in an institution. This is due to the fact that digital competencies enhance their pedagogical competency by enabling them to effectively integrate technology into their teaching practices, fostering engaging and interactive learning experiences. Proficiency in digital tools and resources empowers PSPTs to design meaningful instructional strategies that cater to diverse student needs and enhance overall physics learning outcomes.

**I strongly agree that developing the quality of digital competencies can improve this professional development because we see in terms of the current development of globalization that digital media is never separated from our routine activities. This also affects the learning that will be developed by teachers to strengthen the pedagogical arts that will later be implemented when teaching in an institution (Joko).**

While other PSPTs gave normative opinions regarding the influence of digital competencies on their professional development.

**Learning in the current era emphasizes the use of technology, because if teachers cannot adapt, they may be replaced (Alif and Dian).**

**I feel that I need digital competencies, so, I can keep up with the times (Sari).**

**Figure 1** depicts the key concepts in the relationship between digital competencies and PSPTs' professional development based on participants’ opinions. These abilities enable
PSPTs to master technological knowledge, design attractive physics learning environments, result in the ease of student understanding, improve their pedagogical knowledge, and have cybercrime protection. However, the last keyword is not related to professional development, but to personal resilience. Thus, enhancing digital competencies needs to be considered by educational institutions through programs and initiatives as it determines the professional development of PSPTs.

![Diagram of Digital Competencies and PSPTs' Professional Growth Relationship]

**Fig. 1.** The key concepts of digital competencies and PSPTs’ professional growth relationship

### 3.3 Institution's program to develop PSPTs’ digital competency

Initial teacher education plays a vital role in developing pre-service teachers' professional digital competence, and partnership initiatives between university faculty and mentor teachers are associated with their development. Thus, universities must have programs that can facilitate the improvement of PSPTs' digital competency. Here are their voices in relation to some of the campus programs.

> Now the university has an MBKM [Independence Learning-Campus Freedom] program, so we can do activities like student exchanges, or choose some digital media-related courses at other universities. That’s the first thing, then the university also gives freedom related to the campus library. A lot of friends can come offline to the library, but we can also take advantage of digital media, we can use what is in SIAKAD [Academic System Information], there is also a library that we can get through a forum or class, well we have to register first. In a smaller scope, it is usually student organizations that organize. I have attended some kind of webinar or digital media training, such as UI/UX in the third semester (Joko).

The majority of universities in Indonesia have implemented the MBKM (Independence Learning-Campus Freedom), giving students the right to study outside their study program for one semester and do activities outside the university for two semesters. During this time, PSPTs can study at other universities by taking courses related to digital competencies, as long as they are available. Participants of this program are entitled to course credit recognition of up to 20 credits. Student organizations also play an essential role in organizing...
various activities based on digital competency development, such as UI/UX training in Joko's case. Let’s see Alif's statement regarding another program.

*I think the university is still lacking, more to personal lecturers who utilize digital applications in the development of their learning. From the [physics education] department, there may be multimedia courses. However, because I did not take the learning media expertise group, I did not take the course (Alif).*

This is one of the interesting findings, where the cluster of scientific fields chosen by PSPTs is a factor that has the potential to influence the improvement of PSPTs' digital competency. Department of Physics Education, Universitas Negeri Surabaya has four expertise clusters: assessment, innovative learning, learning media, and philosophy and curriculum of physics learning. Alif admitted that he belongs to the philosophy and curriculum group, so he tends not to take courses related to the use of digital technology in physics learning. In line with Spiteri's research [21], attitude towards digital technology is one of the digital competencies. Alif is one of the representations that his beliefs make him have a negative attitude. Beliefs in this context represent individuals' perceptions of their capabilities to plan and execute specific behaviors: what individuals think they can do, rather than what they will do [22].

Based on the institution's curriculum document, multimedia is a course that designs and develops the use of computers to present and combine text, sound, images, animation, audio and video with tools and connections so that users can navigate, interact, create and communicate easily, often used in the world of informatics. This course should be a facility for PSPTs to improve their skills in proficiently mastering digital technology instruments in physics learning.

Sari gave a similar statement to Alif, but in the context of another course: digital literacy.

*During my digital literacy course, I was given an account to access international journals. However, I forgot what I studied (Sari).*

In the university’s module handbook, this course develops the interest, attitude and ability of PSPTs to use digital technologies and communication devices to access, manage, integrate, analyze, evaluate information, develop new knowledge, and create and communicate with others to contribute actively. Therefore, this course can provide PSPTs with the knowledge and skills to use digital tools and technology in the physics classroom, foster creativity, position students as digital content producers, and support collaborative learning. Moreover, a study found that pre-service teachers who participated in digital literacy workshops gained experience in communicating and building relationships with parents while improving their understanding of the various challenges parents faced when attempting to support their children in school [23]. It to SDGs [24-26] to support the improvement of the quality of education. Especially for improving PSPTs quality in physics innovative models, media, curriculum, learning and teaching [27-32].

4 Conclusion

PSPTs have digital competencies ranging from 4 (intermediate) to 6 (advanced) based on the indicators. Digital competence significantly impacts professional development, particularly in the use of technology for physics learning. It fosters an interactive learning environment and motivates students, enabling teachers to deliver abstract physics material effectively. Universities in the field of education should provide opportunities for the enhancement of PSPTs' digital competence. This can be achieved through the provision of digital literacy
courses and the organization of workshops or seminars. This research contributes to informing teacher education programs about the necessity of integrating targeted training modules aimed at enhancing technological proficiency and professional development among PSPTs. By recognizing the critical role of digital competencies in fostering effective teaching practices, such programs can tailor their curriculum to include specific training modules that equip PSPTs with the necessary skills to navigate the digital landscape of education. Moreover, this targeted approach ensures that PSPTs or general pre-service teachers are adequately prepared to meet the challenges and opportunities presented by the Fourth Industrial Revolution, thereby aligning with the objectives outlined in Sustainable Development Goal 4 (SDG 4) - Quality Education.

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