education sciences

MDPI

Article

Preparing Pre-Service Teachers for the Digital Transformation of Education: Exploring University Teacher Educators' Views and Practical Strategies

Lyubka Aleksieva

Faculty of Educational Studies and the Arts, Sofia University "St. Kliment Ohridski", 1504 Sofia, Bulgaria; l.aleksieva@fppse.uni-sofia.bg

Abstract: The digital transformation of education requires not only the integration of digital technologies in the learning process, but also the development of digital competencies among students. The current status of the process of digital transformation in education in Bulgaria is investigated by the SUMMIT project, the framework in which this research was conducted. The present study examined the preparation of pre-service teachers for the digital transformation of education, focusing on the views and practical strategies of university teachers. The study involved 44 teachers in 48 academic courses from the largest Bulgarian university (Sofia University "St. Kliment Ohridski"). In order to provide a comprehensive view of the pedagogical training of pre-service teachers, mixed research methods were used, including curriculum analysis, semi-structured interviews, short surveys, and observations. The results revealed that although university teacher education programs include the use of digital technologies to improve learning outcomes, they often neglect pre-service teacher training related to preparing learners for the digital age. It was also established that there is a lack of policy and coordination among the different types of courses (information and communication technology in teaching and subject methodologies) in terms of preparing future teachers for digital transformation. University teachers use mostly traditional approaches and employ a limited number of strategies for teaching pedagogical digital competences (PDCs), which raises concerns about the effectiveness of pre-service teacher training. The research highlights the need for a more targeted and holistic approach to the development of PDCs of future teachers. This approach should include policy adjustments related to providing more practical activities and better coordination among courses, as well as guidelines for curricula development, continuing education of university teachers, and provision of adequate technological infrastructure. By implementing such an approach, universities could better prepare pre-service teachers not only to use digital technologies effectively but also to develop students' digital skills that are necessary for success in today's world.

Keywords: digital transformation of education; pre-service teacher preparation; pedagogical digital competence (PDC); university teachers' practical strategies

check for updates

Academic Editor: Eila Jeronen

Received: 19 February 2025
Revised: 19 March 2025
Accepted: 20 March 2025
Published: 23 March 2025

Citation: Aleksieva, L. (2025). Preparing Pre-Service Teachers for the Digital Transformation of Education: Exploring University Teacher Educators' Views and Practical Strategies. *Education Sciences*, *15*(4), 404. https://doi.org/10.3390/educsci15040404

Copyright: © 2025 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Digital transformation consists of a change in the organisation of work motivated by emerging digital technologies and innovative business models (Norton et al., 2020). It is related to building new skills and models through digital technologies in a deep and strategic way (Mahlow & Hediger, 2019), and it affects all fields of human life and, significantly, education. In terms of education, digital transformation is defined as the integration of

digital technology into teaching, learning, assessment, and administration (Mhlanga, 2024). This integration enhances accessibility, engagement, and personalised learning experiences for students (Shenkoya & Kim, 2023). However, digital transformation extends beyond the adoption of digital tools and resources—it requires rethinking of pedagogical approaches, organisational structures, and educational policies to leverage the potential of these technologies effectively (Thyssen et al., 2023; Awang, 2022). It is argued that it also requires a comprehensive shift in culture, pedagogy, and organisational structures (McCarthy et al., 2023). Digital transformation of education is increasingly recognised as a necessity to meet the demands of the Fourth Industrial Revolution (Oliveira & de Souza, 2022). Yet it does not remain without criticism (Castañeda & Selwyn, 2018), and critics emphasise the need for a balanced approach that integrates technology while maintaining the essential pedagogical principles of teaching (Wang, 2023). The modern education system is facing a growing need for the effective development of digital competences, as evidenced by the alarming trends reported in international studies. According to the ICILS 2023 report (Fraillon, 2024), students' achievements in the field of computer and information literacy (CIL) have decreased compared to 2018 and 2013, which translates into both a decrease in average scores and a decrease in the percentage of students reaching the second (out of four) or higher professional level. These data show that instead of advancing, we are seeing a regression in the level of digital skills among students, further indicating the need for digital transformation.

In this context, the preparation of future teachers for the effective use of digital technologies becomes a key element for the successful implementation of this transformation. Teachers must not only be able to use digital tools to improve the learning process but also develop digital competencies in students that they will need in modern society. Therefore, the current study, which is part of a broader study of the state of digital education in Bulgaria within the framework of the Sofia University Marking Momentum for Innovation and Technological Transfer (SUMMIT) project[1], also adopts this twofold perspective—examining both the effective use of digital tools to enhance learning and the development of students' digital competencies. The SUMMIT project covers national study of the level of digital competences of teachers and students, the role of curricula and pedagogical approaches in their development, the use of digital technologies for teaching, learning, and assessment, and methods for preparing future teachers in the field of digital education, as well as management and leadership in this process. This paper focuses on the role of university teachers in preparing pre-service teachers for digital transformation. It examines how and what digital skills they teach, what strategies they use to develop pedagogical digital competencies, and to what extent they prepare pre-service teachers, not only for the integration of technology, but also for the development of students' digital literacy. The latter encompasses a variety of skills, including the ability to access digital content, critically assessing its credibility and effectively using digital tools for communication and collaboration. It is not limited to technical competence but also includes an understanding of the socio-cultural dimensions of digital participation (Pangrazio et al., 2020) emphasise, digital literacy.

In order to effectively prepare future teachers for the digital transformation, their training should not only cover basic digital literacy but also delve into pedagogical applications of technology, such as creating digital content, managing virtual classrooms, and employing blended learning strategies (Srivastava & Dangwal, 2021; García-Delgado et al., 2023). Practical and experiential training should be used to foster a deeper understanding of how to leverage technology for educational purposes, as pre-service teachers often struggle with the integration of digital tools into their teaching practices, primarily due to a lack of hands-on experience (Basilotta-Gómez-Pablos et al., 2022; Jimarkon et al., 2021;

Romero-García et al., 2020). Additionally, pre-service teachers should be encouraged to engage in lifelong learning practices that keep them updated with the latest digital tools and pedagogical strategies (Srivastava & Dangwal, 2021; Fernández-Batanero et al., 2020).

This study will attempt to find what strategies university teachers declare and use in practice and how they foresee the preparation for digital transformation of pre-service teachers. The results are important for the Bulgarian context and may have implications more generally, as many of the challenges related to the digital transformation of education may be similar in other countries. Preparing teachers to work effectively in a digital environment requires strategic approaches that ensure not only increased educational outcomes but also overall readiness of students for life and work in a digitalised society.

2. Literature Review

In recent years, the digital transformation of education, which could be defined as "the integration of digital technologies and practices to enhance teaching and learning processes, widen access to educational resources, promote digital literacy, and foster innovative approaches that improve educational outcomes and prepare learners for the digital age" (Council of Europe, 2024), has dramatically changed the educational landscape. The development of Artificial Intelligence (AI) has further contributed to the change in the educational field. Therefore, digital transformation requires a rethinking of how to prepare students, educators, and system leaders for the innovations and challenges to come (McCarthy et al., 2023). This puts university education in focus and in a leading role in terms of digital transformation in education (Gkrimpizi et al., 2023). Universities have to prepare future teachers for digital transformation, which, as the definition above indicates, includes not only the use of digital technology and practices to enhance learning outcomes, but also involves preparing learners for the digital age. Within these two aspects, the preparation of pre-service teachers for digital transformation should encompass developing their competences to effectively integrate digital technologies in the learning process to increase its quality, and at the same time, to prepare students for the digital world by building their digital literacy. Students' digital literacy is key and should be considered a basic skill, like reading and writing literacy (Aini et al., 2024). It is much more than just technical skills—it includes critical thinking and the responsible use of digital content; the use of digital technologies in the learning process is not enough to effectively develop such skills. Instead, comprehensive strategies are needed (Reid et al., 2023), such as policy initiatives and educational interventions (Susanty, 2024).

Despite the potential advantages of digital transformation, there is a growing body of criticism regarding the digital transformation in education (Castañeda & Selwyn, 2018), which often revolves around concerns related to effectiveness, equity, and the impact on traditional pedagogical methods. Critics argue that the rush to integrate digital tools into education can sometimes overshadow the importance of fundamental teaching practices. Researchers emphasise that simply introducing digital tools is insufficient; there must be a deliberate integration of technology into pedagogical strategies, since without aligning technology use with educational objectives and teaching methods, the potential benefits of digital transformation may not be fully realised (Mhlanga, 2024; Bottino, 2020). Furthermore, various researchers have pointed out that when the focus is on digital tools, it is more difficult to critically evaluate the use of a given technology (Selwyn, 2019; Yang et al., 2022; Curwood & Cowell, 2011), i.e., that critical examination of the role of technology in society is likely to be more effective if it does not involve the technology itself. In this sense, preparing learners for the digital age involves not only integrating technology, but also cultivating critical thinking skills regarding the role of technology in society. Such a critical perspective can sometimes be better achieved through pedagogical approaches that do

not rely on technology. The need for better alignment between digital technologies and educational practices was also noted by Mugge and Gudergan (2017) and Sondermann et al. (2017), who underscored the gap between the theory and practice of digital transformation. This gap often results in a mismatch between the potential of digital tools and their actual implementation in educational settings (Mugge & Gudergan, 2017). Therefore, Stanford's Professor Garcia suggested that the focus of digital transformation should be on creating authentic learning experiences rather than relying solely on technology (Garcia, 2023). Some educators even express apprehension about the potential loss of traditional teaching methods and the human element of education in favour of technology-driven approaches (Awang, 2022). In this regard, McCarthy et al. (2023) recommend a holistic approach which includes technology integration, curriculum development, teacher training, policy adjustments, effective leadership in guiding the digital transformation process, continuous professional development (CPD) for educators to catch up with new technologies, a focus on student-centered learning, and lastly, adequate technological infrastructure (McCarthy et al., 2023). Additionally, concerns regarding the digital divide highlight the risk of exacerbating existing inequalities in access to technology and educational resources (Mhlanga, 2024; Shenkoya & Kim, 2023; Bottino, 2020). Thus, while digital transformation is increasingly prioritised in policy and practice, it must be approached with caution and critical reflection on its implications for educational equity and effectiveness.

2.1. Preparation of Pre-Service Teachers for Digital Education

Pre-service teacher education programmes are recognised as crucial in preparing future educators to effectively integrate information and communication technology (ICT) into their teaching practices, thus facilitating digital education (in this paper, the term "digital education" is used synonymously with "digital transformation in education"). Some researchers argue that ICT integration into teacher training is essential for fostering the digital competencies necessary for modern educational environments (Aslan & Zhu, 2016; Tondeur et al., 2018; Wang, 2023). Teacher training programmes should be adapted to include strategies such as using teacher educators as role models and providing authentic technology experiences to enhance pre-service teachers' confidence and competence in utilising ICT (Aslan & Zhu, 2016; Tondeur, 2018). Moreover, the Synthesis of Qualitative Evidence (SQD) model proposed by Tondeur et al. (2018) emphasises the importance of adopting a systematic approach to integrating technology throughout pre-service teacher education programmes for developing the digital skills of future educators (Tondeur et al., 2017c). Tondeur et al. (2018) also highlight the necessity of a multilevel approach to training that integrates theoretical frameworks, practical training, and ongoing support, and encompasses various strategies to successfully promote digital competencies among pre-service teachers.

Despite these theoretical insights, there are still notable limitations within pre-service teacher education regarding the preparation of educators for digital transformation. Many pre-service teachers report feeling inadequately prepared to use technology in their future classrooms, indicating a gap between training and practical application (Tondeur et al., 2012; Masoumi, 2021). This statement is replicated by Yang et al. (2022), who found that while ICT training is impactful, it does not always translate into effective instructional practice (Yang et al., 2022). The challenges faced by teacher education institutions in promoting digital competencies suggest that a mere inclusion of technology in curricula is insufficient; rather, a comprehensive and reflective approach to teacher education is required to ensure that pre-service teachers can confidently implement digital tools in their pedagogical practices (Tondeur et al., 2012; Masoumi, 2021). Additionally, for preparing learners for the digital age, it is necessary for future teachers firstly to develop their digital

literacy, which should also include training in evaluation of the social and ethical aspects of using technology. Research demonstrates that teachers who understand and can evaluate the impact of technology on society are better equipped to teach students how to deal with the challenges of the digital age (McGarr & McDonagh, 2021). It is important to emphasise critical thinking and teachers' ability to evaluate and selectively use technology, rather than simply integrating it into the classroom (Ayyildiz et al., 2021). Thus, it seems that CPD plays a vital role in addressing the limitations of pre-service teacher education by providing ongoing opportunities for teachers to enhance their pedagogical digital competencies, adapting to the evolving demands of digital education (Mizova & Peytcheva-Forsyth, 2024; Vandeyar & Adegoke, 2024; Althubyani, 2024; Wagner et al., 2024; Pongsakdi et al., 2021; Castaño Muñoz et al., 2023; Spiteri & Rundgren, 2017; Ucan, 2016). Moreover, the integration of collaborative learning and reflective practices within CPD programmes has been shown to significantly enhance teachers' professional growth and their ability to integrate digital tools effectively in their classrooms (Adeyemi, 2015; Saylor & Johnson, 2014).

The first aspect of preparing pre-service teachers for digital transformation refers to equipping them with digital skills and knowledge to effectively integrate technology into teaching to enhance student learning, including collaborative learning, to adapt to evolving learning environments, and to use innovative teaching methods (Sangboonraung et al., 2024; Nykvist et al., 2022). The second aspect concerns the development of digital literacy and critical thinking in learners, which is necessary for them to successfully navigate the digital age (Su, 2023; Fazilla et al., 2022; Ayyildiz et al., 2021). The focus of pre-service teachers' preparation in both aspects is the development of pedagogical digital competence (PDC). This is crucial, as it provides the necessary knowledge and skills to effectively integrate digital technologies into the learning process, which is key to educating students in the digital age (Chu et al., 2023; Boronenko et al., 2022; Purina-Bieza, 2021; Perin & Freitas, 2020). Digital transformation training should include technology integration models, such as the Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006), Substitution, Augmentation, Modification and Redefinition (SAMR) model (Puentedura, 2006), Digital Technology Impact Framework—DTIF (Aubrey-Smith & Twining, 2023), etc., that help teachers align technology with content and pedagogy (Rüth et al., 2022). Furthermore, developing PDCs of future teachers prepares them to teach students about the responsible use of technology, cybersecurity, and online well-being. A systematic review of digital competences for teacher professional development highlights the importance of continuous training and the integration of ICT in teaching practices (Fernández-Batanero et al., 2020). The need for frameworks like the Digital Competence Framework for Educators (DigCompEdu) to guide this development is emphasised (Cabero-Almenara et al., 2023; Fernández-Batanero et al., 2020). There are various models and frameworks related to PDC besides DigCompEdu, such as the Teacher Educator Technology Competencies (TETCs) framework, which further emphasises the need for teacher educators to model and integrate technology in their teaching, ensuring that future teachers are well-prepared to use digital tools effectively (Foulger et al., 2017). Unlike DigCompEdu, TETCs does not include a component related to the preparation of learners for the digital world. Another relevant project is the one developed by UNESCO on ICT Competencies for Teachers (UNESCO, 2008, 2019). In Spain, there is the "Common Framework of Digital Competence for Teachers", developed by the National Institute of Educational Technology and Teacher Training (INTEF, 2017), which is based on the digital competence model DigCompEdu developed by the EU (Basilotta-Gómez-Pablos et al., 2022). For the purposes of this study, the DigCompEdu framework will be used. This choice is justified by the fact that DigCompEdu is the most widespread and adopted framework

in Europe, and in particular, in Bulgaria, where the empirical study will be conducted. Moreover, DigCompEdu domains cover both the pedagogically effective integration of digital technologies and facilitating learners' digital competence, i.e., it is a good basis for holistic preparation for digital transformation

Frameworks such as DigCompEdu guide us towards the understanding that digital competencies are not binary; rather, they exist on a broad spectrum, often categorised into levels that reflect varying degrees of proficiency. DigCompEdu, the European Digital Competence Framework for Educators (Punie, 2017), which is reliable and effective in assessing teachers' digital competences (Cabero-Almenara et al., 2020; Ghomi & Redecker, 2019), allows for a nuanced understanding of the competencies required for pre-service teachers, emphasising that it is not merely a question of whether they possess a particular skill, but rather, the level of competence they achieve. DigCompEdu is related to PDCs, which differ from general digital competencies by focusing on pedagogical strategies tailored to the way students learn in a digital environment. While general digital competences include mere technology-related knowledge and skills, PDCs are related to applying this knowledge in ways that are pedagogically sound and meet learners' needs (Väätäjä & Ruokamo, 2021). In his review, Starkey (2019) defines three aspects of PDC: integrating digital tools into existing pedagogical practice, considering decisions critically, and teaching students who are using technologies for learning. In addition, PDCs are increasingly recognised as essential in teacher training programmes (Gudmundsdottir & Hatlevik, 2018).

DigCompEdu defines six distinct areas of competence that educators should develop to effectively implement inclusive and innovative learning strategies through the use of digital tools (Caena & Redecker, 2019). Each of these six areas includes six proficiency levels (from A1 to C2), ranging from basic awareness and exploration to full integration and pedagogical innovation. DigComp 2.2, the Digital Competence Framework for Citizens (Vuorikari et al., 2022), consists of four proficiency levels (foundation, intermediate, advanced, and highly specialised) with two degrees each. Research indicates that many pre-service teachers enter their training programmes with varying levels of digital literacy, often averaging around an intermediate level (Yontar, 2019). Studies demonstrate that many teachers possess foundational digital skills but often fall short of the advanced competencies required for effective integration of technology in educational settings (Kiryakova & Kozhuharova, 2024; Tzafilkou et al., 2023). In terms of PDC, a minimum level of B1 might be necessary for pre-service teachers to effectively utilise digital tools in their teaching practices, while higher levels (B2 to C2) could be required for more advanced pedagogical applications, such as integrating digital storytelling or game-based learning into their curricula (Rüth et al., 2022). The overall findings suggest that a significant part of teachers operate at a basic to intermediate level of pedagogical digital competence, with many falling into the B1–B2 category. This level demonstrates a foundational understanding of digital tools but a lack of proficiency in applying these skills in innovative and pedagogically effective ways (Iqbal et al., 2024).

The challenges in preparing pre-service teachers for digital transformation are multifaceted. Many pre-service teachers express reluctance to integrate digital tools during their practicum, often due to a lack of confidence or insufficient training in the practical application of those tools (Alsadoon, 2022; Jimarkon et al., 2021; McGarr & McDonagh, 2021). Moreover, self-perception of digital competence varies significantly among teachers. García-Delgado et al. (2023) highlighted that teachers often assess their digital competencies higher than may be warranted, which can lead to a discrepancy between perceived and actual abilities (García-Delgado et al., 2023). Furthermore, studies have shown that in-service teachers generally report higher levels of perceived digital competence compared to their pre-service counterparts, suggesting that practical experience plays a critical role in

developing these competencies (Yang et al., 2022). The importance of practical and experiential learning opportunities within teacher education programmes, where pre-service teachers can engage in authentic digital pedagogical practices to foster a deeper understanding of how to leverage technology for educational purposes, is stressed by some authors (Basilotta-Gómez-Pablos et al., 2022). Training should delve into pedagogical applications of technology, such as creating digital content, managing virtual classrooms, and employing blended learning strategies (Srivastava & Dangwal, 2021; García-Delgado et al., 2023). Additionally, the implementation of self-assessment tools and reflective practices can help pre-service teachers identify their strengths and areas for improvement (Miguel-Revilla et al., 2020; Tsankov & Damyanov, 2019). Teachers' preparation should also include skills to help develop their students' digital literacy in order to effectively prepare them for the digital age (Prachagool et al., 2022).

2.2. Practical Strategies to Prepare Pre-Service Teachers for Digital Transformation

Opportunities for enhancing digital competencies among pre-service teachers lie in the intentional design of teacher education curricula that incorporate technology integration as a core component. Despite the fact that the preparation of future teachers to teach pupils how to participate in a digital world is an important aspect of their preparation for digital transformation (Starkey, 2019), existing research is more focused on the other aspect—the integration of digital technology to enhance learning. Effective strategies include using teacher educators as role models, fostering collaborative learning environments, and providing authentic experiences with digital tools (Nykvist et al., 2022; Aslan & Zhu, 2016). These strategies should be accompanied by integrating theoretical frameworks, practical training, and ongoing support. Structured frameworks, such as the DigCompEdu, outline the essential skills required but also serve as a diagnostic tool for educational institutions to evaluate their training programmes and identify areas for improvement (Tondeur et al., 2023; Sillat et al., 2021).

One of the key strategies for developing pedagogical digital competences is through experiential learning and active methodologies. Research shows that future teachers often have difficulty integrating digital tools into their teaching practice, mainly due to a lack of practical experience (Jimarkon et al., 2021; Romero-García et al., 2020). Therefore, teacher training programmes should include active learning strategies that allow future teachers to work with digital technologies in a real learning environment. Such strategies are described in the SQD model, including using teacher educators as role models, facilitating peer collaboration, and providing authentic technology experiences (Gümüş et al., 2024; Tondeur, 2018). The SQD model by Tondeur et al. (2018) is a framework designed to improve the preparation of pre-service teachers for effective technology integration in education. Although this model is only targeted to one of the aspects of pre-service teacher preparation for digital transformation, it is particularly significant, as it provides a structured approach to understanding and implementing technology integration (Knezek et al., 2023; Tondeur et al., 2020, 2019). The model synthesises qualitative research findings to identify key strategies that can be employed in teacher education programmes. These strategies, along with their characteristics and benefits derived from the literature, have been systematically organised by the author and are presented in Table 1.

Table 1. Description and benefits of SQD strategies.

Practical Strategy	Description	Advantages
Teacher Educators as Role Models	Teacher educators to demonstrate effective technology use in their own teaching.	By serving as role models, educators can influence pre-service teachers' attitudes and competencies regarding technology integration (Tondeur et al., 2017a, 2019; Bwalya et al., 2023). Research indicates that when pre-service teachers observe their educators using technology effectively, they are more likely to adopt similar practices in their own classrooms (Baran et al., 2019; Tondeur et al., 2019).
Reflection on Technology's Role in Education	Pre-service teachers to reflect critically on how technology can enhance learning outcomes.	Reflection helps pre-service teachers understand the pedagogical aspects of technology use and encourages an attitude towards continuous improvement in their teaching practices (Tondeur, 2018; Aslan & Zhu, 2016). Studies have shown that reflective practices can significantly enhance pre-service teachers' confidence and competence in using technology (Howard et al., 2019).
Instructional Design with Technology	Equipping pre-service teachers with the skills to design instructional materials that effectively incorporate technology.	This strategy aims for a systematic approach for integrating technology into lesson planning, ensuring that technology serves a learning goal rather than being used for its own sake (Kukul, 2024; Tondeur et al., 2019; Tondeur, 2019). Effective instructional design is critical for maximising the educational benefits of technology (Zhang & Tang, 2021; Aslan & Zhu, 2016).
Authentic Experiences	To provide hands-on experiences where pre-service teachers can practice using technology in real or simulated classroom environments.	Experiential learning allows pre-service teachers to apply theoretical knowledge in practical settings, thereby enhancing their readiness to integrate technology into their future teaching (Tondeur et al., 2017b, 2018; Bwalya et al., 2023). Evidence suggests that experiential learning significantly boosts pre-service teachers' confidence and skills in technology integration (Baran et al., 2019; Tondeur et al., 2019).
Collaboration	To promote collaborative learning among pre-service teachers, encouraging them to work together to solve problems and share insights related to technology integration.	Collaborative environments foster a sense of community and support, which can improve learning outcomes and prepare pre-service teachers to work effectively in teams (Tondeur et al., 2021, 2019). Research has shown that collaborative learning can lead to improved technology integration skills among pre-service teachers (Howard et al., 2019).
Feedback[2]	To provide constructive feedback to pre-service teachers regarding their use of technology in teaching.	Feedback helps pre-service teachers to identify areas for improvement and reinforces effective practices, contributing to their overall professional development (Kukul, 2024; Tondeur et al., 2019). Studies indicate that timely and specific feedback is crucial for developing pre-service teachers' competencies in technology integration (Baran et al., 2019; Bwalya et al., 2023).

In addition to the SQD model, the Diana Laurillard Conversational Learning Framework (Laurillard, 2002) offers a valuable approach to preparing future teachers for integrating technology into the classroom. It includes six types of learning activities:

(1) Acquisition (students learn new information by reading, watching, or listening);
(2) Investigation (students explore, compare, and analyse concepts and ideas, developing critical thinking);
(3) Practice (students apply what they have learned in practice, improving their skills through exercises and tasks);
(4) Production (students create their own materials or projects, demonstrating understanding and creativity);

(5) Collaboration (students work in a team, exchanging ideas and knowledge to achieve common goals);
(6) Discussion (students participate in discussions, sharing opinions and receiving feedback, which helps a deeper understanding of the material).

This framework emphasises the importance of diverse learning activities that engage students in meaningful interactions with technology, fostering active learning and adaptability in the digital age. However, key to the development of PDCs is the practice that allows learners to apply theoretical knowledge, thus leading to a better understanding and development of skills, as well as the acquisition of complex concepts and procedures (Laurillard, 2012). Participating in hands-on activities allows pre-service teachers to effectively integrate digital tools into their teaching methods. Collaboration and discussion are also essential, as they encourage the exchange of ideas and experiences, which has the potential to lead to a deeper understanding of digital pedagogy (Laurillard, 2012).

Another framework suitable for examining the digital transformation of learning is Digital Technology Impact Framework (DTIF) by Aubrey-Smith and Twining. When learning with technology, the DTIF model identifies three modes of technology use in education—support: technology is used to enhance existing teaching practices without changing them fundamentally; extend—technology enables teaching and learning experiences that go beyond what is possible in a traditional classroom (e.g., enabling collaboration across distances or providing access to a broader range of resources) and transform—fundamental change of the way education is delivered, creating entirely new teaching and learning practices.

To summarise, preparing pre-service teachers for digital transformation involves implementing practical strategies that align with both theoretical frameworks and hands-on experiences, which are emphasised as very important to integrate technology in teacher education (Knezek et al., 2023; Basilotta-Gómez-Pablos et al., 2022; Jimarkon et al., 2021; Romero-García et al., 2020; Sondermann et al., 2017).

2.3. University Teachers' Views and Their Influence

All the above strategies play a key role in the preparation of pre-service teachers, but it should be borne in mind that a significant role in university teachers' teaching practices is played by their pedagogical beliefs and views on digital transformation. The importance of aligning pedagogical beliefs with the use of digital technology in education has been repeatedly emphasised in the literature (Tondeur et al., 2017c; Twining et al., 2013). Research indicates that teacher educators' beliefs about technology directly impact their instructional strategies and the learning experiences they provide for pre-service teachers (Tondeur et al., 2017c). In addition to beliefs, teachers' attitudes also play an important role—teachers with a positive attitude towards digital tools are more likely to incorporate them effectively into their teaching strategies, thereby enhancing student engagement and learning outcomes (Sjöberg et al., 2024; Voithofer & Nelson, 2020). The influence of teachers' views on practice is evident in studies that demonstrate a correlation between educators' digital competence and their willingness to experiment with new teaching methodologies (Howard et al., 2019). The interrelation between teachers' views on digital education and their teaching practices is further emphasised by the observation that teachers with a higher self-assessment of their digital competence are more likely to use technology in ways that support and extend learning, rather than merely using it as a substitute for traditional methods (Scherer et al., 2017). However, the impact of these views on practice can be complex, as even teachers with similar levels of digital competence may adopt different instructional strategies, influenced by their broader educational philosophies and the specific context of their teaching (Sjöberg et al., 2024; Wohlfart & Wagner, 2023), and

by various other factors, including the availability of resources, administrative support, and professional development opportunities (Levin & Wadmany, 2006). Thus, fostering a holistic understanding of digital education among university teachers which includes their competences, beliefs, contextual factors, and attitudes, is essential for promoting effective and innovative teaching practices in the digital age.

Therefore, this study aims to explore university educators' views on digital transformation and preparation of pre-service teachers for it. Also to identify the practical strategies educators use to prepare pre-service teachers for digital transformation. In order to fulfil these goals, an empirical study was conducted at the largest university in Bulgaria, which prepares the main share of teachers in the country—Sofia University "St. Kliment Ohridski". First, we will describe the national context in which the study is conducted.

2.4. Bulgarian Context

In Bulgaria the development of pre-service teachers' digital competences is influenced by the European Digital Competence Framework, and the Digital Education Action Plan, which Bulgaria has chosen to implement, as well as the unique organisational structure of teacher education in the country. Bulgaria faces specific challenges and opportunities in this regard, shaped by its educational policies, cultural factors, and the existing infrastructure for teacher training. The organisation of Bulgarian teacher education is distinct, often characterised by a centralised system that may not always align with the rapidly evolving demands of digitalisation. Teaching capacity is typically acquired after a 4-year bachelor's or 2-year master's degree (for primary and preschool teachers) or after a bachelor's degree in various subjects (e.g., mathematics, literature, biology, etc.) and a one-year pedagogical specialisation (master's or CPD programme). Bulgarian *Ordinance on the state requirements for acquiring the professional qualification* "Teacher" (2021) provides in the university preparation of pre-service teachers only one compulsory course in the field of pedagogical digital competences, named "Information and Communication Technologies in Education and Work in a Digital Environment" and two optional courses, named "Digital Competence and Digital Creativity" and "Development of Lessons for Learning in an Electronic Environment." Additionally, in the other academic courses there is also a potential for pedagogical digital competences of pre-service teachers to be developed, yet, there are not any specific regulations for this. Kiryakova and Kozhuharova (2024) stated that the issues related to the development of digital competences should be addressed in the curricula of Bulgarian educational organisations as they should offer flexible study programmes to prepare future teachers to work in a digital environment. Bulgarian research demonstrates the need for systematised approach to support the development of digital competences, in accordance with existing frameworks and national regulations (Kiryakova & Kozhuharova, 2024), which should encompass strategies that focus on pedagogically effective application of digital technologies to improve teaching and learning (Nikolova et al., 2024; Mizova & Peytcheva-Forsyth, 2024). It is evident that national policies, documents and research mainly focus on the aspect of digital transformation related to the improvement of educational outcomes. Studies in Bulgaria emphasise that teachers actively use digital technologies, but continuous professional development and effective strategies to improve teacher qualifications in the digital domain are needed to ensure their adaptation to the rapidly changing digital landscape (Kiryakova & Kozhuharova, 2024; Nikolova et al., 2024; Mizova & Peytcheva-Forsyth, 2024; Peytcheva-Forsyth & Racheva, 2024; Musić et al., 2020), thus replicating the results from international studies cited in previous sections. Furthermore, according to Eurostat (2024), Bulgaria ranks among the lowest in the European Union in terms of digital skills, with only Romania scoring lower.

This demonstrates the need for targeted interventions to improve digital literacy, for which the adequate preparation of pre-service and in-service teachers plays a key role.

In addition to the specifics of the structure of teacher training, the Bulgarian context of digital education is also influenced by other factors. Bulgaria is a country with a declining and aging population, which poses challenges to the education system. As one of the economically weaker countries in the European Union, Bulgaria has limited financial resources, which makes it difficult to adequately invest in technological infrastructure and personal training. In addition, the country continues to experience the consequences of the evolution of the education system after the communist period, with some traditional teaching methods remaining resilient. Digital literacy issues are particularly relevant in this context, as the level of digital competences among teachers and students varies widely. According to a study by Peytcheva-Forsyth and Racheva (2024), based on SELFIE (Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies) for teachers[3], 60% of the 96 university professors from Sofia University surveyed assessed their PDCs at an intermediate level (B1 and B2), which demonstrates their confidence in the use of digital tools and methodologies in teaching practice. Of these, 21% considered themselves experts (level B2), and 15% of respondents assessed themselves at the C1 level, which means that they not only master digital tools, but also motivate and guide others to use them. (The level of self-assessment of the 418 schoolteachers surveyed in the same study varies in the different subdomains, mainly between A1 and B1.) Bulgarian results were similar to those obtained for teachers around the world in self-assessment against the DigCompEdu standards (Inamorato dos Santos et al., 2023; Cabero-Almenara et al., 2023; Santo et al., 2022) and placed the average level of self-assessment of university teachers' PDCs at intermediate (B1).

In conclusion, in order to prepare pre-service teachers for digital transformation, the effective development of their PDCs is necessary. This development depends to a large extent on the learning strategies used, the learning activities implemented, but also on the views and beliefs of university professors, which are central to shaping their teaching practices, especially in the context of digital integration. Aligning pedagogical beliefs with learning strategies, promoting a positive attitude towards technology, and ensuring continuous professional development of teachers are essential for improving teaching practices and digitally transforming education. Therefore, the focus of this study will be on the exploration of university educators' views regarding digital transformation and preparation of pre-service teachers for it. The answers to the following questions will be sought:

RQ 1: *What views do university educators hold regarding the digital transformation of education and preparation of pre-service teachers for it?*

RQ 2: *What practical strategies do university educators employ in their courses to develop pedagogical digital competences of pre-service teachers?*

RQ 3: *To what extent do the observed teaching practices align with the views expressed by university educators?*

The answers to these questions will contribute to the existing literature on teacher education and digital transformation and will have some practical implications for curriculum developers and policymakers.

3. Methodology

3.1. Research Design

The aim of this study is to explore university educators' views on the digital transformation of education and the preparation of pre-service teachers for it, identifying the practical strategies they use to develop pedagogical digital competences and examining the alignment between their expressed views and observed teaching practices.

The research design employed mixed quantitative and qualitative methods, which include curricula analysis, semi-structured interviews, short surveys, and observations. The curricula analysis was based on the DigCompEdu framework to explore the declared topics and strategies for preparing pre-service teachers for digital transformation. The interviews of university teachers build on this and explore their views on the digital transformation and preparation of pre-service teachers for it. In addition to the interviews, the university teachers were asked to fill out a short survey to self-assess their practical strategies for the development of the PDC according to the SQD model. The SQD tool used for the survey is a Bulgarian translation of the instrument validated by Knezek et al. (2023). The survey is subsequently compared with the observations. Real practice observations aim to identify university teachers' practical strategies for preparing pre-service teachers for digital transformation. This design enables data triangulation, ensuring a more robust and comprehensive analysis. The research methodology follows the multi-perspective approach described by Mizova et al. (2025), which, like the present study, was developed under the SUMMIT project. All research tools were also created within the framework of this project.

Our data analysis included a content analysis of 48 course curricula. The thematic analysis for interview data (45 respondents) explored university teachers' views on digital transformation and the development of pedagogical digital competences, their approaches, and practical strategies to teach PDC. The qualitative analysis software Quirkos[4] was used to support the analysis. The university teachers' practical strategies were also investigated through a short questionnaire based on the SQD model. Most observations (43) were made in three different classes, each lasting about 90 min, for each university teacher. The remaining observations (5) were conducted in two longer sessions, each around 120 min. In total, 139 observations were carried out.

The frameworks applied to the analysis of the interviews, questionnaire, and observations, include:

- DigCompEdu framework, including its six subdomains (professional engagement, digital resources, assessment, teaching and learning, empowering learners, and facilitating learner's digital competence) and six proficiency levels (newcomer, explorer, integrator, expert, leader, and pioneer);
- Tondeur's SQD model (role model, reflection, instructional design, access to resources, authentic experiences, and feedback);
- Diana Laurillard's Conversational Framework—six types of learning activities (acquisition, collaboration, discussion, investigation, practice, and production);
- Digital Technology Impact Framework (DTIF) by Aubrey-Smith and Twining, including three modes of technology usage in education (support, extend, and transform).

3.2. Sample

The SUMMIT project, of which this study is part, encompassed more than 80 university teachers from all 16 faculties of the Sofia University "St. Kliment Ohridski" (Bulgaria), involved in the preparation of pre-service teachers. This was a convenience sample of all teachers in Sofia University who teach core courses according to the Bulgarian Ordinance on the state requirements for acquiring the professional qualification "Teacher", divided into

the following groups—general pedagogical, psychological, methodological, and ICT-based courses. Methodological courses prepare future teachers to teach and manage learning processes in specific subjects, integrating modern pedagogical approaches and technologies (e.g., "Methodology of Teaching Geography", "Methodology of Teaching Chemistry", and "Methodology of ICT Education"). ICT-based courses focus on the use of ICT in education. The compulsory course, "ICT and Work in a Digital Environment", aims to develop the skills of pre-service teachers regarding the integration of digital technologies into teaching. Additional courses, such as "Instructional Design for Technology Enhanced Learning" and "Pedagogical Functions of Interactive Whiteboard", further enhance their digital competencies. Future teachers typically study multiple methodological courses and at least one ICT course as part of their training.

For this study, only courses in methodological and ICT-based courses have been selected, which are expected to develop key competencies, including PDC. There was a total of 54 courses. All data collected were reviewed for completeness, and only courses for which curriculum was available, interviews carried out (including the short SQD survey), and observations were conducted, were included in the study. As a result, 48 courses were included in the study, all of them compulsory, of which 22 are ICT-based and 26 are methodological (the full list and descriptions of all included courses are given in Supplementary Materials). It is important to note that not all of these courses encompass practical sessions. The Bulgarian Ordinance on teacher qualification specifies as mandatory only the number of lecture hours in the only mandatory discipline "ICT and work in a digital environment", i.e., there is no obligation to undertake practical ones. Yet, most curricula of ICT courses (20) provide practical (hands-on) classes, seminars, or both. Only 3 of the ICT programmes provide just lectures and no seminars/practical classes. In the methodological curricula, however, in seven disciplines, there are no seminars/hands-on classes provided. Four of them are in a bachelor's degree and are basic, e.g., Methodology of Teaching Bulgarian Language, and Methodology of Teaching Biology and the History Lesson. The master's course curricula do not provide seminars/practical classes in the Methodology of Teaching Chemistry or in the Methodology of Teaching Physics and Astronomy.

There was a total of 44 university teachers who taught in the sample courses. Their profiles are presented in Table 2.

Table 2. Participants' profile.

Participants	Total №	Courses Taught (Total Courses 48)	Gender	Academic Position
Participants in the interviews	44	23 in methodological courses (1 of them teach in 2 courses)	Female—28	Assistant Professor—5
		19 in ICT-based courses (1 of them teach in 2 courses)	Male—16	Senior Assistant Professor—14
		2 teachers in both ICT and Methodological courses		Associate Professor—19
				Professor—6

3.3. Procedure

The study was implemented from November 2023 to February 2024. Firstly, the curricula for the selected representative courses were analysed. Then, all university teachers were sent short surveys to self-assess their teaching strategies according to the SQD-model in the corresponding courses. After their self-assessment, interviews were administered (December 2023–March 2024) and afterwards, observations of their teaching practices were conducted (January and April 2024). The observations included three study sessions for each teacher.

Ethical Considerations

The research follows the ethical guidelines of Sofia University "St. Kliment Ohridski" and complies with national and institutional regulations regarding academic research. Prior to data collection, informed consent was obtained from all participating university teachers. The nature, purpose, and scope of the study was explained to each participant, including how the data would be used and the measures in place to ensure confidentiality. Participants were informed of their right to withdraw from the study at any point without any consequences. Data were anonymised during analysis and reporting to protect the identities of participants. The study guarantees that all participants' rights, privacy, and professional integrity are respected throughout the research process.

4. Findings

4.1. Findings on University Teachers' Declared Practices and Curricula Content for Preparing Pre-Service Teachers for Digital Transformation

4.1.1. Findings from the Analysis of Curricula

In order to find out what university teachers envisage in the preparation of future teachers for digital transformation, what goals they address, and what strategies they declare, their course curricula were reviewed and analysed. The total number of curricula analysed was 48, of which 22 were ICT-based courses and 26 were methodological courses. At Sofia University, the curriculum of the course is written in a specific form, which includes information about the workload, assessment, annotation of the course, prerequisites, learning outcomes, learning content, exam synopsis (if any), and bibliography.

The analysis of the curricula of ICT and methodological courses at Sofia University reveals a fragmented approach to the development of pedagogical digital competences of pre-service teachers. ICT courses focus on the DigCompEdu areas the Creation of Digital Resources (18 curricula) and Teaching and Learning (13 curricula), including topics such as the Management of Learning in Electronic Environments and the Use of Interactive Technologies. Conversely, methodological courses offer significantly less explicit digital-related content, with most references being implicit. The areas of DigCompEdu that are found explicitly addressed in the courses are presented in the Figure 1.

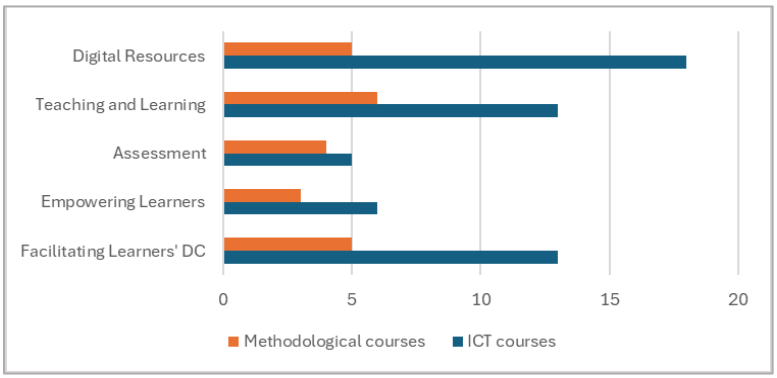


Figure 1. DigCompEdu areas addressed in course curricula.

The ICT courses are aimed at simultaneously developing basic digital competencies in pre-service teachers (skills for working with various software applications, creating and processing multimedia materials) as well as some PDCs, such as the use of electronic platforms and apps for learning and assessment and developing critical thinking in the use of digital resources. However, there are different approaches to the scientific content in "ICT and Learning in a Digital Environment" in the different faculties of Sofia University. Some curricula focus more on general digital competencies, while others focus on pedagogical

ones. For example, in seven courses, there are specific goals related to e-learning (e.g., at the Faculty of Pedagogy, trainees are expected to learn "skills for designing e-learning—development of asynchronous lessons in the e-learning environment Moodle"). Half of the curricula (11) have an explicit focus on the design and development of teaching materials and their integration into relevant subjects (e.g., in the Faculty of Mathematics programme, future teachers will learn the principles and approaches for the effective development of teaching materials and how to present them effectively to learners).

Only six of the methodological courses encompass explicit learning content or expected learning outcomes that are related to the development of the PDCs. For example, disciplines such as "Didactics of Engineering and Technology" and "Methodology of Geography Education" clearly indicate the use of digital technologies in the educational process (learning content topics are included, such as "Conducting training in technology and entrepreneurship in an electronic environment (virtual classroom)", "ICT—essence, features, place in geography education"; or "work on fine arts in online galleries"). A total of 18 courses could provide methodological training in the field of digital technologies, but in an implicit form. For example, the curriculum on the methodology of the "Didactics of Science in the Primary School" includes the topic "the use of teaching aids and didactic materials in the teaching", which also implies the use of digital technology; however, this had to be verified by observations. Few curricula (3) focus on modern educational strategies such as constructivist approaches or interactive methods, which are often related to digital technologies. However, this is not specifically mentioned in these curricula—they only include learning content topics such as "Constructivist approach in science education—Principles of Constructivist Teaching and Learning"; "Interactive Methods in Teaching Chemistry" (Methodology of Teaching Chemistry); or "Interactive Methods in Literary Education—the Constructivist Design of Learning as an Interactive Teaching Practice" (Methodology of Literature Education), etc.

While many courses address PDC in areas such as digital resources, teaching, and learning, other critical areas such as assessment and learners' empowerment are underrepresented. In addition, there is also a lack of a systematic approach to teaching pre-service teachers how to develop the digital skills of the students, even in the core methodological course curricula as "School course on information technology".

Given the fact that pre-service teachers attend several methodological courses and at least one on ICT, the need for a coordinated integration of pedagogical digital competencies into methodological courses is clearly outlined. At the national and university levels, however, there is a lack of clear coordination between ICT and methodological courses. This issue is further complicated by the autonomy of Sofia University lecturers in determining the content of their courses, which highlights the need for guidelines to ensure consistency in the development of their PDC.

4.1.2. Findings from the Analysis of SQD-Survey

A short survey was provided for the university teachers as the first part of the interview. The interviewers received the results in advance so that they could use them during the interview. The questionnaire was filled out by hand or in an electronic file by the university teachers and was sent to the interviewers. In the survey, each teacher had to evaluate to what extent they applied each of the SQD strategies. For each strategy, four sub-strategies were proposed, to be evaluated in a six-point Likert scale, with the lowest level being "completely disagree" (1) and the highest "completely agree" (6). All the university teachers in the sample (44) participated by filling in the survey for all the sample courses in which they teach (a total of 48–22 from ICT-based and 26 from methodological courses). As some teachers teach in more than one course, only one survey response per teacher was

selected in our comparative analysis. For teachers teaching several courses of the same type, one course was randomly selected. For the two teachers who teach both ICT and methodological courses, one was included in the analysis based on their methodological course and the other was included based on their ICT course. As a result, the final dataset consisted of 44 unique survey responses to ensure that each participant was represented only once in the analysis. The summarised statistical results from the survey and the reported key practices for each strategy for all teachers are presented in Table 3:

Table 3. Statistical results and reported key practices for SQD strategies.

	Role Model	Reflection	Instructional Design	Collaboration	Authentic Experiences	Feedback
Mean	5.3	4.9	5	4.8	4.6	4.5
Standard deviation	0.5	0.4	0.6	0.4	0.4	0.5
Min. value	2	1	1	1	1	1
Max. value	6	6	6	6	6	6
Key Practices Reported	Giving examples of using ICT in educational setting, demonstrating best practices	Assisting pre-service teachers in designing lessons that (fully) integrate ICT	Providing opportunities for pre-service teachers to reflect on the role of ICT and discuss the challenges of ICT integration	Encourage collaboration and sharing experiences among students and teachers	Providing opportunities for pre-service teachers to test different ways of using ICT	Providing sufficient feedback and guidance and regular assessment on ICT competence development

According to the survey results, teachers of ICT courses generally point out that they apply most strategies compared to teachers in methodological disciplines. Yet, both groups had the highest degree of agreement that they use the strategies role model (5.3) and learning design (5) (see Table 3). The lowest-scoring strategies, authentic experience (4.6) and feedback (4.5) highlight a gap in opportunities for pre-service teachers to practice ICT integration in real classroom settings. While many educators claim that they create opportunities for students to test different ways of using ICT, hands-on training remains limited, which can be explained by the fact that not all the courses encompass practical sessions (see the Section 3 for details).

In Table 4, the mean values of the two groups of lecturers in ICT or Methodological courses are also indicated. To compare and establish statistically significant differences between the two groups, a T-test was done. For each strategy (Role Model, Reflection, Instructional Design, Collaboration, Authentic Experiences, and Feedback), the differences between the two groups of teachers—those who teach ICT courses and those who teach methodological courses—were tested. The following hypotheses were formulated:

Null hypothesis (H_0): There is no statistically significant difference between teachers in ICT courses and those in methodological courses in terms of the use of a given strategy.

Alternative hypothesis (H_1): There is a statistically significant difference between teachers in ICT courses and those in methodological courses in terms of the use of a given strategy.

Before conducting the calculations, statistical significance was determined using a 95% confidence level, where the absolute value of the t-statistic exceeded 1.96 ($|t| > 1.96$). A difference between two groups was deemed statistically significant when the probability of

the null hypothesis being true (i.e., results occurring due to chance or sampling error) was less than 5%, as indicated by a p-value below 0.05 ($p < 0.05$).

Table 4. Comparison of teachers of ICT and methodological courses.

	Role Model	Reflection	Instructional Design	Collaboration	Authentic Experiences	Feedback
Teachers of ICT courses—Mean	5.7	5.1	5.4	5.2	4.8	4.9
Teachers of Methodological courses—Mean	4.8	4.7	4.5	4.5	4.5	4.2
T-statistic	2.5	2.5	2.6	2.6	2.7	2.7
p-value	0.02	0.01	0.01	0.01	0.01	0.01

Not surprisingly, the results of the T-test (see Table 4) demonstrate that there were statistically significant differences between educators of ICT courses and those in methodological disciplines in all strategies. Since the p-values for all strategies were less than 0.05, the null hypothesis (H_0) was rejected and it was accepted that there was a statistically significant difference between the two groups of teachers for all strategies. Teachers of ICT courses declared that they use all the strategies significantly more actively compared to methodological teachers. The differences were statistically significant ($p < 0.05$) for all strategies, suggesting that teachers of ICT courses are more committed to demonstrating effective practices for integrating ICT into education by providing students with examples and guidance on using technology in the classroom. Although this was likely due to their specialisation and experience in the field of ICT, its impact will be further explored in the findings in the Observations section, particularly in relation to different aspects of digital transformation.

4.1.3. Findings from the Interviews Analysis

To take a deeper look at what views university educators hold regarding the digital transformation of education and preparation of pre-service teachers for it, and to find out what practical strategies they employ in their courses in this respect, 44 university teachers who teach ICT and methodological courses (a total of 48 courses—22 ICT-based and 26 methodological courses—see the Section 3) were interviewed. The semi-structured interviews were based on DigComp 2.2. and DigCompEdu and were analysed using qualitative categorical analysis, applying a hierarchical coding approach. The coding process was based on a set of predefined categories aligned with the interview questions, supplemented by additional codes that emerged inductively from the data. The predefined categories included: Discussion of the interviewee's SQD survey responses; Discussion of curriculum documentation; Teacher's views on digital education; Teacher's views of constraints; Teacher's digital pedagogy; Teacher's practice; Students' digital competences; Developing students' digital competences; and Students' pedagogical digital competences (Developing students' pedagogical digital competences; Developing students' self-regulative knowledge; School pupils' digital competences; Developing critical digital literacy; and Assessment of students' pedagogical digital competences). During the coding process, additional subcategories were inductively derived, reflecting emerging themes in the data.

For the following analysis, two sets of teachers' views were distinguished—(1) views on the preparation of future teachers for digital transformation of education, and (2) practical strategies for the development of pedagogical digital competencies of future teachers. Limitations in these processes are also presented under these same headings.

Views of University Teachers on the Digital Transformation of Education and the Preparation of Pre-Service Teachers for It

University teachers see digital transformation as necessary and useful for modern education. For 36 respondents, digitalisation in education is a requirement of the present (54 mentions). Some of them highlighted that ICT skills are important for labour market competitiveness (20 mentions by 17 respondents). They share that: "*it is absolutely necessary to prepare students for life in the digital age, as technology enters all areas, and in a number of areas in our time, digital competence is required*." (Assistant in an ICT course). However, some of the teachers expressed this need in a more neutral way: "*For better or worse, we are contemporaries and live in the digital age, and adapting to these conditions is imperative*." (Professor in a methodological course). In general, what most teachers shared was related to the need for digital transformation of education in view of the world we live in, and not, for example, to improve the quality of education. Other aspects of digital transformation related to adapting to student expectations in the digital age also surfaced from teachers' responses. However, this in itself does not guarantee an improvement of educational outcomes, nor the preparation of students for the digital world, but rather, an acceptance of the fact that this is the reality, and we must comply with it. Another example is the following opinion: "*Material development today means the development of technology, including digital technologies. They determine our life, our activity. They are a given. We exist in it and we must take them into account in our daily lives and in our studies*." (Associate Professor in methodological course)

Many university teachers agreed that the teaching of digital competences should be a mandatory part of education (27 respondents, 51 mentions): "*The future teachers must have high levels of digital competence in order to be able to successfully carry out their professional and pedagogical commitments*" (Associate Professor in an ICT course), "*especially after Covid 19, this is imperative"* (Professor of a methodological course). Although some educators in methodology courses emphasised that digital technologies could improve the quality of school lessons ("*A history lesson cannot be prepared qualitatively and interestingly without the use of digital technologies, and therefore the mastery of PDC. The present school generation learns best through the use of ICT*"—Associate Professor in a methodological course), generally, the focus that educators place on the digital transformation is the use of technology as a means of supporting teaching. Only the ICT Associate Professor from the Faculty of Education shared that the use of digital technologies increases the activity and motivation of students ("*For me, the most important functions of ICT in the classroom are to support learners' learning, to increase their interest, activity and motivation*".) Additionally, very little is mentioned about the need to prepare future teachers to develop digital competences in students. What was felt in a large part of the interviews was that the teachers do not appreciate this key aspect of digital transformation. Only two teachers of ICT courses focused on this aspect: "*. . .students must have digital literacy and digital competencies not only as citizens, but also as teachers . . .. not only to use technology effectively, but also to teach children to do it, for which they need to have slightly different competencies; . . .. I repeat many times to the pre-service teachers that technology should be used purposefully and should serve clear pedagogical goals, not just be used for the sake of modernity*." (Associate Professor in ICT who prepares primary teachers); "*. . . universities should prepare future teachers to use ICT, to respond to children's interests, to motivate them to learn, to develop their creativity and to increase their independence*." (Associate Professor in ICT from Faculty of Education).

The responses of the university teachers imply that they probably do not distinguish among the different aspects of digital transformation. This, in turn, potentially means that they are also unaware of their role in this process. Teachers of ICT courses tend to associate digital transformation more with the improvement of educational goals, instead

of preparing students for the digital society, which is rather a priority for teachers of methodology courses. This focus is expected in specialised methodological courses which prepare pre-service teachers to teach ICT, but not for the others. Furthermore, while teachers of methodology courses acknowledge the importance or preparing students for the digital age, their descriptions of instructional practices focus primarily on using technology as a support tool for learning rather than actively fostering digital competencies in students. These results suggest that there is some confusion in teachers' understandings and priorities, implying that teachers need guidance.

Pedagogical Preparation of Future Teachers for Digital Transformation in Education

In response to the question "Do you think it is important to develop pedagogical digital competencies in pre-service teachers and why?", all interviewees believed that the development of pedagogical digital competencies is important and necessary. The main factors that educators identified concerning the importance of developing PDC included the needs to adapt to new technologies, improve the learning process, and to facilitate communication and interaction with students—"*For me, it is extremely important to develop PDC in students-future teachers. They must have both theoretical knowledge about the possibilities of technology in teaching the subject they teach, as well as methodological skills to properly integrate technologies and, last but not least, to be able to work with various software and applications to achieve the pre-set educational goals*"—Associate Professor in an ICT course. From the answers of the university teachers, it is obvious that the reasons for the importance of PDCs do not include the development of skills to prepare learners for the digital age. In general, their focus has shifted entirely to the first aspect of digital transformation—improving educational outcomes. This is also supported by the opinions expressed by teachers related to key PDCs for the successful professional realisation of future teachers, which they define as creating digital learning content/resources (74 mentions from 36 respondents) and working with digital learning resources/tools (65 mentions from 26 respondents). According to the respondents, these competences are important because they support better teaching and understanding of the learning material and could facilitate communication and collaboration between teachers and students and improve the assessment process.

However, in order to prepare learners for the digital world, it is important that pre-service teachers themselves develop their own critical thinking in a digital context. In this direction, when discussing the development of general (non-pedagogical) digital competences of future teachers, the development of critical digital literacy is the most frequently mentioned category by university teachers, with nearly 200 mentions (42 respondents), equally between ICT and methodological teachers. What makes an impression is that teachers deeply appreciate the need for critical evaluations of information, the importance of safety, and ethical issues (including those related to AI) by the future teachers. Some such examples are presented in Table 5:

Table 5. University teachers' statements about critical digital literacy of pre-service teachers.

Critical Digital Literacy Aspect	University Teachers' Quotes
Data privacy	*"Above all, I pay attention to privacy when working in a digital environment, especially to students (pre-service teachers—author's note) to be careful where and how they leave their data." (associate professor in ICT course)*
Data security and safety	*"Privacy, monitoring, data security—these are questions that we usually consider in the context of using social networks. Security, safety—such topics." (professor in methodological course)*

Table 5. *Cont.*

Critical Digital Literacy Aspect	University Teachers' Quotes
Ethical issues	*"Teaching and discussing these and other ethical issues, in turn, helps future teachers to understand the characteristics and impact of information technology on society and learn how to use it responsibly and effectively, as well as ethically, of course." (associate professor in methodological course)*
Data and information literacy	*"Working with data and information is something that is key in this case. And certainly, part of their grade depends on how they did in the course with this type of literacy." (senior assistant in ICT course)*
Critical evaluation of digital resources	*"…. the final requirement for students is that they plan a whole lesson in which technology is intensively used for different purposes, and if years ago I required them to develop the appropriate resources, now I do not require it—I demand that they have effectively and critically selected those which are relevant and can support the corresponding goals." (ICT associate professor)*

Despite the fact that teachers claimed that they develop pre-service teachers' critical digital literacy, which is a prerequisite for the building of similar literacy in pupils, the university teachers did not discuss at all the development of the 6th DigCompEdu domain "Facilitating learner's digital competences". This omission raises questions about the extent to which they actively address this aspect in their teaching. In order to look deeper into this issue, an interview with a teacher who prepares pre-service teachers to teach ICT was specially analysed in more depth. This associate professor teaches the course that, according to its official curriculum, aims "to prepare students in a theoretical, technological and organisational plan for conducting the training in computer modelling and ICT in the real conditions and specifics of the Bulgarian school". In his interview, when discussing PDCs of pre-service teachers, he only emphasised the importance of teaching safety rules and giving more examples to pupils, thus applying a more practical approach. According to him, such an approach should be used regardless of what is included in the textbooks, because it cannot describe all real threats in the digital world. In no other part of the interview did this lecturer comment on the pedagogical preparation of pre-service teachers in terms of preparing pupils for the digital age. The main focus in his whole interview was the low level of basic digital competences of pre-service teachers, which he attributed to their poor preparation at school. At the same time, this teacher himself did not demonstrate a strong focus on improving this preparation. This implies that even in key teacher training courses for teaching ICT, there may be a lack of active work towards the development of digital literacy of pupils.

University teachers were also asked whether they think that their academic courses contribute to the development of the PDC of pre-service teachers, and most of them agreed. Examples of contributions are related to the competencies that they consider most important—the use of digital resources and tools in the learning process, creation, and adaptation of digital content. It is noteworthy that seven of the lecturers (all in methodological disciplines) stated that they do not purposefully develop PDC, which could mean that they rely on ICT educators for this. Although there was a general agreement on the importance of PDC and the need for their development in the learning process, educators do not purposefully prepare pre-service teachers to teach pupils key skills related to digital transformation, such as digital literacy for working with data and information, critical thinking, ethical issues, etc. Many teachers pointed out different limitations in teaching and developing PDC, which are obstacles to the digital transformation at the university itself. These obstacles are mainly related to the material base and the lack of sufficient funding for the purchase of technological means and are presented in the Table 6:

Table 6. Limitations in teaching and developing PDC according to university teachers.

Limitation	University Teacher Quotes
Deficiencies in the material and resource environment (68 mentions, 31 respondents)	*"... in this faculty many people want to be in a computer lab, and not all rooms are such ... about the whiteboard course, because the topic for interactive whiteboard is integrated into the course, we are usually not in the room where there is an interactive whiteboard. This is a kind of limitation. " (professor in methodological course)* *"For me, the restrictions are mainly technical, related to available technology" (assistant professor in ICT course)* *„... everything current teachers have access to, should also be accessible to future teachers, including the "Digital backpack" (a platform with open e-resources for teachers—author's note), electronic diary, and other tools." (associate professor in ICT and methodological courses)* *"The main limitation is the lack of affordable educational software for students to work with... universities need to allocate funds for the purchase of such software in order to develop digital competencies in future teachers". (associate professor in ICT course)*
Regulatory restrictions (44 mentions, 20 respondents)	*„Regarding the institutional context and national policy, it is very limiting for me that the use of specific technologies is required, for example, Microsoft office." (assistant professor in ICT course)* *"...at the institutional level, it would be good to make a decision on the mandatory use of Moodle even for full-time and part-time students as administrative support." (associate professor in ICT course)* *"Building STEM Classrooms everywhere (in schools—authors note), but not in the faculties" (senior assistant professor in methodological course).* *"Practical training in delivering lessons with ICT is needed." (assistant professor in ICT course)* *"The Qualification Ordinance requires very few courses in the field of ICT (associate professor in ICT course)* *"... universities are not sufficiently included in the so-called qualification courses of teachers (in the Ordinance)... here is my experience ... these courses... are not well done ... they are quite general and rather do not ... develop and update the skills and competencies of teachers. And I think that universities should be much more seriously involved in such programmes with qualification courses for teachers..." (assistant professor in ICT course)*
Deficiencies in the digital competence of pre-service teachers (22 mentions, 13 respondents)	*"I encounter difficulties primarily in master's and CPD programs, where motivation to work with technology is weaker." (associate professor in ICT)* *"Unfortunately, I cannot guarantee overall high results (regarding PDC—author's note), because really the basic competencies are too different and sometimes, they are an obstacle." (associate professor in ICT course)* *"... surprisingly, many master's students struggle with even basic tasks, such as writing with a text editor or searching for relevant information for their assignments." (senior assistant professor in methodological course)*

In addition, one lecturer pointed out as a restriction "the lack of interest of students in working in the course" (Assistant Professor in an ICT course), but found that this restriction was "directly related to the limitations I have already mentioned—the lack of the necessary technical equipment in the classrooms in which we work". In this conclusion, the additional aspect related to the digital transformation surfaced, namely, to adapt to the expectations of the learners.

In general, university educators express concern about access to technology and material resources that hinder the effective use of ICT in education. They also note that pre-service teachers' digital competence is often insufficient. However, teachers of ICT are more explicit in pointing out these limitations. It is noteworthy that some of the regulatory restrictions are related to the requirement for the application of various software, with only two teachers mentioning the ordinance on acquiring the qualification "teacher", which

provides only one compulsory and another optional ICT-oriented disciplines. The teachers also referred to the need for practical classes, which was implied also in the analysis of the SQD survey. For the deficiencies of general digital competences in students, it should be noted that teachers detected such not only in undergraduates, but also in master's programme students. This draws attention to the implication that not only the schools but also the universities fail to sufficiently build the general digital competencies of students. Another reason may be that students in masters' programmes may have completed their undergraduate degrees at a time when digital technologies were not a compulsory part of the curriculum.

Declared Practical Strategies of University Teachers for the Development of PDC of Pre-Service Teachers

Our analysis of the declared practical strategies was based on the SQD model, which was also adopted in the survey. The declared strategies of teachers according to the SQD model are related to the integration of technologies in teaching and learning, which reflects the first aspect of digital transformation—improving educational outcomes. University teachers did not explicitly declare either goals or strategies for the development of the second aspect—preparation of learners for the digital age. Regarding practical strategies according to Tondeur's SQD model (2018), during the interview, each teacher shared additional information beyond what was indicated in the short surveys. Some of the most typical examples are presented in the following Table 7.

Table 7. Declared SQD strategies by university teachers.

Strategy	University Teachers' Quotes
Role Model (51 mentions by 29 respondents)	*"I demonstrate opportunities for the construction of creative digital practices." (associate professor in methodological course)* *"I include examples of software and applications that facilitate teaching and learning such as interactive whiteboard, Mozabook, virtual reality, computer games, social networks, etc." (associate professor in ICT course)*
Authentic Experience (40 mentions, 28 respondents)	*"I try as much as possible to provide opportunities for students to test the digital resources they have created. An example of this are the open lessons in our partner schools, where students use a demonstration with a drone, mapping with QGIS or StoryMap when developing the new educational content." (associate professor in methodological course)* *"…...students-future teachers …. create e-courseS, setting them up, adding students, and developing content of all kinds." (associate professor in ICT course)*
Collaboration (37 mentions. 26 respondents)	*"Collaboration applies to the use of digital tools for collaborative activity, for example in some of the interactive games (Kahoot) and others." (associate professor in methodological course)* *"I encourage students to collaborate in the creation of digital resources…... with joint efforts, while everyone contributes their ideas and suggestions…." (professor in methodological course)*
Instructional Design (38 mentions, 25 respondents)	*"During the practical classes, together with the students, we develop learning resources applicable in practice (at school during their pedagogical internship)." (associate professor in methodological course)* *"I pay special attention to the design of learning… It is presented how the process itself is constructed: design of activities—training, application of interactive methods leading to knowledge acquisition (i.e., learning), assessment" (associate professor in methodological course)*

Table 7. *Cont.*

Strategy	University Teachers' Quotes
Feedback (39 mentions, 24 respondents)	*"I provide sufficient feedback to students on the use of ICT in my classes when they present their course projects. I give feedback not only on the content, but also on how appropriately they used technologies for the layout and presentation of their ideas and content of the course project." (associate professor in ICT course)* *„. . .. I constantly give feedback. Feedback is extremely important in the training of the master's programmes and the postgraduate course. There I put more effort because students are not so motivated to work with technology." (associate professor in methodological course)*
Reflection (40 mentions, 21 respondents)	*"We pay special attention to reflection and try to give such tasks that make students analyse their activities, make sense of it, answer what they would improve, what they should do next time." (associate professor in ICT course)* *„After each demonstration, with the students we discuss the lesson content. We jointly outline the pros and cons . . .." (associate professor in methodological course)* *"I use formative assessment. The role of reflection is for students to improve their developments, . . . as well as to improve their future work." (associate professor in ICT course)*

The university teachers' statements reveal that, despite teaching different types of courses, they use similar strategies, with role models and authentic experiences being the most commonly declared approaches. Most strategies are widely applied, according to teachers, with minimal differences in their frequency of mention. Yet, more teachers from methodological courses indicated that they use a role model (16 methodological, 13 ICT), authentic experience (17 methodological, 11 ICT), collaboration (15 methodological, 11 ICT), and reflection (14 methodological and only 7 ICT). Many teachers (28) declared that they provide students with an authentic experience and opportunities to work with technology and design digital lessons to be tested in a real educational environment. Yet, due to some of the previously mentioned institutional limitations (lack of practical classes), some teachers explicitly shared that "*there is no opportunity for authentic teaching by pre-service teachers in a real educational environment*." (Associate Professor in a methodological course, in which no practical classes are provided). Despite its potential to improve digital skills and create a stronger sense of community among students, collaboration was less emphasised. Some teachers said that they encourage students to work in teams, share ideas and resources, create common digital products, and exchange and evaluate the created artifacts. It is noteworthy that two ICT lecturers shared that sometimes, group work is necessary due to the fact that students have to work on one device. Reflection and feedback are considered by the teachers as important for the development of students' critical thinking and self-esteem. Through reflection, students "*become aware of their own digital competence" (associate professor in ICT course)*. For the provision of constructive feedback, ongoing support and guidance teachers shared that they use various communication and assessment platforms, such as Teams, Zoom, and even social media. However, they face common challenges—for example, providing timely and individualised feedback. Many educators declared they apply holistic approaches including most of the strategies. In the examples below, these are design of learning, collaboration, authentic experience, reflection, and feedback: "*I let students discuss among themselves the possible applications of technology in control lessons, sometimes purposefully organising them into working groups. When the practices at school begin, we apply the lessons constructed by the students, after which we always discuss the course of the lesson, possibly the gaps and difficulties*." (Assistant Professor in a methodological course); "*I encourage them to reflect on what they have created when developing digital learning materials. Would digital artefact, for example, motivate them and help them acquire knowledge and skills? What needs to be changed in order for this artefact to be effective? That is, we are working in the*

direction of reflecting on what has been created and how it could be improved, putting ourselves in the shoes, figuratively speaking, of the pupil." (Assistant Professor in an ICT course).

The university teachers use a combination of different types of activities (as described in Laurillard's framework) in the implementation of the above-mentioned strategies, with the declared emphasis on discussions and practice. The activities that teachers claimed they use are described and sorted by frequency in Table 8.

Table 8. Declared learning activities by university teachers.

Activity Type	University Teachers' Quotes
1. Discussions (48 mentions, 22 respondents)	*"A significant part of the discussions with students, as well as the cases that I offer for discussion, problematise some of the most alarming, toxic effects of digital technologies and the possibilities for constructing other, fruitful digital practices." (associate professor in methodological course)* *"Discussions are an essential approach or method in our training. We also discuss the possibilities of technology in the context of inclusive education." (associate professor in ICT course)* *"... the students themselves participate directly in the discussions and express a personal attitude to the negative effects of the application of digital competencies in the pedagogical discourse, and beyond it—during the performance of various activities both personally and socially." (professor in methodological course)*
2. Practice Practical tasks for creating digital learning products (40 mentions, 20 respondents)	*"We try to structure them (our classes—authors' note) in such a way that we set the tone in which they themselves can create content and structure content when they are in a situation to teach. That is, in each topic there is lecture material, there is, for example, a theoretical part, then there is a practical part with tasks that they can do in practice during the seminars at the university and that remains as a homework practice." (senior assistant professor in ICT course)*
3. Production (28 mentions, 24 respondents)	*"The course includes a variety of activities related to the development of digital content—scientific essays, presentations, posters, interactive multimedia presentations for teaching, scientific report, etc." (associate professor in ICT course)*
4. Acquisition (Demonstrations in class—34 mentions, 19 respondents)	*"..... I use technology when I visualise content, which are most often PowerPoint presentations, but they are usually, especially on the topic that is related to the development of pedagogical competencies very directly, always with links to other applications that I demonstrate to students and clarify to them their functions to support various educational goals." (associate professor in ICT course)*
5. Investigation (19 mentions, 8 respondents)	*"..... I spend time after they (pre-service teachers—authors' note) have done preliminary research using ICT to manifest critical thinking and we deal with the simple tasks for children to think critically. Is this a fact or is it an opinion?" (assistant professor in methodological course)* *„...when students have to solve certain methodological problems or methodological cases, they sometimes look for information on the Internet, look for documents, articles, sometimes look for interesting experiments, methodological solutions, including those that they can apply." (associate professor in methodological course)* *"For the development of digital control lessons, students extract information from the Internet, analyse it and evaluate it critically, structure it with the relevant learning resource, e.g., didactic test or set of problems in Mozaik." (assistant professor in methodological course)* *"For example, scanning an assignment and there is a programme like Photomath and I ask students to explore this programme." (assistant professor in ICT course)*

According to university teachers, discussions help students develop skills in searching, analysing, and using digital resources for learning purposes. Such activities could stimulate critical thinking and the exchange of ideas among students, which could also support the second aspect of digital transformation. However, there is a lack of a clear focus on this aspect. The results demonstrate that apart from the discussions, the most commonly stated approach was the inclusion of practical tasks. The latter aimed mostly at creating

educational digital products such as presentations, games, and videos (51 mentions by 23 lecturers). According to the university teachers, the above-mentioned activities allow students to apply theoretical knowledge in practice and develop skills for working with various digital tools. Such activities could be successfully implemented in instructional design and authentic experience strategies. Demonstrations of working with ICT in teaching are important for the visualisation of the processes and techniques that students need to master and should successfully correspond to role model strategy. Collaboration was discussed above as a strategy in the context of the SQD model, but here it should be noted that group work as an activity was mentioned by only three lecturers.

4.2. Findings from Observations: Actual Practices of University Teachers in Preparing Pre-Service Teachers for Digital Transformation

4.2.1. Context of Observations

In order to identify the actual practices of university teachers regarding the preparation of pre-service teachers, almost 140 observations were conducted. Nineteen of the observed courses were held in a seminar room equipped with the personal laptop of the lecturer, a multimedia projector, personal devices of students (smartphones, laptops, tablets). Eighteen of the observed courses were held in a computer lab, which included desktop computers or laptops for students (about 15–20 pieces), a laptop for the teacher, a multimedia projector or an interactive whiteboard, and personal devices for students (smartphones, laptops). These were mainly ICT courses (only 3 methodological). The remaining 10 courses were conducted online as part of a blended learning programme of students. For this purpose, platforms such as BigBlueButton, MS Teams, and Google Meet were used, and each of the students used their personal digital device (computer, laptop, smartphone). The average number of students in lectures was about 45. For seminars, it was about 15–20 students, and for practical classes it varied from 8 to 25 students, depending on the course. The most widely used software applications in teaching were PowerPoint and Moodle, and occasionally learning applications were integrated, such as Kahoot, WordWall, and Learning Apps.

4.2.2. Observed Activities

The observation reports were based on the six types of activities suggested by Laurillard (2012) and the three modes of technology usage related to learning with technology proposed by Aubrey-Smith and Twining (2023). The total number of analysed activities was 151; 96 of them revealed opportunities for the development of PDC (52 in ICT and 44 in methodological courses). This represents 64% of the activities. Most often, these were activities that combine acquisition and discussion (31 activities—20 in ICT and 11 in methodological courses). A typical approach of educators was to present information (e.g., through a presentation) and conduct a discussion with participants on issues related to the demonstrated learning content. Sixteen of the activities (11 ICT and 5 methodological) were only for acquisition, i.e., passive observation of presented information, and 4 activities were only for discussion. The least observed activities were those in which there is only production (6 activities—5 in ICT) or only practice (3 activities—2 in ICT), despite the fact that there was a lot of emphasis on these in the interviews. Activities for practice and production were mainly observed within the framework of collaboration—13 more activities for practice and 7 for production were provided as a group activity. In some of these activities, students engaged in production that included the creation of digital resources, the development of lessons, and the use of various learning applications. These kinds of activities have the potential to best develop pre-service teachers' competencies by providing authentic experiences, and thus, lasting acquisition of knowledge. Moreover, such activities provide an opportunity for pre-service teachers to learn with and from others.

In ICT courses, however, group work is often forced—in four courses, such a practice was observed due to the lack of sufficient digital devices. The observed practical activities were mostly related to the development of PDC to support teaching and learning through the creation of digital resources.

In terms of the approaches used for the development of PDC, the observations demonstrated that, in most courses, they were represented mostly by a presentation by the teacher, during which questions occasionally arise that are answered. In support of these observations is also the frequent usage of PowerPoint presentations to visualise the learning content. However, more interactive methods, such as discussions (in 24 activities) and collaboration (25 activities—13 in ICT), were also frequently observed, and sometimes, interactive digital resources were used for this purpose. Although it was not often mentioned in interviews, collaboration was represented by group work in combination with one or more of the following: discussions (19 activities), practice (13 activities), production (7 activities), and investigation (7 activities) in groups. Some of these group activities (6) took place in a virtual environment, so it was not possible to see exactly what the learners were doing there, as the observer did not have access to the individual groups. Despite the fact that in various activities (20) students were required to investigate (such as searching on the Internet, e.g., the answer to teachers' questions), there was no purposeful work in this direction, nor were guidelines given for conducting these searches. Thus, it cannot be said that intentional training in terms of data and information literacy was observed. Educators often incorporate learning activities, assignments, and assessments which require learners to express themselves through digital means and to modify and create digital content in different formats. What was not often observed was teaching learners how copyright and licenses apply to this digital content or how to reference sources and attribute licenses. In two of the courses (methodological) it was mentioned that there is a requirement for sources to be referenced in a specific format, but without any additional instructions.

4.2.3. Addressed PDC

Generally, a limited number of competences from the DigCompEdu framework were addressed. The most frequently addressed competencies during the observations in a total of 63 activities (35 in ICT and 28 in methodological courses) were combinations of domains 2. Digital Resources (DigCompEdu subdomains 2.1, 2.2, 2.3—Selection, creation, modification of digital resources) and 3. Teaching (specifically subdomains 3.1 Teaching and 3.2 Guidance). In the second domain, teachers used and demonstrated various digital resources that students could use in their work, such as e-textbooks, multimedia and interactive resources, and educational games and applications. Students were encouraged to create and modify digital content, such as presentations, videos, and interactive resources. These activities were also related to the third domain—Teaching and Learning, with a focus more on teaching and guidance subdomains. Activities were also provided in the domain 3.3 Collaborative Learning—educators, although not very often, require students to collaborate in a digital environment using platforms such as MOODLE and virtual classrooms. Additionally, five activities addressed only the 2nd domain and 31 addressed the 3rd domain, 10 of the latter in combination with the 4th domain—Assessment (DigCompEdu subdomains 4.1, 4.2, 4.3). They were related to work with interactive applications that allow students to be assessed (Kahoot, Google Forms, Wordwall, etc.). In a total of 15 activities, again in combination with teaching and digital resources, some topics linked to the 5th domain Empowering learners (subdomains 5.1, 5.2, 5.3) were also featured. These were mainly in ICT courses (10 activities), with a special focus on inclusion of learners with SEN—specific resources and how to adapt them for learning purposes. In methodological courses, the focus was more on strategies for differentiating the work through e-resources

(5.2) and to engage the active attention of students. No activities were observed in Area 6 (Facilitating learners' DC).

It could be summarised that the most common activities for the development of the PDC were:

- The integration of digital resources in teaching and learning—university teachers used and demonstrated various digital resources such as electronic textbooks, multimedia and interactive resources, and educational games and applications, e.g., presentations and videos in PowerPoint, Google Slides, and Canva, interactive activities and quizzes in Kahoot, Google Forms, WordWall, LearningApps, and more, and how they can be applied in teaching practice;
- Creating digital content for teaching: Pre-service teachers were encouraged to create and modify digital content, such as presentations, videos, and interactive resources (e.g., presentations and videos in PowerPoint, Google Slides, and Canva, interactive activities and quizzes in Kahoot, Google Forms, WordWall, LearningApps, and more).

In ICT courses, the main emphasis was placed on the use of digital technologies for teaching and learning. Virtual classrooms, interactive presentations, and various digital tools were often used. In methodological courses, the focus was mainly on the integration of digital resources into traditional teaching methods. Mainly e-textbooks, multimedia presentations, and online platforms were used to create learning materials.

4.2.4. Observed Practical Strategies

The main SQD strategy observed was Feedback (in 21 activities)—teachers often gave feedback to students and encouraged reflection on completed tasks. The next most commonly used strategies were Role Model (12 activities) and Reflection (11 activities). Educators often used demonstrations and examples to show students how to use different technologies and resources in the learning process. This approach was observed for visualising complex concepts, and most often this strategy was expressed through using a presentation (PowerPoint, Canva, Prezi, etc.), demonstrating different strategies, digital resources, and applications for teaching and using technology in an educational environment. For example, university teachers work on certain tasks in MOODLE (the learning management system used by Sofia University), demonstrating the ways of digital communication, or make demonstrations and interactions with various online applications such as Kahoot and WordWall. In these cases, pre-service teachers take on the role of pupils and play out quizzes (practice); to some extent, such activities may be related to the strategy of Authentic Experience. The latter was not explicitly detected, but this can be explained by the fact that lectures and seminars held at the university were observed but not practices at school. Learning design was covered in some of the methodological disciplines (7), in which students were required to plan activities for interaction with students in a digital environment. Although collaboration was quite common as a type of activity according to the Laurillard framework, actual work in groups, in which everyone from the group contributes to the overall result, was observed in only 9 activities (out of 25). Six collaboration activities were conducted in a virtual classroom, so the quality of group work could not be well evaluated. In the other collaborative activities, pre-service teachers worked in groups, taking turns using one digital device (material deficiency) or other learning aid.

Observations indicated that teachers more often use strategies such as Feedback, Role Modelling, and Reflection, but the application of Authentic Experience, Learning Design, and Collaborative Work was quite limited. Although digital resources and tools are used in the training, students often remain in a passive role instead of actively participating in the learning process. The lack of real hands-on tasks and effective group interaction limits the development of key skills such as teamwork and problem solving. The need for

a more learner-centred approach is underscored here to encourage pre-service teachers' active participation and work in real or simulated educational settings.

4.2.5. Modes of Applying Digital Technology

As can be seen from all the above, the most common mode of using technology in the DTIF model was Support—in 45 activities (mainly the use of various visualisation tools by the teacher). The Extend mode was used in 25 activities (interaction in Moodle and other platforms for group work, interactive visualisation of learning content for students, working with an interactive whiteboard in a specialised course, providing feedback in Moodle with comments (forum type), multimedia posters, and creating hypertext) and lastly, Transform mode in only 9 activities. The latter were: in the ICT courses—creating video, images (for educational purposes), databases, and programming; and in the methodological courses—in the course for teaching ICT (programming), in course for computer heuristics (working with GeoGeobra—software for geometric simulations), and in the course Methodology of Teaching Fine Arts (virtual galleries). In the remaining 27 activities, the individual modes were combined in different ways. For example, a presentation was used that integrates mind maps or quizzes with which learners interact, or a code was written that then visualises certain learning content. However, the supporting role of technology was predominant, which demonstrates that technologies are often used to support or slightly enhance existing teaching practices rather than fundamentally transforming them. In addition, it is noteworthy that many teachers use a limited set of technologies, which could also limit the opportunities for the development of a variety of pedagogical digital competencies in future teachers and further reduce the effectiveness of training.

4.3. Triangulation of Findings: The Overall Picture

The triangulation of data from curricula, surveys, interviews, and observations provided a comprehensive understanding of how university educators prepare future teachers for digital transformation in education. Although they use digital resources and tools for teaching and learning and teach pre-service teachers how to integrate technologies in the class, there is a lack of a systematic and holistic approach to the development of their PDC. Moreover, while educators recognise the importance of preparing pre-service teachers for digital transformation, their descriptions of teaching approaches in this area revealed a degree of ambiguity or inconsistency in their understanding of this transformation. The development of PDC according to curricula, interviews, and observations is mostly focused on the use of technology for teaching and learning, rather than on providing skills to future teachers to promote digital competence of students. All data implies that the 6th domain of Digital Competence Framework for Educators—Facilitating learners' digital competence—remains underdeveloped. Therefore, pre-service teachers are probably not acquiring the necessary pedagogical skills to foster digital citizenship and critical thinking in their future students through university education. However, this assumption requires further investigation and will be a subject for future research.

From the analysis of the curricula, it became clear that the ICT courses provide activities for preparing students for the effective use of ICT in the learning process and the integration of technologies in it. The main focus in the ICT curricula was related to a higher degree to the development of basic digital competencies and to a lower degree to PDCs. The latter was also developed in the methodological courses in the form of using different technologies in teaching. This was confirmed by observations—often methodical teachers were more active in the development of PDCs. All the collected data demonstrated that the focus in teaching PDCs was mostly related to the competencies for creating digital content and using it for teaching and learning.

Although in the surveys and interviews, educators claimed that they use the Role Model, Authentic Experience, Collaboration, and Reflection strategies to develop pre-service teachers' PDCs, in real practice, these strategies are being applied to a limited extent. In contrast to the results of the short survey, in the interviews, many teachers from methodological courses indicated that they use the above-mentioned strategies. This may have been due to the specific objectives of these courses, which are aimed mostly at developing future teachers' pedagogical skills. On the other hand, ICT courses may focus more on technical aspects and skills, which could explain the lower frequency of declared usage of these pedagogical practices. However, this does not explain the divergence in the stated strategies between the interviews and the survey. This may be due to the fact that the interviewers required examples from teachers, and thus, teachers more thoroughly rethought and declared their strategies in the interviews. Unlike the results of the SQD survey, where the Feedback strategy was the least common, here, it was the main observed strategy. Moreover, fewer educators pointed to Instructional Design as their strategy in the interviews in comparison with the survey, and it was not frequently observed. Collaboration appeared to be applied in a more passive way, rather than as a process of co-creation. These results imply that while educators acknowledge the importance of the key strategies to develop PDCs, some constraints (e.g., institutional or logistical) may limit their effective application (for example, the lack of enough practical classes in their courses). In interviews, teachers often mentioned technical difficulties and the lack of access to adequate technological resources (computer rooms, interactive whiteboards, specialised software), which they pointed out as a reason that they fail to conduct hands-on activities. This was also indicated by the fact that the least observed activities were Practice and Production, although teachers declared that they are actively working to develop pre-service teachers' PDCs through such practical tasks. Many teachers demonstrated approaches of teaching implemented in activities such as Acquisition and Discussion, with limited application of student-centred approaches.

The observed practical activities were mostly related to the development of PDCs to support teaching and learning through the creation of digital resources which fully correspond to what is stated in the curricula and interviews of teachers, where the areas of competence "Digital Resources" and "Teaching and Learning" from DigCompEdu were identified as the most prominent. Observations confirmed that educators often use digital tools to visualise learning content, but they provide limited interactive and practical tasks to encourage active learner participation. In general, the results demonstrate that despite the presence of certain practices to develop PDC, there is a lack of a comprehensive approach to prepare future teachers for digital transformation. A need for better coordination of the development of the PDC in the different courses (ICT and methodological) is emphasised, as well as the development of pre-service teachers' skills to foster critical thinking and the digital literacy of pupils. The findings reveal that the university teachers do not clearly distinguish between these two different aspects of the digital transformation of education and need guidance. To address these issues, institutional support and professional development of teachers could be beneficial in effectively preparing future teachers for the requirements of the digital age.

5. Discussion

The analysis of the data collected through all research methods (course curricula, surveys, semi-structured interviews, and observations of study sessions) revealed that the main priority and focus in the preparation of pre-service teachers falls on the aspect of digital transformation related to improving learning outcomes. This is undoubtedly an important aspect, which many researchers highlight as fundamental (Mhlanga, 2024;

Sangboonraung et al., 2024; Nykvist et al., 2022; Tondeur et al., 2017a). Yet, there is a lack of prioritisation of the preparation of learners for the digital age, which is key to the development of a generation that is sensitive to the requirements of the 21st century and a digital world. Although university teachers recognise that the preparation of pre-service teachers for digital transformation is important and necessary, they do not explicitly define such goals and do not work purposefully in this direction. University teachers acknowledge the importance of developing the PDCs of pre-service teachers and understand them in the way they are described in some of the literature sources (Väätäjä & Ruokamo, 2021). Yet, the reasons for the importance of the PDCs that they mention do not include the development of skills to prepare learners for the digital age, which is an important aspect of PDC (Council of Europe, 2024; Starkey, 2019). Additionally, while educators acknowledge the importance of critical digital literacy, which is consistent with the emphasis placed in the literature on its key role in the pre-service teachers' preparation (Prachagool et al., 2022), observations revealed that explicit teaching of it is rare. Skills such as information critical assessment, ethical considerations, and media literacy were not systematically integrated in the pre-service teacher training. This could be due to many factors, such as a limited understanding of digital transformation and a lack of awareness of educators' role in the process. The existing literature does not address the impact of such limited understanding among university educators, making this an area that requires further exploration.

What is particularly concerning is that even in key teacher training courses for teaching ICT, there may be a lack of active work towards the development of digital literacy of pupils. University educators do not purposefully develop the PDC domain Facilitating Learners' Digital Competence. The reason for this limited preparation for digital transformation of pre-service teachers may be complex, e.g., university teachers themselves do not appear to have the necessary competencies, although in their study, Peytcheva-Forsyth and Racheva (2024) found that these same teachers provided responses to the self-assessment instrument SELFIE that would indicate a self-perception of a proficiency level of B2, which is an "expert" level and should be enough for the development of digital competencies of future teachers. Also, observations demonstrated that in most cases, teachers use technology merely as a substitute for traditional methods, which corresponds to the lower self-assessment of their digital competence (Scherer et al., 2017). There may be a discrepancy between what they declare and their inner beliefs, i.e., they are not motivated to teach specific PDCs, and it is possible that regardless of the level of self-evaluation, their practices are influenced by various factors, such as access to resources, administrative support, and professional development opportunities (Levin & Wadmany, 2006), or by their broader educational philosophies (Sjöberg et al., 2024; Wohlfart & Wagner, 2023). Yet, the teachers who declared constructivist and more modern approaches in their curricula do not tie them to technology. Moreover, the views of many teachers in methodological courses often reveal a lack of deep inner conviction about the importance of teaching PDC—their motivation looks rather external, related to students' expectations and the need for adaptation. In this context, there is an implication that material constraints are used as an argument for the lack of effort in certain areas. Furthermore, the development of PDCs in terms of facilitating pupils' critical thinking and safe behaviour in the digital environment is sometimes even better without using digital tools (Selwyn, 2019; Yang et al., 2022; Curwood & Cowell, 2011); as such, material restrictions do not play a crucial role in this case.

PDC development of pre-service teachers is mainly related to the Digital Resources and Teaching and Learning domains of DigCompEdu, which is in line with various studies which suggest that such skills should be the focus of teaching PDC (Srivastava & Dangwal, 2021; García-Delgado et al., 2023). Many teachers in their curricula and in their interviews declared practical course orientations, which is in accordance with the requirements for

more hands-on activities in the formation of digital competencies of pre-service teachers (Knezek et al., 2023; Basilotta-Gómez-Pablos et al., 2022; Jimarkon et al., 2021; Romero-García et al., 2020; Sondermann et al., 2017). In practical strategies for the preparation of future teachers, Authentic Experiences occur sporadically, mostly through simulations, which is in contrast to the literature, which recommends this strategy for the effective development of pre-service PDCs (Knezek et al., 2023; Basilotta-Gómez-Pablos et al., 2022; Jimarkon et al., 2021; Romero-García et al., 2020). A lack of opportunities for authentic learning is problematic, as it can cause pre-service teachers to struggle in integrating digital tools into their practice (Jimarkon et al., 2021; Romero-García et al., 2020). This issue reveals a need for providing more practical training to better prepare pre-service teachers for this aspect of digital transformation. On a positive note, the more frequent use of reflection strategies by university teachers helps future teachers to identify strengths and areas for improvement, supporting their overall PDC development (Miguel-Revilla et al., 2020; Tsankov & Damyanov, 2019).

What is evident from all the data is the lack of a unified perspective or a consistent approach to the development of the PDC of pre-service teachers. For general digital competences, there are specific uniform curricula at the level of secondary education, but for higher education in Bulgaria, the only regulation is related to one compulsory discipline, whose curriculum is not unified. The curriculum in this compulsory discipline (ICT and Work in Digital Environment) differs, even within the same faculty, certainly between different faculties in one university, and especially among the different universities in Bulgaria. PDCs are likely expected to be developed through methodological courses in unison with the new paradigms of learning and modern teaching tools. However, in these courses, teachers primarily rely on electronic textbooks, in which there are some digital resources, i.e., they substitute traditional technology with digital, rather than transforming their pedagogy. Nonetheless, the responsibility for the development of PDC in pre-service teachers should not rest solely on university teachers. Clear standards or guidelines are needed to provide a consistent framework, whether at the university or at national level. In addition, teachers should be supported purposefully and not rely on their own initiative and professional self-actualisation. Universities themselves should have a clear policy towards the development of digital and pedagogical digital competencies for teachers. They should coordinate the teaching of ICT and methodological disciplines in terms of PDC development. At the same time, technical limitations should be recognised by the universities as a significant obstacle, and universities should take the necessary measures to address them.

All the findings confirm what was stated by McCarthy et al. (2023), i.e., that for a preparation of pre-service teachers for digital transformation, a holistic approach is needed, which includes policy adjustments, effective leadership in guiding the digital transformation process, curriculum improvement, CPD for educators, focus on student-centred learning, and adequate technological infrastructure (McCarthy et al., 2023).

6. Conclusions

The findings of this study highlight significant gaps between the current level of teacher preparation for digital transformation and the competencies required to effectively promote students' digital skills. It has been established that there is a lack of policy and coordination among the different types of courses (Information and Communication Technology in teaching and Subject methodologies) in terms of preparing future teachers for digital transformation. While notable efforts are being made to integrate digital tools into teaching practices, these efforts remain limited to enhancing learning outcomes, and little attention is being paid to preparing learners for the digital age. University teachers

use mostly traditional approaches and employ a limited number of strategies for teaching PDC, which raises concerns about the effectiveness of pre-service teacher training.

To address these gaps, a more systematic and strategic approach needs to be taken by universities, first to coordinate the pedagogical digital competences taught in ICT and methodological courses, and then to more purposefully integrate the last domain of DigCompEdu, i.e., the Facilitation of students' digital competences, into teacher preparation programmes, e.g., in ICT courses. This DigCompEdu domain is directly related to the preparation of learners for the digital age. Its integration should also foresee increasing opportunities for authentic experiences through digital projects for real-world teaching and school practice, expanding the scope of digital tools and platforms beyond basic presentation and learning management systems. To this end, institutional policies will be needed, including the provision of more practical classes in the curricula, as well as the provision of guidance and coordination for the preparation of future teachers in the field of PDC. Further research should also focus on a more in-depth study of the pedagogical digital competences of university teachers themselves, as SELFIE results provide a guideline, although relying on self-reporting may not fully reflect actual competence levels. If necessary, relevant courses for educators should be conducted, providing guidance, for example, through CPD qualifications, joint projects with other universities in different countries, etc. Further updating the methods and technologies used in teaching should be undertaken with in-service teachers within the framework of appropriate CPD courses as well. An important step is also to overcome technical and material constraints through institutional support, which could be partnering with schools that have good digital infrastructures to provide technology-related practices for beginning teachers. While institutional support which includes funding for software and digital infrastructure remains essential, exploring collaborative opportunities can help overcome financial constraints and provide hands-on experience with advanced technologies. By addressing these recommendations, universities could better prepare pre-service teachers not only to use digital technologies effectively but also to facilitate their students to acquire the digital skills needed to succeed in today's world.

7. Limitations of the Study

The first limitation of this study is that it covered only one university—Sofia University "St. Kliment Ohridski", with 44 university teachers preparing pre-service teachers. Although it is the largest in the country, the results provide context-specific insights relevant to Sofia University and cannot be generalised to the entire higher education system in Bulgaria. Other universities should also be involved in future research in order to draw representative conclusions about the preparation of future teachers for the digital transformation in Bulgarian education.

Secondly, the study envisaged the preparation of pre-service teachers only by surveying university teachers and their training. For a more complete view, future research should also include an evaluation of pre-service teachers' digital competences and a study of their views. Furthermore, the study did not examine what pre-service teachers actually do in practice after their training and how this aligns with the methods and content covered during their preparation. Such research would provide insights into the effectiveness of pre-service teachers' preparation and its impact on real-world teaching practices.

Thirdly, a limitation of the study was that it did not fully explore the structural barriers hindering the effective implementation of digitalisation strategies in higher education. Further investigation into these challenges is needed to better understand how they impact the preparation of pre-service digital competences for the digital transformation of education.

Lastly, only three observations were carried out in the individual courses. Although this allowed us to devise a summary analysis of the practices, we did not fully cover all aspects of teaching in the respective courses.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci15040404/s1.

Funding: This study is financed by the European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project No. BG-RRP-2.004-0008.

Institutional Review Board Statement: The study was conducted in accordance with the Code of Ethics and approved by the Ethics Committee of Sofia University "St. Kliment Ohridski" (No. 93-P-289/19 December 2023).

Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets presented in this article are not readily available because the data are part of an ongoing study. Requests to access the datasets should be directed to the lead researcher of project SUMMIT DigEdu-SU (European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project No. BG-RRP-2.004-0008)—prof. dr. Roumiana Peytcheva-Forsyth (r.peytcheva@fp.uni-sofia.bg).

Acknowledgments: I would like to thank Roumiana Peytcheva-Forsyth and Harvey Mellar, who are the authors of the methodology and research instruments used in this study. They also played a key role in structuring the research framework, provided access to the collected data, and offered valuable guidance throughout the development of this article. I deeply appreciate their significant intellectual contribution and continuous support.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

PDC	Pedagogical digital competences
ICT	Information and communication technologies
SUMMIT	Sofia University Marking Momentum for Innovation and Technological Transfer
CPD	Continuous Professional Development
SELFIE	Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies
TPACK	Technological Pedagogical Content Knowledge
SAMR	Substitution, Augmentation, Modification and Redefinition
DTIF	Digital Technology Impact Framework
TETCs	Teacher Educator Technology Competencies
SQD	Synthesis of Qualitative Evidence

Notes

1 European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project No BG-RRP-2.004-0008; https://summit.uni-sofia.bg/ (accessed on 31 January 2025).

2 The model was updated in 2024 by Gümüş et al. (2024). The Feedback component was removed as a separate construct (new ring in the SQD model), since they found to be embedded within the other strategies rather than functioning as an independent construct.

2 The model was updated in 2024 by Gümüş et al. (2024). The Feedback component was removed as a separate construct (new ring in the SQD model), since they found to be embedded within the other strategies rather than functioning as an independent construct.

[3] SELFIE (Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies)—self-assessment tool for teachers, based on the European Commission framework on promoting digital-age learning in educational organisations https://education.ec.europa.eu/selfie/about-selfie (accessed on 1 February 2025). The paper by Mizova et al. (2025) presents an account of the main psychometric properties of this Bulgarian version of the SELFIE instrument used in the study. Data was collected from two independent samples composed of university professors (n = 94) and teachers from the secondary education system (n = 281). High values for Cronbach's alpha were observed (0.975 for university professors and 0.896 for school teachers). Correlation analysis confirmed strong and significant relationships between the subscales, and also confirmed that the individual subscales measure different aspects of the construct.

[4] Quirkos (software tool for qualitative text analysis)—https://www.quirkos.com/index.html (accessed on 31 January 2025).

References

Adeyemi, A. (2015). International approaches to professional development for mathematics teachers. *Journal of Teaching and Learning*, *10*(1). [CrossRef]

Aini, D. N., Abdulkarim, A., & Rahmat, S. (2024). Effectiveness of digital literacy learning model with video content project in enhancing sustainable (SDG) civic intelligence. *Journal of Lifestyle and SDGs Review*, *5*(1), e02616. [CrossRef]

Alsadoon, E. (2022). Digital teaching competencies evaluation of teachers in Saudi Arabia: A systematic review. *Journal of Education and Practice*, *13*(21), 1–9. [CrossRef]

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

Aslan, A., & Zhu, C. (2016). Influencing factors and integration of ict into teaching practices of pre-service and starting teachers. *International Journal of Research in Education and Science*, *2*(2), 359. [CrossRef]

Aubrey-Smith, F., & Twining, P. (2023). *From EdTech to PedTech: Changing the way we think about digital technology*. Routledge.

Awang, M. I. (2022, December 8–9). *The digitalization of learning assessment* [Paper presentation]. International Conference on Multidiciplinary Research, Balaclava, Mauritius. [CrossRef]

Ayyildiz, P., Yilmaz, A., & Baltaci, H. S. (2021). Exploring digital literacy levels and technology integration competence of turkish academics. *International Journal of Educational Methodology*, *7*(1), 15–31. [CrossRef]

Baran, E., Canbazoglu Bilici, S., Albayrak Sari, A., & Tondeur, J. (2019). Investigating the impact of teacher education strategies on preservice teachers' TPACK. *British Journal of Educational Technology*, *50*(1), 357–370. [CrossRef]

Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L. A., & Otto, A. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, *19*(1), 8. [CrossRef]

Boronenko, T. A., Kaisina, A. V., & Fedotova, V. S. (2022). Characteristics of professional competencies of computer science teacher in digital learning environment: Digital competence. *Perspectives of Science & Education*, *56*(3), 680–698. [CrossRef]

Bottino, R. (2020). Schools and the digital challenge: Evolution and perspectives. *Education and Information Technologies*, *25*(3), 2241–2259. [CrossRef]

Bwalya, A., Rutegwa, M., Tukahabwa, D., & Mapulanga, T. (2023). Enhancing pre-service biology teachers' technological pedagogical content knowledge through a TPACK-based technology integration course. *Journal of Baltic Science Education*, *22*(6), 956–973. [CrossRef]

Cabero-Almenara, J., Gutiérrez-Castillo, J. J., Barroso-Osuna, J., & Rodríguez-Palacios, A. (2023). Digital teaching competence according to the digcompedu framework. Comparative study in different Latin American universities. *Journal of New Approaches in Educational Research*, *12*(2), 276–291. [CrossRef]

Cabero-Almenara, J., Gutiérrez-Castillo, J. J., Palacios-Rodríguez, A., & Barroso-Osuna, J. (2020). Development of the teacher digital competence validation of DigCompEdu check-in questionnaire in the university context of Andalusia (Spain). *Sustainability*, *12*(15), 6094. [CrossRef]

Caena, F., & Redecker, C. (2019). Aligning teacher competence frameworks to 21st century challenges: The case for the European Digital Competence Framework for Educators (Digcompedu). *European Journal of Education*, *54*(3), 356–369. [CrossRef]

Castañeda, L., & Selwyn, N. (2018). More than tools? Making sense of the ongoing digitizations of higher education. *International Journal of Educational Technology in Higher Education*, *15*, 1–10. [CrossRef]

Castaño Muñoz, J., Vuorikari, R., Costa, P., Hippe, R., & Kampylis, P. (2023). Teacher collaboration and students' digital competence-evidence from the SELFIE tool. *European Journal of Teacher Education*, *46*(3), 476–497. [CrossRef]

Chu, J., Lin, R., Qin, Z., Chen, R., Lou, L., & Yang, J. (2023). Exploring factors influencing pre-service teacher's digital teaching competence and the mediating effects of data literacy: Empirical evidence from China. *Humanities and Social Sciences Communications*, *10*(1), 1–11. [CrossRef]

Council of Europe. (2024). *Digital transformation*. Available online: https://www.coe.int/en/web/education/digital-transformation (accessed on 13 January 2025).

Curwood, J. S., & Cowell, L. L. H. (2011). iP oetry: Creating Space for new literacies in the English curriculum. *Journal of Adolescent & Adult Literacy*, *55*(2), 110–120. [CrossRef]

Eurostat. (2024). *Skills for the digital age*. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=627685 (accessed on 13 January 2025).

Fazilla, S., Yus, A., & Muthmainnah, M. (2022). Digital literacy and TPACK's impact on preservice elementary teachers' ability to develop science learning tools. *Profesi Pendidikan Dasar*, *9*(1), 71–80. [CrossRef]

Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & García-Martínez, I. (2020). Digital competences for teacher professional development. Systematic review. *European Journal of Teacher Education*, *45*(4), 513–531. [CrossRef]

Foulger, T. S., Graziano, K. J., Schmidt-Crawford, D., & Slykhuis, D. A. (2017). Teacher educator technology competencies. *Journal of Technology and Teacher Education*, *25*(4), 413–448.

Fraillon, J. (2024). *An international perspective on digital literacy: Results from ICILS 2023*. International Association for the Evaluation of Educational Achievement.

Garcia, A. (2023). *Technology might be making education worse*. StanfordReport. Available online: https://news.stanford.edu/stories/2023/04/technology-might-be-making-education-worse (accessed on 5 January 2025).

García-Delgado, M. Á., Rodríguez-Cano, S., Delgado-Benito, V., & Di Giusto-Valle, C. (2023). Digital teaching competence among teachers of different educational stages in Spain. *Education Sciences*, *13*(6), 581. [CrossRef]

Ghomi, M., & Redecker, C. (2019). *Digital competence of educators (DigCompEdu): Development and evaluation of a self-assessment instrument for teachers' digital competence.* International Conference on Computer Supported Education, Science and Technology Publications. Available online: https://publications.informatik.hu-berlin.de/archive/cses/publications/CSEDU_2019_39_CR.pdf (accessed on 20 December 2024).

Gkrimpizi, T., Peristeras, V., & Magnisalis, I. (2023). Classification of barriers to digital transformation in higher education institutions: Systematic literature review. *Education Sciences*, *13*(7), 746. [CrossRef]

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. [CrossRef]

Gümüş, M. M., Kayhan, O., Kukul, V., & Korkmaz, Ö. (2024). Preparing teachers to integrate technology in education according to SQD model: Scale development and validation. *Education and Information Technologies*, *29*(4), 3993–4023. [CrossRef]

Howard, S., Tondeur, J., Ma, J., & Yang, J. (2019). *Seeing the wood for the trees: Insights into the complexity of developing pre-service teachers' digital competencies for future teaching*. ASCILITE Publications. [CrossRef]

Inamorato dos Santos, A., Chinkes, E., Carvalho, M. A., Solórzano, C. M., & Marroni, L. S. (2023). The digital competence of academics in higher education: Is the glass half empty or half full? *International Journal of Educational Technology in Higher Education*, *20*(1), 9. [CrossRef]

INTEF. (2017). *Common digital competence framework for teachers—September 2017*. Ministry of Education, Culture and Sport.

Iqbal, I., Hussain, I., & Tahir, M. S. (2024). Teachersâ€™ Digital Competence and its Relationship with Teacher Effectiveness at Higher Education Level in Punjab. *Journal of Education and Social Studies*, *5*(2), 271–285. [CrossRef]

Jimarkon, P., Wanphet, P., & Dikilitas, K. (2021). Pre-service teachers' digital experiences through digital pedagogical practices in Norway. *Nordic Journal of Comparative and International Education (NJCIE)*, *5*(4), 86–103. [CrossRef]

Kiryakova, G., & Kozhuharova, D. (2024). The digital competences necessary for the successful pedagogical practice of teachers in the digital age. *Education Sciences*, *14*(5), 507. [CrossRef]

Knezek, G., Christensen, R., Smits, A., Tondeur, J., & Voogt, J. (2023). Strategies for developing digital competencies in teachers: Towards a multidimensional Synthesis of Qualitative Data (SQD) survey instrument. *Computers & Education*, *193*, 104674. [CrossRef]

Kukul, V. (2024). Should I use digital storytelling in my future classroom? Why or why not? Investigating pre-service math teachers' acceptance of digital storytelling. *E-Learning and Digital Media*, *21*(1), 70–86. [CrossRef]

Laurillard, D. (2002). *Rethinking university teaching: A conversational framework for the effective use of learning technologies*. Routledge. [CrossRef]

Laurillard, D. (2012). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge.

Levin, T., & Wadmany, R. (2006). Teachers' beliefs and practices in technology-based classrooms: A developmental view. *Journal of Research on Technology in Education*, *39*(2), 157–181.

Mahlow, C., & Hediger, A. (2019). Digital Transformation in Higher Education—Buzzword or Opportunity? *eLearn*, *2019*(5), 13. [CrossRef]

Masoumi, D. (2021). Situating ICT in early childhood teacher education. *Education and Information Technologies*, *26*(3), 3009–3026. [CrossRef]

McCarthy, A. M., Maor, D., McConney, A., & Cavanaugh, C. (2023). Digital transformation in education: Critical components for leaders of system change. *Social Sciences & Humanities Open*, *8*(1), 100479. [CrossRef]

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

Mhlanga, D. (2024). Digital transformation of education, the limitations and prospects of introducing the fourth industrial revolution asynchronous online learning in emerging markets. *Discover Education*, *3*(1), 32. [CrossRef]

Miguel-Revilla, D., Martínez-Ferreira, J. M., & Sánchez-Agustí, M. (2020). Assessing the digital competence of educators in social studies: An analysis in initial teacher training using the TPACK-21 model. *Australasian Journal of Educational Technology*, *36*(2), 1–12. [CrossRef]

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers college record*, *108*(6), 1017–1054. [CrossRef]

Mizova, B., & Peytcheva-Forsyth, R. (2024, June 25–28). *Bulgarian national priorities for integrating ICT in education in the mirror of european policiesfor digitalization of education* [Paper presentation]. 19th Iberian Conference on Information Systems and Technologies, Salamanca, Spain.

Mizova, B., Peytcheva-Forsyth, R., & Mellar, H. (2025). A Multi-faceted approach to researching the level of digitalization in initial teacher preparation. *Strategies for Policy in Science and Education*, *33*(1), 28–53. [CrossRef]

Mugge, P., & Gudergan, G. (2017, January 4–7). *The gap between the practice and theory of digital transformation* [Paper presentation]. Hawaii International Conference of System Science (pp. 1–15), Hilton Waikoloa Village, HI, USA.

Musić, J., Bonković, M., Kružić, S., Marasović, T., Papić, V., Kostova, S., Dimitrova, M., Saeva, S., Zamfirov, M., Kaburlasos, V., Vrochidou, E., & Papakostas, G. (2020). Robotics and information technologies in education: Four countries from Alpe-Adria-Danube Region survey. *International Journal of Technology and Design Education*, *32*, 749–771. [CrossRef]

Nikolova, N., Zafirova-Malcheva, T., Kirilova, B., & Mihnev, P. (2024). Development of digital competences in the Bulgarian secondary school context–a literature review of good practices. *Frontiers in Education*, *9*, 1434797. [CrossRef]

Norton, A., Surendra, S., & Edwards, N. (2020). *Digital transformation—An enterprise architecture perspective* (3rd ed.). PublishNation Limited. Available online: https://publishnation.co.uk (accessed on 13 January 2025).

Nykvist, S., Mukherjee, M., & Blundell, C. N. (2022). Innovative Approaches Used to Prepare Pre-service Teachers to Activate Learning with Digital Technologies. In T. Bourke, D. Henderson, R. Spooner-Lane, & S. White (Eds.), *Reconstructing the work of teacher educators*. Springer. [CrossRef]

Oliveira, K. K. d. S., & de Souza, R. A. C. (2022). Digital transformation towards education 4.0. *Informatics in Education*, *21*(2), 283–309. [CrossRef]

Pangrazio, L., Godhe, A., & Ledesma, A. (2020). What is digital literacy? A comparative review of publications across three language contexts. *E-Learning and Digital Media*, *17*(6), 442–459. [CrossRef]

Perin, E., & Freitas, M. (2020). Digital competencies of the teacher in the basic education. *International Journal of Humanities and Social Science*, *10*(2), 59–67. [CrossRef]

Peytcheva-Forsyth, R., & Racheva, V. (2024, July 1–3). *Bridging digital competences: A comparative analysis between university teacher trainers and secondary school teachers in Bulgaria* [Paper presentation]. EDULEARN24 Proceedings, Palma de Mallorca, Spain. [CrossRef]

Pongsakdi, N., Kortelainen, A., & Veermans, M. (2021). The impact of digital pedagogy training on in-service teachers' attitudes towards digital technologies. *Education and Information Technologies*, *26*(5), 5041–5054. [CrossRef]

Prachagool, V., Nuangchalerm, P., & Yawongsa, P. (2022). Digital literacy of pre-service teachers in the period time of COVID-19 pandemic. *Journal of Educational Issues*, *8*(2), 347–358. [CrossRef]

Puentedura, R. (2006). *Transformation, technology, and education* [Blog post]. Available online: http://hippasus.com/resources/tte (accessed on 10 January 2025).

Punie, Y. (2017). *European framework for the digital competence of educators: DigCompEdu*. Publications Office of the European Union.

Purina-Bieza, K. E. (2021). Pedagogical digital competence and its acquisition in a teacher education programme. *Human, Technologies and Quality of Education*, *24*, 333–351. [CrossRef]

Reid, L., Button, D., & Brommeyer, M. (2023). Challenging the myth of the digital native: A narrative review. *Nursing Reports*, *13*(2), 573–600. [CrossRef]

Romero-García, C., Buzón-García, O., & de Paz-Lugo, P. (2020). Improving future teachers' digital competence using active methodologies. *Sustainability*, *12*(18), 7798. [CrossRef]

Rüth, M., Birke, A., & Kaspar, K. (2022). Teaching with digital games: How intentions to adopt digital game-based learning are related to personal characteristics of pre-service teachers. *British Journal of Educational Technology*, *53*(5), 1412–1429. [CrossRef]

Sangboonraung, W., Daungtod, S., Nilsook, P., Jitsupa, J., Skunhom, V., & Techachokwiwat, N. (2024). Empowering pre-service teachers for the digital transformation of education from new normal to next normal. *Journal of Education and Learning*, *13*(4), 211–230. [CrossRef]

Santo, E. D. E., Dias-Trindade, S., & Reis, R. S. D. (2022). Self-assessment of digital competence for educators: A Brazilian study with university professors. *Research, Society and Development*, *11*(9), e26311930725. [CrossRef]

Saylor, L. L., & Johnson, C. C. (2014). The role of reflection in elementary mathematics and science teachers' training and development: A meta-synthesis. *School Science and Mathematics*, *114*(1), 30–39. [CrossRef]

Scherer, P., Tondeur, J., & Siddiq, F. (2017). On the quest for validity: Testing the factor structure and measurement invariance of the technology-dimensions in the Technological, Pedagogical, and Content Knowledge (TPACK) model. *Computers & Education*, *112*, 1–17. [CrossRef]

Selwyn, N. (2019). Approches critiques des technologies en éducation: Un aperçu. *Formation et Profession*, *27*(3), 6–21. [CrossRef]

Shenkoya, T., & Kim, E. (2023). Sustainability in higher education: Digital transformation of the fourth industrial revolution and its impact on open knowledge. *Sustainability*, *15*(3), 2473. [CrossRef]

Sillat, L. H., Tammets, K., & Laanpere, M. (2021). Digital competence assessment methods in higher education: A systematic literature review. *Education Sciences*, *11*(8), 402. [CrossRef]

Sjöberg, J., Hoveskog, M., Tell, J., & Cherni, W. (2024). Unveiling university students' perceptions on their teachers' digital competence. *Education Sciences*, *14*(8), 891. [CrossRef]

Sondermann, D. V. C., Nobre, I. A. M., Maissiat, J., & Passos, M. L. S. (2017, November 9–11). *Educational technologies and teacher training: From theory to pedagogical practices* [Paper presentation]. 2017 International Symposium on Computers in Education (SIIE) (pp. 1–6), Lisbon, Portugal. [CrossRef]

Spiteri, M., & Chang Rundgren, S. N. (2017). Maltese primary teachers' digital competence: Implications for continuing professional development. *European Journal of Teacher Education*, *40*(4), 521–534. [CrossRef]

Srivastava, S., & Dangwal, K. L. (2021). Digital competence: Where do the higher education teachers stand. *Universal Journal of Educational Research*, *9*(10), 1765–1772. [CrossRef]

Starkey, L. (2019). A review of research exploring teacher preparation for the digital age. *Cambridge Journal of Education*, *50*(1), 37–56. [CrossRef]

Su, Y. (2023). Delving into EFL teachers' digital literacy and professional identity in the pandemic era: Technological Pedagogical Content Knowledge (TPACK) framework. *Heliyon*, *9*(6), e16361. [CrossRef] [PubMed]

Susanty, S. (2024). The use of digital technologies in social education: Opportunities and challenges. *Social Education Research Review*, *1*(1), 1–6. Available online: https://jurnal-nusantara.bangangga.com/index.php/serr/article/view/53 (accessed on 10 February 2025).

Thyssen, C., Huwer, J., Irion, T., & Schaal, S. (2023). From TPACK to DPACK: The "Digitality-related pedagogical and content knowledge"-model in STEM-education. *Education Sciences*, *13*(8), 769. [CrossRef]

Tondeur, J. (2018). Enhancing future teachers' competencies for technology integration in education: Turning theory into practice. *Seminar. net*, *14*(2), 216–224. [CrossRef]

Tondeur, J. (2019). Teachers' pedagogical beliefs and technology use: A chicken and the egg dilemma. In M. A. Peters (Ed.), *Encyclopedia of teacher education*. Springer.

Tondeur, J., Aesaert, K., Prestridge, S., & Consuegra, E. (2018). A multilevel analysis of what matters in the training of pre-service teacher's ICT competencies. *Computers & Education*, *122*, 32–42. [CrossRef]

Tondeur, J., Howard, S., Van Zanten, M., Gorissen, P., Van der Neut, I., Uerz, D., & Kral, M. (2023). The HeDiCom framework: Higher education teachers' digital competencies for the future. *Educational Technology Research and Development*, *71*(1), 33–53. [CrossRef]

Tondeur, J., Pareja Roblin, N., Van Braak, J., Voogt, J., & Prestridge, S. (2017a). Preparing beginning teachers for technology integration in education: Ready for take-off? Technology. *Pedagogy and Education*, *26*(2), 157–177. [CrossRef]

Tondeur, J., Petko, D., Christensen, R., Drossel, K., Starkey, L., Knezek, G., & Schmidt-Crawford, D. A. (2021). Quality criteria for conceptual technology integration models in education: Bridging research and practice. *Educational Technology Research and Development*, *69*(4), 2187–2208. [CrossRef]

Tondeur, J., Scherer, R., Baran, E., Siddiq, F., Valtonen, T., & Sointu, E. (2019). Teacher educators as gatekeepers: Preparing the next generation of teachers for technology integration in education. *British Journal of Educational Technology*, *50*(3), 1189–1209. [CrossRef]

Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2017b). A comprehensive investigation of TPACK within pre-service teachers' ICT profiles: Mind the gap! *Australasian Journal of Educational Technology*, *33*(3), 46–60. [CrossRef]

Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2020). Enhancing pre-service teachers' technological pedagogical content knowledge (TPACK): A mixed-method study. *Educational Technology Research and Development*, *68*(1), 319–343. [CrossRef]

Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017c). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, *65*(3), 555–575. [CrossRef]

Tondeur, J., Van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education*, *59*(1), 134–144. [CrossRef]

Tsankov, N., & Damyanov, I. (2019). The digital competence of future teachers: Self-assessment in the context of their development. *International Journal of Interactive Mobile Technologies*, *13*(12), 4–18. [CrossRef]

Twining, P., Raffaghelli, J., Albion, P., & Knezek, D. (2013). Moving education into the digital age: The contribution of teachers' professional development. *Journal of computer assisted learning*, *29*(5), 426–437. [CrossRef]

Tzafilkou, K., Perifanou, M., & Economides, A. A. (2023). Assessing teachers' digital competence in primary and secondary education: Applying a new instrument to integrate pedagogical and professional elements for digital education. *Education and Information Technologies*, *28*(12), 16017–16040. [CrossRef]

Ucan, S. (2016). The role of continuous professional development of teachers in educational change: A literature review. *Harran Maarif Dergisi*, *1*(1), 36–43. [CrossRef]

UNESCO. (2008). *ICT competency standards for teachers: Policy framework* (CI-2007/WS/21). United Nations Educational, Scientific and Cultural Organization, UK. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000156210 (accessed on 10 February 2025).

UNESCO. (2019). *ICT competency framework for teachers*. United Nations Educational, Scientific and Cultural Organization. ISBN 978-92-3-100285-4. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000265721 (accessed on 10 February 2025).

Vandeyar, T., & Adegoke, O. O. (2024). Teachers' ICT in pedagogy: A case for mentoring and mirrored practice. *Education and Information Technologies*, *29*(14), 18985–19004. [CrossRef]

Väätäjä, J. O., & Ruokamo, H. (2021). Conceptualizing dimensions and a model for digital pedagogy. *Journal of Pacific Rim Psychology*, *15*, 1834490921995395. [CrossRef]

Voithofer, R., & Nelson, M. J. (2020). Teacher educator technology integration preparation practices around TPACK in the United States. *Journal of Teacher Education*, *72*(3), 314–328. [CrossRef]

Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2: The digital competence framework for citizens—With new examples of knowledge, skills and attitudes*. Publications Office of the European Union. JRC128415. [CrossRef]

Wagner, M., Ley, T., Kammerer, L., & Helm, C. (2024). Exploring teacher educators' challenges in the context of digital transformation and their self-reported TPACK: A mixed methods study. *European Journal of Teacher Education*, *47*, 1–19. [CrossRef]

Wang, S. (2023). A review of research exploring pre-service teacher education for the digital era. *International Journal of Education and Humanities*, *9*(1), 188–193. [CrossRef]

Wohlfart, O., & Wagner, I. (2023). Teachers' role in digitalizing education: An umbrella review. *Educational Technology Research And Development*, *71*(2), 339–365. [CrossRef] [PubMed]

Yang, L., Martínez-Abad, F., & García-Holgado, A. (2022). Exploring factors influencing pre-service and in-service teachers perception of digital competencies in the Chinese region of Anhui. *Education and Information Technologies*, *27*(9), 12469–12494. [CrossRef] [PubMed]

Yontar, A. (2019). Digital literacy levels of teacher candidates. *Journal of Mother Tongue Education*, *7*(4), 815–824. [CrossRef]

Zhang, W., & Tang, J. (2021). Teachers' TPACK development: A review of literature. *Open Journal of Social Sciences*, *9*(7), 367–380. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.