

DIGITAL COMPETENCE IN PHYSICS TEACHER EDUCATION: COMPARATIVE CURRICULUM ANALYSIS AND EVIDENCE FROM ALBANIAN TEACHERS AND STUDENT TEACHERS

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Abstract

The rapid digital transformation of education has significantly changed the competencies expected from teachers, particularly in science education. Physics teachers are increasingly required to integrate digital technologies, simulations, virtual laboratories, and interactive learning environments into their instructional practices. This study investigates the extent to which current physics teacher education programmes prepare future and practicing teachers for technology-enhanced instruction. A mixed-method research design was employed, combining comparative curriculum analysis with empirical research. The study compared Master's programmes for physics teacher education in Albania, Kosovo, Montenegro, North Macedonia, Italy, and the Netherlands, focusing on pedagogical, didactic, practical, theoretical, digital, and research components. In addition, questionnaire data were collected from 63 upper-secondary physics teachers and 13 student teachers enrolled in the Master of Science in Physics Teaching programme. Findings indicate that the Albanian programme provides a balanced pedagogical and theoretical foundation; however, the digital component remains relatively limited compared with several European programmes. Teachers and student teachers acknowledged the importance of digital technologies for improving conceptual understanding and student engagement, while simultaneously identifying deficiencies in technology-related preparation, practical training, and access to educational technologies. The results suggest a need for curriculum modernization through stronger integration of digital competence, simulation-based learning, virtual laboratories, and innovative teaching methodologies. Such reforms would contribute to aligning teacher

preparation programmes with European educational frameworks and the demands of contemporary STEM education.

Key words: Physics education; teacher education; digital competence; technology integration; STEM education; digital transformation.

Përmbledhje

Transformimi i shpejtë digjital i arsimit ka ndryshuar ndjeshëm kompetencat që priten nga mësuesit, veçanërisht në edukimin shkencor. Mësuesit e fizikës përballen gjithnjë e më shumë me nevojën për të integruar teknologjitë digjitale, simulimet, laboratorët virtualë dhe mjediset interaktive të të nxënit në praktikën e tyre mësimore. Ky studim synon të analizojë në çfarë mase programet aktuale të formimit të mësuesve të fizikës përgatisin mësuesit e ardhshëm dhe ata në detyrë për mësimdhënie të mbështetur nga teknologjia. Në studim është përdorur një qasje e kombinuar metodologjike, e cila ndërthur analizën krahasuese të kurrikulave me kërkimin empirik. Janë krahasuar programet e formimit të mësuesve të fizikës në Shqipëri, Kosovë, Mal të Zi, Maqedoni të Veriut, Itali dhe Holandë, duke u fokusuar në komponentët pedagogjikë, didaktikë, praktikë, teorikë, digjitalë dhe kërkimorë. Gjithashtu, janë mbledhur të dhëna përmes pyetësorëve nga 63 mësues të fizikës në arsimin e mesëm të lartë dhe 13 studentë të programit Master i Shkencave në Mësuesi Fizikë. Rezultatet tregojnë se programi shqiptar ofron një bazë të qëndrueshme pedagogjike dhe teorike, por komponenti digjital mbetet relativisht i kufizuar në krahasim me disa programe europiane. Mësuesit dhe studentët vlerësojnë rëndësinë e teknologjisë për rritjen e të kuptuarit të koncepteve fizike dhe të përfshirjes së nxënësve në procesin mësimor, por njëkohësisht evidentojnë mangësi në përgatitjen për përdorimin e teknologjisë, laboratorëve virtualë dhe metodave bashkëkohore të mësimdhënies. Studimi nxjerr në pah nevojën për modernizimin e programeve të formimit të mësuesve përmes forcimit të kompetencave digjitale, integritit të simulimeve, laboratorëve virtualë dhe metodave inovative të mësimdhënies, në përputhje me standardet europiane dhe kërkesat e arsimit bashkëkohor.

Fjalë kyçe: edukimi në fizikë; formimi i mësuesve; kompetenca digjitale; integrimi i teknologjisë; arsimi STEM; transformimi digjital.

Introduction

Digital transformation has become one of the most influential forces shaping contemporary education systems. Advances in information and communication technologies have transformed teaching methodologies,

learning environments, assessment practices, and professional expectations for educators. Teachers are increasingly expected not only to possess strong disciplinary knowledge but also to demonstrate digital competence and the ability to integrate technology effectively into teaching and learning processes (Redecker, 2017).

Physics education is particularly influenced by technological developments. The abstract nature of many physical concepts often requires visualization, experimentation, modelling, and simulation. Digital tools such as virtual laboratories, interactive simulations, data acquisition systems, and online collaborative platforms provide opportunities for enhancing conceptual understanding and student engagement (Voogt et al., 2013).

European educational policies increasingly emphasize digital competence as a core element of teacher professionalism. The European Digital Education Action Plan (2021–2027) identifies digital literacy, technology-enhanced teaching, and innovative pedagogical approaches as priorities for educational development (European Commission, 2021). Similarly, the DigCompEdu framework highlights the importance of integrating digital technologies into professional teaching practice (Redecker, 2017).

In Albania, teacher preparation programmes have undergone significant reforms during the last decade. Nevertheless, questions remain regarding the extent to which these programmes prepare future teachers to meet the challenges of digitally enhanced education. This issue is particularly relevant in physics education, where technological tools can substantially improve the teaching and learning of scientific concepts.

The present study aims to:

1. Compare physics teacher education programmes in Albania and selected European countries.
2. Investigate teachers' perceptions regarding digital competence and technology integration.
3. Examine student teachers' preparedness for technology-enhanced instruction.
4. Identify curriculum gaps and propose directions for programme improvement.

Digital competence in teacher education

The rapid digitalization of society has fundamentally transformed educational systems and the role of teachers. In contemporary education, teachers are expected not only to possess strong disciplinary and pedagogical knowledge but also to demonstrate advanced digital competencies that enable them to design, implement, and evaluate technology-enhanced learning environments. Consequently, digital competence has become a central element of teacher professionalism and an essential component of teacher education programmes worldwide.

According to the European Framework for the Digital Competence of Educators (DigCompEdu), digital competence encompasses a broad range of skills, including the ability to select and create digital resources, facilitate online collaboration, support student engagement through technology, and use digital tools for assessment and feedback (Redecker, 2017). Digital competence therefore extends beyond technical proficiency and includes pedagogical decision-making, ethical considerations, communication skills, and the critical evaluation of digital information.

Recent studies have demonstrated that teachers with higher levels of digital competence are more likely to integrate technology effectively into classroom practices and create student-centred learning environments (Caena & Redecker, 2019). Furthermore, digital competence has become increasingly important following the COVID-19 pandemic, which accelerated the adoption of online and blended learning approaches worldwide (OECD, 2023). As a result, universities and teacher preparation institutions are under growing pressure to ensure that future teachers develop the necessary skills to teach in technologically rich educational settings.

For science teachers in particular, digital competence plays a crucial role in facilitating inquiry-based learning, data analysis, scientific modelling, and collaborative problem-solving. Consequently, contemporary teacher education programmes are expected to provide systematic opportunities for student teachers to acquire and apply digital skills throughout their studies rather than through isolated technology-related courses.

Technology integration in physics education

Physics education has traditionally relied on experimental investigation, laboratory activities, mathematical modelling, and conceptual reasoning. However, technological innovations have significantly expanded the possibilities for teaching and learning physics. Digital simulations, virtual

laboratories, modelling software, data acquisition systems, and interactive multimedia tools now offer opportunities to visualize abstract phenomena and support deeper conceptual understanding.

Many concepts in physics, such as electromagnetic fields, quantum phenomena, wave propagation, and atomic structure, are difficult to observe directly in conventional classroom environments. Digital simulations allow students to explore these concepts through visualization and interactive experimentation. Research indicates that simulation-based learning can improve conceptual understanding, increase student motivation, and support the development of scientific reasoning skills (de Jong et al., 2013).

Virtual laboratories have become particularly important in situations where access to physical laboratory equipment is limited. Such environments enable students to perform experiments repeatedly, manipulate variables safely, and investigate phenomena that may be difficult or expensive to reproduce in traditional laboratories. Studies have shown that combining physical and virtual experimentation can enhance learning outcomes and foster deeper understanding of scientific concepts (Zacharia & Olympiou, 2011).

Technology integration also supports active learning approaches in physics education. Interactive platforms, online assessment systems, collaborative digital tools, and educational applications facilitate student engagement and encourage participation in inquiry-based activities. Furthermore, digital resources can help teachers differentiate instruction and adapt learning experiences to diverse student needs.

Despite these advantages, effective technology integration depends heavily on teacher preparedness. Teachers require not only technical skills but also pedagogical knowledge that enables them to use technology meaningfully within specific disciplinary contexts. Consequently, the preparation of future physics teachers must include opportunities to develop both technological competence and pedagogical strategies for technology-enhanced instruction.

European frameworks for teacher preparation

European educational policies increasingly emphasize the importance of preparing teachers for rapidly evolving educational and technological environments. Contemporary teacher education programmes are expected to balance disciplinary expertise, pedagogical knowledge, practical teaching experience, research skills, and digital competence development.

One of the most influential frameworks in this area is the European Digital Education Action Plan (2021–2027), which promotes the development of high-performing digital education ecosystems and the enhancement of digital skills for all citizens (European Commission, 2021). The plan highlights the need for teacher education programmes to integrate digital technologies systematically and prepare educators capable of supporting learning in digital environments.

Another important framework is DigCompEdu, which identifies six areas of educator competence: professional engagement, digital resources, teaching and learning, assessment, learner empowerment, and facilitating learners' digital competence (Redecker, 2017). These areas provide guidance for universities and policymakers seeking to modernize teacher preparation programmes.

In addition to European policy frameworks, the Technological Pedagogical Content Knowledge (TPACK) model has become widely used in teacher education research. The TPACK framework argues that effective teaching with technology requires the integration of three forms of knowledge: content knowledge, pedagogical knowledge, and technological knowledge (Koehler et al., 2013). Rather than treating technology as a separate skill, the framework emphasizes the interconnected nature of these domains and their importance in designing meaningful learning experiences.

Recent developments in STEM education have further reinforced the need for interdisciplinary and technology-rich approaches to teacher preparation. Modern educational systems increasingly expect teachers to facilitate problem-based learning, critical thinking, collaboration, and creativity while incorporating digital technologies into everyday teaching practices. Consequently, many European universities have revised their curricula to strengthen practical training, technology integration, and competency-based learning outcomes.

The analysis of European teacher education programmes therefore provides a useful reference for evaluating the strengths and limitations of national programmes and identifying opportunities for curriculum modernization in response to contemporary educational challenges.

Materials and methods

Research design

This study employed a mixed-method research design that combined qualitative and quantitative approaches in order to obtain a comprehensive understanding of the current state of physics teacher education in Albania and its alignment with contemporary educational and technological requirements. Mixed-method research is particularly appropriate when investigating educational phenomena because it allows researchers to integrate numerical data with participants' experiences and perceptions, thereby providing a more complete interpretation of the research problem (Creswell & Creswell, 2018).

The study was conducted in two interconnected phases. The first phase focused on a comparative analysis of teacher education curricula in Albania and selected European countries. This stage aimed to identify similarities and differences in programme structures, with particular attention to the development of pedagogical, didactic, practical, digital, theoretical, and research competencies. The second phase consisted of an empirical investigation involving physics teachers and student teachers. Through questionnaire-based data collection, the study explored participants' perceptions regarding digital competence development, technology integration in teaching, professional preparation, and the challenges associated with implementing innovative teaching practices.

The integration of curriculum analysis and empirical evidence enabled the study to examine both the structural characteristics of teacher education programmes and the experiences of individuals directly involved in the teaching profession. Such an approach contributes to a more comprehensive understanding of how teacher education programmes respond to the demands of digital transformation in education.

Comparative curriculum analysis

The comparative component of the study examined Master's programmes for physics teacher education offered in Albania, Kosovo, Montenegro, North Macedonia, Italy, and the Netherlands. These countries were selected because they represent different approaches to teacher preparation within the European Higher Education Area and provide useful perspectives for evaluating the Albanian programme.

The analysis was based on official curriculum documents, study plans, course descriptions, and programme specifications obtained from university websites

and institutional documentation. Following procedures commonly used in comparative education research (Bray et al., 2014), programme components were classified into six categories: pedagogical, didactic, practical, theoretical, digital, and research-oriented courses.

Pedagogical courses included subjects related to educational psychology, pedagogy, and classroom management. Didactic courses referred to subject-specific teaching methodologies. Practical components included teaching practice and school placements. Digital components included courses focusing on educational technologies, digital pedagogy, simulations, and ICT applications in education. Research components included thesis work and research methodology courses. Theoretical components referred to disciplinary physics content courses.

For each programme, the number of courses, European Credit Transfer and Accumulation System (ECTS) credits, and proportional representation of each component within the curriculum were calculated. The percentage distribution of curriculum components enabled direct comparisons among programmes despite differences in institutional structures and national educational systems. Particular attention was given to the digital component, as the primary objective of the study was to investigate the extent to which teacher education programmes prepare future physics teachers for technology-enhanced learning environments.

The comparative analysis also considered contemporary European policy frameworks, including the European Digital Education Action Plan (European Commission, 2021) and the European Framework for the Digital Competence of Educators (Redecker, 2017), which emphasize the importance of integrating digital competence into teacher preparation programmes.

Participants

Ethical considerations

Participation in the study was voluntary and anonymous. All participants provided informed consent prior to completing the questionnaire. The collected data were used exclusively for research purposes and were processed in accordance with ethical principles for educational research and data protection requirements.

The empirical component of the study involved a total of 76 participants drawn from two distinct groups. The first group consisted of sixty-three physics teachers of ages 25 – 50 currently employed in upper-secondary schools in

Albania. These participants represented different levels of professional experience and provided valuable insights into the practical realities of teaching physics in contemporary educational settings.

The second group consisted of thirteen student teachers enrolled in the Master of Science programme in Physics Teaching at the Faculty of Natural Sciences, University of Tirana. These participants were selected because they represent future physics teachers who are currently undergoing professional preparation and are directly affected by the structure and content of the programme under investigation.

The inclusion of both practicing teachers and student teachers allowed the study to capture perspectives from individuals at different stages of professional development. This approach facilitated the identification of strengths and weaknesses within the teacher education programme from both retrospective and prospective viewpoints.

Participation in the study was voluntary, and respondents completed the questionnaires anonymously. The confidentiality of all participants was ensured throughout the research process in accordance with established ethical principles for educational research.

Data collection instruments

Data were collected through two structured questionnaires specifically designed for the purposes of this study. Questionnaire-based research is widely recognized as an effective method for gathering information regarding participants' attitudes, perceptions, experiences, and professional practices (Cohen et al., 2018).

The questionnaire administered to practicing physics teachers consisted of closed-ended and open-ended questions organized into several thematic sections. These sections addressed university preparation for teaching, exposure to educational technologies during initial teacher education, current use of digital technologies in classroom practice, participation in professional development activities, perceived challenges associated with technology integration, and recommendations for improving teacher preparation programmes.

The questionnaire designed for student teachers explored similar themes while focusing more specifically on their experiences within the Master's programme. Students were asked about the use of digital technologies during their studies, their preparation for technology-enhanced teaching, training

related to simulations and virtual laboratories, perceptions of digital competence development, and suggestions for curriculum improvement.

The combination of closed-ended and open-ended questions allowed the study to generate both quantitative and qualitative data. Quantitative responses provided measurable indicators of participants' perceptions and experiences, whereas qualitative responses offered deeper insights into their views regarding curriculum strengths, weaknesses, and future needs.

Data analysis

The collected data were analyzed using both quantitative and qualitative procedures. Quantitative questionnaire responses were processed using descriptive statistical techniques, including frequencies, percentages, and graphical representations. Descriptive statistics are particularly appropriate for educational studies aiming to summarize participant responses and identify general trends within a sample population (Field, 2018).

Responses obtained from open-ended questions were analyzed through thematic analysis. This method involves identifying recurring themes, patterns, and categories within qualitative data and has been widely used in educational research to interpret participants' experiences and perceptions (Braun & Clarke, 2006). Through this process, common concerns, recommendations, and observations expressed by teachers and student teachers were systematically categorized and interpreted.

The findings from the empirical investigation were subsequently compared with the results of the curriculum analysis. This triangulation of data sources enhanced the credibility of the study by allowing curriculum structures to be examined alongside the experiences and perceptions of programme stakeholders. The integration of quantitative and qualitative evidence contributed to a more comprehensive evaluation of physics teacher education and its capacity to address the challenges associated with digital transformation in contemporary education. Given the exploratory nature of the study and the relatively small sample size, descriptive statistics were considered appropriate for identifying general trends.

Results and discussions

Comparative analysis of physics teacher education programmes

The comparative analysis of Master's programmes for physics teacher education revealed substantial differences in curriculum structures among the

countries included in the study. Although all programmes aimed to prepare future teachers for secondary education, significant variations were identified regarding the balance between theoretical preparation, pedagogical training, practical experience, research activities, and digital competence development.

Table 1. Presentation of Albania, Kosovo, and Montenegro by Percentage According to Components

Comparison Elements	Albania Subjects	ECTS Credits	Percentage	Kosovo Subjects	ECTS Credits	Percentage	Montenegro Subjects	ECTS Credits	Percentage
Pedagogical Component	6	30	25%	6	26	21.60%	2	6	5%
Didactic Component	2	12	10%	2	12	10%	2	9	7.50%
Practical Component	2	9	7.50%	3	15	12.50%	2	6	5%
Theoretical Component	7	30	25%	7	39	32.50%	10	89	74.20%
Digital Component	2	9	7.50%	2	8	6.70%	2	10	8.30%
Research Component	1	30	25%	1	20	16.70%	0	0	0%
TOTAL	20	120	100%	21	120	100%	18	120	100%

As shown in Table 1, the Albanian programme demonstrates a relatively balanced distribution of curriculum components. Pedagogical courses account for 25% of the programme, while theoretical and research-oriented courses each represent an additional 25%. In contrast, the practical component represents only 7.5% of the total curriculum, while the digital component accounts for 7.5% (9 ECTS credits).

Compared with neighbouring countries, Kosovo presents a similar structure, although with a slightly stronger emphasis on theoretical preparation (32.5%) and practical training (12.5%). Montenegro, on the other hand, demonstrates a highly theory-oriented curriculum, with theoretical subjects accounting for more than 74% of the programme and virtually no research component. Such a distribution may provide strong disciplinary preparation but offers fewer opportunities for the development of pedagogical innovation and reflective professional practice.

Table 2. Presentation of North Macedonia, Italy, and the Netherlands by Percentage According to Components

Comparison Elements	North Macedonia Subjects	ECTS Credits	Percentage	Italy Subjects	ECTS Credits	Percentage	The Netherlands Subjects	ECTS Credits	Percentage
Pedagogical Component	4	20	16.60%	3	15	12.50%	3	12.5	10.40%
Didactic Component	4	28	23.40%	3	18	15%	3	17.5	14.60%
Practical Component	3	19	15.80%	2	12	10%	3	30	25%
Theoretical Component	5	22	18.40%	12	57	47.50%	2	10	8.35%
Digital Component	2	10	8.30%	3	18	15%	2	10	8.35%
Research Component	2	21	17.50%	0	0	0%	3	40	33.30%
TOTAL	31	120	100%	23	120	100%	16	120	100%

The comparison becomes even more significant when examining programmes from Italy and the Netherlands (Table 2). The Italian programme allocates approximately 15% of the curriculum to digital competence development, representing almost twice the proportion observed in Albania. Furthermore, Italian programmes incorporate technology-enhanced learning environments, educational software, and digital teaching methodologies as integral elements of teacher preparation.

The Dutch programme exhibits a different model characterized by a strong emphasis on research (33.3%) and practical training (25%). This reflects contemporary European trends that view teachers not only as classroom practitioners but also as reflective professionals capable of conducting educational inquiry and evidence-based decision making (European Commission, 2021).

Overall, the comparative analysis suggests that the Albanian programme provides a solid foundation in pedagogy and disciplinary knowledge; however, it allocates fewer opportunities for digital competence development and practical experiences than several European programmes. These findings are consistent with recommendations from DigCompEdu, which emphasizes the integration of digital competence throughout teacher education curricula (Redecker, 2017).

Furthermore, this study explored the perceptions of 63 upper-secondary physics teachers and 13 Master's students enrolled in the Physics Teacher

Education programme regarding the integration of digital technologies, the adequacy of teacher preparation programmes, and the implementation of modern teaching approaches in physics education. The findings provide valuable insights into the current state of teacher preparation and the challenges associated with digital transformation in science education. In the figures below, are presented some of the teachers' questionnaires results.

1. Teachers' perspectives on initial preparation and technology integration

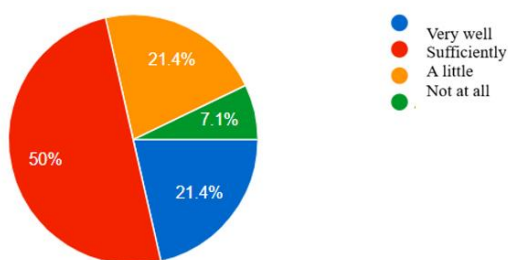


Figure 1. Percentage distribution of responses regarding whether the university program prepared teachers for the use of technology in the classroom.

The data presented in Figure 1 indicate that most participants perceived their university studies as providing adequate preparation for the use of technology in teaching. However, a considerable proportion (50%) reported that their preparation was only partially sufficient. This finding is consistent with previous research suggesting that teacher education programmes often include theoretical exposure to educational technologies but provide limited opportunities for authentic classroom implementation (Tondeur et al., 2017).

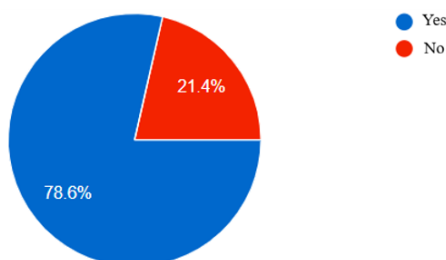


Figure 2. Percentage distribution of responses on whether teachers attended courses related to technology in teaching during their studies.

The 78.6% of respondents reported having attended courses related to technology-enhanced teaching during their university studies. This result reflects the growing inclusion of digital competence within teacher education curricula. Nevertheless, the findings of the present study suggest that the existence of technology-related courses alone may not guarantee confidence or competence in classroom application.

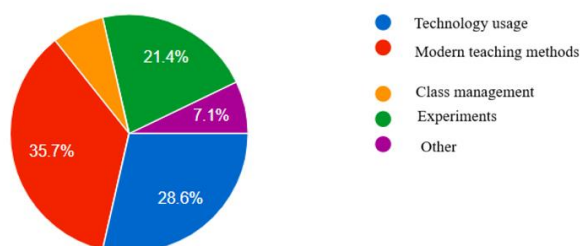


Figure 3. Percentage distribution of responses on skills perceived as lacking in university preparation.

Despite generally positive perceptions of university preparation, respondents identified significant gaps in their initial training. The most frequently reported deficiencies concerned digital technologies, contemporary teaching methodologies, and the organisation of laboratory activities and experiments. These findings highlight the need for stronger alignment between university curricula and the evolving demands of twenty-first-century education.

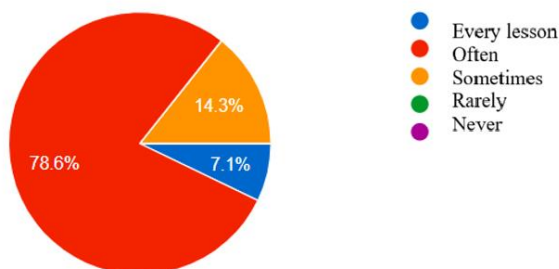


Figure 4. Frequency of digital tool use in teaching

Teachers reported frequent use of digital tools during physics instruction. This demonstrates an increasing acceptance of technology as a pedagogical resource and reflects broader educational trends towards digitalisation. The

findings suggest that teachers recognise the educational benefits of technological tools and actively seek to integrate them into instructional practice.

Although teachers expressed positive attitudes towards technology integration, they also identified several barriers to implementation. The most significant challenge was the lack of technological equipment in schools. Additional obstacles included insufficient internet access, limited instructional time and inadequate opportunities for professional training. These findings suggest that successful technology integration requires not only teacher competence but also institutional and infrastructural support.

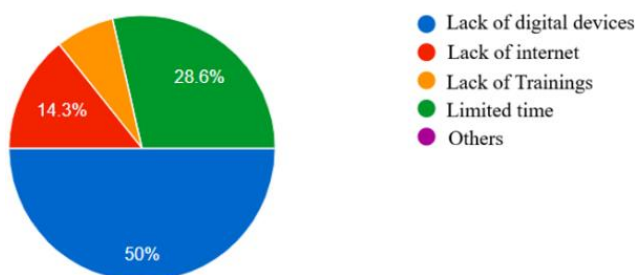


Figure 5. Main challenges in using technology in the classroom.

What was interesting was the fact that most respondents indicated that they had participated in postgraduate or in-service training related to educational technology. This demonstrates a strong commitment to continuous professional development and highlights teachers' awareness of the importance of updating their pedagogical competencies.

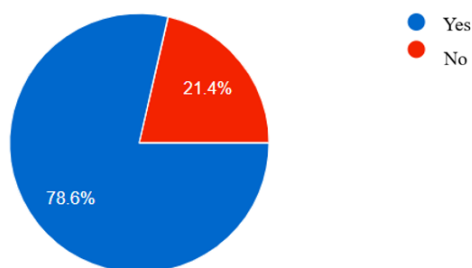


Figure 6. Postgraduate training on the use of technology in teaching

Almost all participants considered professional development training essential for effective teaching. Teachers recognised that continuous learning is necessary to keep pace with technological developments and changing educational expectations. This finding aligns with European recommendations concerning lifelong professional learning for teachers.

2. Students' perspectives on digital readiness

The student questionnaire provided complementary evidence regarding the effectiveness of current teacher preparation programmes. As can be seen by the figures below, students reported frequent use of digital platforms during their university studies, indicating that digital learning environments have become a regular component of higher education. Most students confirmed that their study programme includes courses focused on educational technology and digital pedagogy.

This demonstrates institutional efforts to integrate digital competence into teacher education. Students generally reported feeling prepared to use technology in future classroom settings. Nevertheless, several respondents expressed the need for more practical experiences and direct classroom application before entering the teaching profession.

The findings reveal exposure to a variety of digital tools during university studies, including presentation software, simulations and online learning platforms. Such experiences contribute to the development of digital teaching competencies. Most participants (69.2%) believed that their university programme contributes partially positively to preparing future teachers for digitally enriched educational environments.

However, they also recognised the need for further development of practical teaching skills.

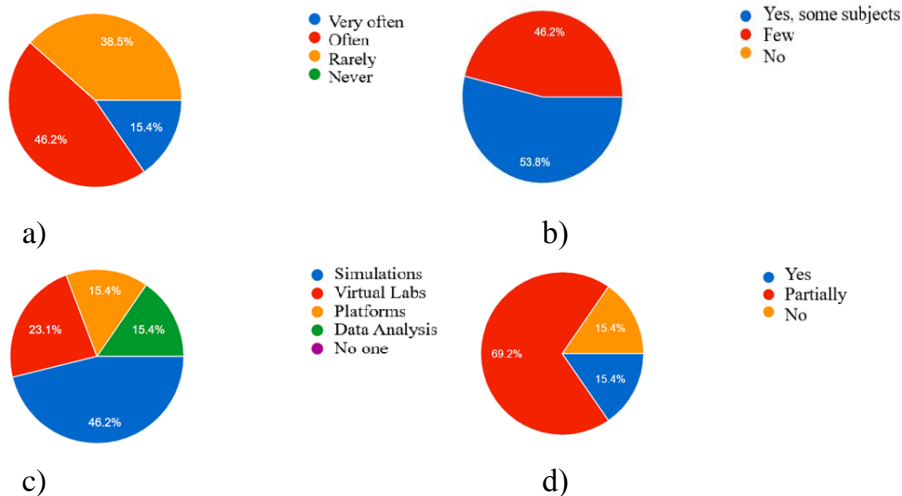


Figure 7. Students results. a) Frequency of digital platform use in the university teaching process. b) Inclusion of courses related to the use of technology in teaching within the study program. c) Digital tools used during studies. d) Perception of how well the university program prepares students for digital teaching environments.

Students emphasised the importance of strengthening competencies related to educational technologies, simulations, laboratory work and innovative pedagogical approaches. Their responses consistently highlighted the need for increased practical training and authentic teaching experiences.

3 Synthesis of findings

The combined analysis of teacher and student responses reveals a generally positive perception of technology integration within physics education. Nevertheless, several persistent challenges remain. Both groups identified insufficient practical preparation, limited exposure to modern teaching methodologies and inadequate technological infrastructure as major concerns. These findings suggest that although progress has been made in incorporating digital competence into teacher education programmes, further curricular reforms are required.

The results are particularly relevant in the context of the European Digital Education Action Plan (2021–2027), which emphasises the development of digital skills, innovative pedagogies and technology-supported learning environments. While Albania has made significant progress in aligning its educational policies with European priorities, the findings indicate that

additional efforts are needed to strengthen practical training, improve technological infrastructure and support continuous professional development for physics teachers.

Limitations of the study

This study has several limitations that should be acknowledged. First, the sample of student teachers was relatively small ($n = 13$), which may limit the generalizability of the findings. Second, the study relied on self-reported questionnaire data, which may be influenced by participants' subjective perceptions and social desirability bias. Third, participants were selected through voluntary participation, which may have introduced sampling bias. Finally, differences in curriculum structures across countries may limit direct comparability of programme components despite the use of common classification criteria.

Conclusions and recommendations

This study examined the development of digital competence within physics teacher education through a comparative analysis of teacher preparation programmes and an empirical investigation involving practicing physics teachers and student teachers in Albania. The findings provide important insights into the strengths and limitations of current programmes in relation to the demands of contemporary education and European educational frameworks.

The comparative curriculum analysis revealed that the Albanian Master's programme in Physics Teaching provides a relatively balanced structure, combining theoretical, pedagogical, and research-oriented components. This balance contributes to the development of strong disciplinary knowledge and pedagogical foundations among future teachers. However, the analysis also demonstrated that the digital component occupies a relatively small proportion of the curriculum compared with several European programmes, particularly those implemented in Italy and the Netherlands, where greater emphasis is placed on digital competence, practical training, and technology-enhanced teaching methodologies.

The empirical findings support the conclusions drawn from the curriculum analysis. Both practicing teachers and student teachers acknowledged the significant role of technology in facilitating the teaching and learning of physics. Participants emphasized that digital tools, simulations, multimedia resources, and virtual laboratories contribute substantially to the

understanding of complex scientific concepts and increase student engagement during classroom activities. These findings are consistent with previous studies highlighting the positive impact of technology-enhanced learning environments on science education (de Jong et al., 2013; Redecker, 2017).

Despite these positive perceptions, the study identified several challenges that continue to affect the effective integration of technology into physics education. Participants reported limitations in their initial preparation for technology-enhanced teaching, insufficient exposure to simulations and virtual laboratories during their studies, and a lack of continuous professional development opportunities focused on digital competence. Furthermore, infrastructural challenges, including inadequate technological equipment, unreliable internet access, and limited laboratory resources, remain significant barriers to innovation in teaching practice.

The convergence of evidence from curriculum analysis, teacher questionnaires, and student questionnaires indicates that the modernization of physics teacher education has become a strategic necessity. While the current programme successfully develops pedagogical and disciplinary competencies, additional efforts are required to strengthen digital competence, practical training, and the application of innovative teaching methodologies. Such reforms are essential if future physics teachers are to respond effectively to the challenges of digital transformation and contemporary STEM education.

Overall, the study concludes that digital competence should no longer be viewed as an additional or optional component of teacher education. Rather, it should be considered a fundamental element of professional preparation, integrated systematically throughout the curriculum and supported by appropriate institutional resources, technological infrastructure, and continuous professional development opportunities.

Based on the findings of this study, several recommendations can be proposed for universities, policymakers, and institutions responsible for teacher education and professional development.

First, universities should strengthen the integration of digital competence across all components of physics teacher education programmes. Rather than limiting technology-related content to isolated courses, digital pedagogy should be embedded throughout subject-specific didactics, teaching practice, assessment activities, and research projects. Particular attention should be

given to the use of simulations, virtual laboratories, interactive educational platforms, and data-analysis tools relevant to physics education.

Second, teacher education programmes should increase opportunities for practical and experiential learning. Extended school placements, laboratory-based activities, microteaching sessions, and technology-enhanced teaching practice would enable student teachers to apply theoretical knowledge in authentic educational settings. Such experiences are essential for developing confidence and competence in the use of digital technologies during classroom instruction.

Third, universities should modernize laboratory facilities and expand access to digital learning resources. Investments in virtual laboratories, simulation software, interactive technologies, and online learning environments would contribute significantly to improving the quality of teacher preparation and ensuring alignment with international educational standards.

Fourth, policymakers should support the implementation of national strategies aimed at strengthening digital competence among teachers. These strategies should include investments in educational infrastructure, reliable internet connectivity, digital equipment, and sustainable funding mechanisms that enable schools to adopt innovative teaching practices. Aligning teacher education programmes with the DigCompEdu framework and other European policy initiatives would further contribute to improving educational quality and international competitiveness.

Finally, continuous professional development should become a central element of teacher career progression. Training programmes should focus on emerging technologies, digital pedagogy, artificial intelligence applications in education, virtual experimentation, and innovative STEM teaching methodologies. Such initiatives would help practicing teachers remain responsive to technological developments and educational innovations throughout their professional careers.

In the short term, universities may strengthen the use of simulations and digital resources within existing courses. In the medium term, investments in laboratory infrastructure and digital equipment should be prioritised. In the long term, national professional development frameworks aligned with DigCompEdu may support the continuous development of digital competence among physics teachers.

In conclusion, strengthening digital competence within physics teacher education represents a crucial step toward improving the quality of science education in Albania. By combining curriculum modernization, enhanced practical training, technological investment, and continuous professional development, teacher education institutions can better prepare future educators for the realities of twenty-first-century teaching and learning.

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