CTE Workshop Proceedings, 2025, Vol. **12**, pp. 312–328 https://doi.org/10.55056/cte.878

Integrated approach to the formation of information and digital competence in future primary school teachers

Olga G. Yaroshenko[1], Olena D. Samborska[2]

[1]*Institute of Higher Education of NAES of Ukraine, 9 Bastionna Str., Kyiv, 03056, Ukraine*
[2]*Bar Humanitarian and Pedagogical College named after Mykhailo Hrushevsky, 1 Hrushevsky Sq., Bar, 23000, Ukraine*

Abstract. This article presents an expanded analysis of the experimental verification of an integrated approach to modernizing information and digital training of future primary school teachers. The research responds to the growing importance of digital competence in contemporary educational environments, particularly in light of the digital transformation of society. The study employed a comprehensive experimental design involving control and experimental groups of students at pedagogical colleges over a two-year period. The integrated approach encompassed all major forms of the educational process, including an author's elective course "Modern Information and Digital Technologies in the Educational Process of Primary School". Robust methodological support was developed, consisting of electronic teaching materials, interactive learning activities, and practical tasks embedded throughout the curriculum. Statistical analysis of cognitive, operational, and value components of students' information and digital (ID) competence confirmed the significant effectiveness of the integrated approach. The experimental group demonstrated markedly higher levels of digital competence formation across all measured dimensions. Beyond statistical validation, the research revealed how this approach better prepared future teachers for the challenges of online education during the COVID-19 pandemic. This study contributes to the theoretical understanding of digital competence formation in teacher education and provides practical insights for modernizing primary teacher preparation in the digital age.

Keywords: integrated approach, information and digital competence, future primary school teachers, digital training modernization, educational process forms, control and experimental groups, pedagogical colleges, cognitive component, operational component, value component, COVID-19 pandemic, digital transformation

1. Introduction

The pervasive digitalization of contemporary society has transformed virtually every aspect of human activity, with education standing among the most significantly impacted domains. Information and digital technologies (IDT) have become integral components of quality assurance systems in education worldwide, fundamentally altering teaching and learning processes [23]. This transformation has been particularly pronounced during the recent pandemic period, when digital infrastructures became not merely supplementary but essential to educational continuity [10].

The imperative to enhance educational systems through innovative technologies is highlighted in numerous policy frameworks, including the UNESCO Education Position Paper [9], the National Strategy for Education Development in Ukraine [14], and the Conceptual Principles of Pedagogical Education in Ukraine [20]. These frameworks

0000-0003-1555-0526 (O. G. Yaroshenko); 0000-0002-8071-9730 (O. D. Samborska)
o.yaroshenko@ihed.org.ua (O. G. Yaroshenko); samborska@ukr.net (O. D. Samborska)
https://ihed.org.ua/about/staff/yaroshenko-olga-grygorivna/ (O. G. Yaroshenko);
https://www.bar-bgpk.com.ua/administraciya (O. D. Samborska)

underscore the need for systematic integration of digital technologies into educational processes at all levels.

Information and digital training in institutions of higher pedagogical education presents unique challenges and opportunities. Unlike many other educational contexts, pedagogical institutions must address a dual purpose: not only must they employ digital technologies as tools for effective teaching and learning, but they must also prepare future teachers to implement these technologies skillfully in their own professional practice [1, 8]. This dual focus requires that graduates develop the ability to transfer acquired digital knowledge and skills to schoolchildren, taking into account the diverse cognitive and developmental characteristics of young learners.

The context of educational reform in Ukraine further amplifies the importance of this work. The implementation of the State Standard of Primary Education [19], the National Strategy for Education Development [14], and the New Ukrainian School Concept [18] all emphasize the need to modernize teacher training and align educational programs with the requirements of the digital economy and evolving information environments. These policy imperatives create a pressing need to reconsider how primary school teachers are prepared to navigate and leverage digital technologies in their future professional activities.

1.1. Current research on information and digital training

The scholarly landscape regarding information and digital technologies in education has expanded considerably in recent years. Researchers have examined various aspects of this domain, including the integration of digital tools into educational practices, the development of digital competence frameworks, and the transformation of pedagogical approaches in digitally mediated environments.

For this study, particular attention was given to research focused on the preparation of future primary school teachers for using digital technologies. Andriievska [1] analyzed the training of future primary school teachers to use information and communication technologies at the didactic level, substantiating the essence of their readiness for this component in professional activities. Drokina [8] identified the structural components of information competence in future primary school teachers and substantiated a structural-functional model for its formation. Both researchers primarily focused on methodological training of students and the development of readiness to use IDT in primary education.

Onishchenko [15] established connections between the formation of future primary school teachers' information competence and the broader informatization of higher pedagogical education. In her monograph and dissertation, Petukhova [17] focused on developing future primary school teachers' IT competence, revealing specific features of IDT use depending on the information and communication environment of students' professional training.

Upatova [25] studied the system of methodical training of future primary school teachers, including aspects related to using IDT in primary education. However, IDT and targeted ID training were not the primary focus of this research.

While acknowledging the significant contributions of these researchers, it is important to note that a comprehensive approach to modernizing the training of primary education bachelors – one that addresses all forms of educational process organization – has not yet been the subject of targeted pedagogical research. The formation of information and digital competence as a key competence for learners thus remains a critical task for professional education theory and methodology.

1.2. Theoretical foundation and previous work

In our previous research [28], we established the content and component composition of information and digital competence for future primary school teachers and substantiated the integrated approach to modernizing their digital training. That work provided the theoretical foundation for the current study, which seeks to empirically verify the effectiveness of this approach in real educational settings.

The present article builds upon that foundation by reporting the results of an experimental verification of the integrated approach to information and digital training of future primary school teachers. This verification was conducted within actual pedagogical college environments at the bachelor's level of higher education. The experimental work encompassed all major forms of the educational process, including classroom instruction, independent study, practical training, and assessment activities.

2. Conceptual framework of digital competence

2.1. Digital competence in the European context

The concept of digital competence has evolved significantly in recent years, particularly in the European educational context. The European Digital Competence Framework (DigComp), developed by the European Commission's Joint Research Center, has become a reference point for understanding and developing digital competence across educational systems [26]. This framework conceptualizes digital competence as a multidimensional construct comprising knowledge, skills, and attitudes necessary for confidently and critically using digital technologies [7].

DigComp has progressed through several versions since its initial development in 2013, with each iteration reflecting the changing digital landscape and educational needs. The current version, DigComp 2.2, encompasses five key competence areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving. Each area contains specific competences that are further detailed through proficiency levels, from basic to highly specialized [3].

For teacher education specifically, the European Framework for the Digital Competence of Educators (DigCompEdu) has provided a structure for understanding and developing the digital competence of educational professionals. This framework addresses the unique requirements of educators to effectively integrate digital technologies into their teaching practice [5]. Unlike general digital competence frameworks, DigCompEdu specifically focuses on how educators can leverage digital technologies to enhance teaching and learning processes, emphasizing pedagogical rather than purely technical aspects of digital competence.

These European frameworks represent a shift in thinking about digital competence, moving away from narrow conceptions focused primarily on technical skills toward a more holistic understanding that encompasses critical thinking, creativity, and ethical considerations. This evolution aligns with broader educational goals of preparing individuals for active participation in an increasingly digital society [4].

2.2. Dimensions of digital competence in primary education

Within the specific context of primary education, digital competence takes on particular dimensions and characteristics. According to López García, Sánchez Gómez and García-Valcárcel Muñoz-Repiso [12], digital competence in primary education can be conceptualized along three primary dimensions: technological fluency, learning-knowledge, and digital citizenship. These dimensions reflect the need for future primary teachers to not only master technical aspects of digital technologies but also understand their pedagogical implications and social-ethical dimensions.

Technological fluency encompasses the basic skills required to operate digital devices and applications, including hardware manipulation, software usage, and general

technical knowledge. Learning-knowledge refers to the pedagogical application of digital technologies in educational contexts, including the design of digital learning activities, the development of digital content, and the assessment of digital learning outcomes. Digital citizenship addresses the ethical, legal, and social aspects of digital technology use, including digital identity management, online safety, and the cultivation of responsible digital behavior [6].

These dimensions align with the broader European frameworks while addressing the specific needs of primary education contexts. For future primary school teachers, developing competence across all three dimensions is essential for effective integration of digital technologies into their professional practice.

2.3. Integrated approach to development of digital competence

The integrated approach to developing digital competence in future primary teachers represents a comprehensive strategy that addresses all aspects of the educational process. This approach is characterized by several key features:

1. Digital competence development is embedded across the curriculum rather than isolated in specific courses or modules. This ensures that students encounter digital technologies in various contexts and develop a nuanced understanding of their application.
2. The approach employs a range of teaching and learning methods, including direct instruction, collaborative learning, problem-based learning, and project-based activities. This methodological diversity reflects the multifaceted nature of digital competence.
3. Students engage with digital technologies in authentic contexts that mirror real-world educational settings. This includes developing digital learning materials, designing digital learning activities, and implementing digital assessment strategies.
4. The approach emphasizes reflection on digital technology use, encouraging students to critically evaluate their experiences and develop a personal philosophy regarding digital technology integration.
5. Assessment strategies address all dimensions of digital competence, including technical skills, pedagogical application, and ethical considerations. This comprehensive assessment approach provides a holistic view of students' development.

This integrated approach aligns with contemporary thinking about effective teacher education, which emphasizes the importance of comprehensive, coherent, and contextualized learning experiences [11]. By addressing digital competence development across the entire educational program, this approach avoids the fragmentation and decontextualization that can occur when digital competence is treated as a discrete, isolated component of teacher education.

3. Methodology and experimental design

3.1. Research objective and questions

The primary objective of this study was to experimentally verify the effectiveness of the integrated approach to modernizing information and digital training of future primary school teachers in real educational settings at the bachelor's level of higher education. Specifically, the study sought to answer the following research questions:

1. Does the integrated approach to information and digital training lead to higher levels of ID competence formation compared to traditional approaches?
2. Which components of ID competence (cognitive, operational, value) are most significantly affected by the integrated approach?

3. How does the integrated approach prepare future teachers for the practical application of digital technologies in primary school settings?

3.2. Experimental setting and participants

The experiment was conducted across three pedagogical colleges in Ukraine: Bar Humanitarian Pedagogical College named after Mikhailo Hrushevsky, Uman Humanitarian Pedagogical College named after T.H. Shevchenko, and Khmelnytsky Pedagogical College of Khmelnytsky Humanitarian and Pedagogical Academy. These institutions were selected based on their programs in primary education at the bachelor's level and their willingness to participate in the experimental implementation of the integrated approach.

The study involved 112 students who had completed the educational qualification level of junior specialist (professional junior bachelor) and were continuing their studies at the bachelor's level with a reduced period of study (120 ECTS credits). All participants had entered their programs based on basic general secondary education.

For the formative stage of the pedagogical experiment, participants were divided into control (54 students) and experimental (58 students) groups. Assignment to groups was done to ensure comparable initial levels of digital competence based on preliminary assessment. The control group continued their studies according to the established methodology, while the experimental group's education was modified according to the integrated approach to training modernization.

3.3. Experimental design and procedure

The experiment followed a quasi-experimental design with pre-test and post-test measurements. The formative stage lasted two years, during which students studied key information and digital training disciplines, including "Practical Course of Informatics with Elements of Programming", "Methods of Teaching Informatics Education", and an elective course "Modern Information and Digital Technologies in the Educational Process of Primary School". Students also completed teaching and undergraduate practices during this period.

The implementation of the integrated approach in the experimental group involved systematic modifications to all forms of the educational process:

3.3.1. Curriculum content

The content of core disciplines was supplemented with information on the professionally oriented use of IDT in primary school education and the application of network services as pedagogical tools. Learning outcomes were expanded to include the ability to use IDT for ensuring quality student learning, conducting educational activities in digital environments, monitoring educational progress, adapting educational processes based on digital data, creating electronic documents, organizing online events, and understanding the role of digital resources in society.

3.3.2. Educational process forms

Lecture formats were diversified through interactive work with students, problem-based learning approaches, and expanded teaching aids using interactive whiteboards, phantoms, cases, tests, and videos. Various lecture types were implemented, including lectures-presentations, dual lectures, lectures-consultations, and lectures-press conferences.

Practical classes incorporated audiovisual media, digital devices, telecommunications, video computer systems, multimedia, interactive whiteboards, and virtual reality media. Tasks for group and individual activities were expanded to include professionally oriented assignments related to IDT use in primary schools. Students engaged

in modeling and conducting parts of lessons using digital tools, with a focus on developing digital literacy.

Independent work was reorganized to incorporate e-learning technologies, supported by an electronic teaching kit including syllabus, lecture course, practical work instructions, independent work recommendations, test control tasks, assessment criteria, and a glossary. Students were encouraged to use G Suite network services to create and maintain blogs or websites, enabling them to share their developments and experiences.

Student teaching practice was modified to emphasize the use of modern IDT in primary school settings. Students studied positive experiences of IDT use in primary schools, analyzed lessons incorporating digital educational resources, and produced digital handouts and demonstration materials. They also gained experience working with parents to organize schoolchildren's work with electronic educational resources and conducted public presentations on innovative digital educational materials.

3.3.3. The elective course

A key component of the experimental methodology was the elective course "Modern Information and Digital Technologies in the Educational Process of Primary School". This course, allocated two credits (36 hours of classroom instruction and 24 hours of independent work), was structured around four modules:

1. Theoretical and methodological principles of informatization of primary education and digital competence of pedagogical workers
2. Development of teachers' digital intelligence: a guide to digital tools in the effective management of the educational process
3. Google services in the work of primary school teachers
4. Digital technologies in management, organizational and methodical work of primary school

The course emphasized creative project tasks, particularly the development of electronic teaching materials for use in primary school lessons. Students worked in small groups using network services, gaining access to Google Drive and other collaboration platforms. Independent work was organized through Google Classroom, with materials placed in the online environment and accompanied by methodical support for remote interaction.

3.3.4. Assessment methods

Control measures included traditional forms such as oral examination, written control tasks, questionnaires, and testing, supplemented by the protection of internship reports prepared as presentations and expert evaluation of student projects. During the COVID-19 pandemic, students in the experimental group created distance learning materials for primary school subjects and implemented these projects in assigned classes, with experts evaluating the content, volume, curriculum compliance, presentation form, and interactive elements of the developed courses.

3.4. Data collection and analysis

Data collection focused on measuring students' ID competence across three key components: cognitive, operational, and value. Assessment of these components was conducted at the beginning (initial measurement) and end (final measurement) of the formative stage of the pedagogical experiment for both control and experimental groups.

The results were analyzed using descriptive statistics to identify patterns and trends in the development of ID competence components. Statistical evaluation of the

experimental results was performed using the chi-square criterion (χ^2) to determine the statistical significance of differences between the control and experimental groups.

4. Results and discussion

4.1. Initial and final measurements

The initial and final measurements of students' ID competence in both control and experimental groups revealed significant differences in developmental trajectories across all three components: cognitive, operational, and value. Table 1 presents the complete results of these measurements, showing the distribution of students across high, sufficient, and average levels for each component.

Table 1
The results of the initial and final measurements of students' ID competence in the control and experimental groups.

ID competence components	Levels	Groups							
		Control				Experimental			
		Measurements							
		Initial		Final		Initial		Final	
		People	%	People	%	People	%	People	%
Cognitive	High	12	22.2	16	29.6	11	19	26	44.8
	Sufficient	16	29.6	19	35.2	19	32.8	19	32.8
	Average	26	48.2	19	35.2	28	48.3	13	22.4
Operating activity	High	11	20.4	12	22.2	12	20.7	28	48.3
	Sufficient	17	31.5	18	33.3	18	31	21	36.2
	Average	26	48.2	24	44.4	28	48.3	8	13.8
Value	High	13	24.1	11	20.4	10	17.2	32	55.2
	Sufficient	13	24.1	18	33.3	22	38	20	34.5
	Average	28	51.8	25	46.3	26	44.8	6	10.3

At the initial measurement stage, both groups showed comparable distributions across all components, with approximately 20-24% of students at the high level, 24-33% at the sufficient level, and 45-52% at the average level. This similarity in starting points provides a solid basis for comparing the effects of the different educational approaches implemented in the control and experimental groups.

4.2. Development dynamics of ID competence components

The dynamics of ID competence component formation during the formative stage of the pedagogical experiment revealed substantial differences between the control and experimental groups. These differences are visualized in figures 1, 2, and 3, which present the initial and final measurements for each component.

Figure 1 demonstrates that after the formative stage, the number of students with a high level of cognitive component in the experimental group increased by 25.8 percentage points (from 19% to 44.8%), while the number with an average level decreased by 25.9 percentage points (from 48.3% to 22.4%). In contrast, the control group showed a more modest increase of 7.4 percentage points in the high level (from 22.2% to 29.6%), with 35.2% of students remaining at the average level – 12.8 percentage points higher than in the experimental group.

The operational component (figure 2) showed even more pronounced differences. In the experimental group, the percentage of students with a high level increased by 27.6 percentage points (from 20.7% to 48.3%), while those at the average level decreased by 34.5 percentage points (from 48.3% to 13.8%). The control group showed minimal

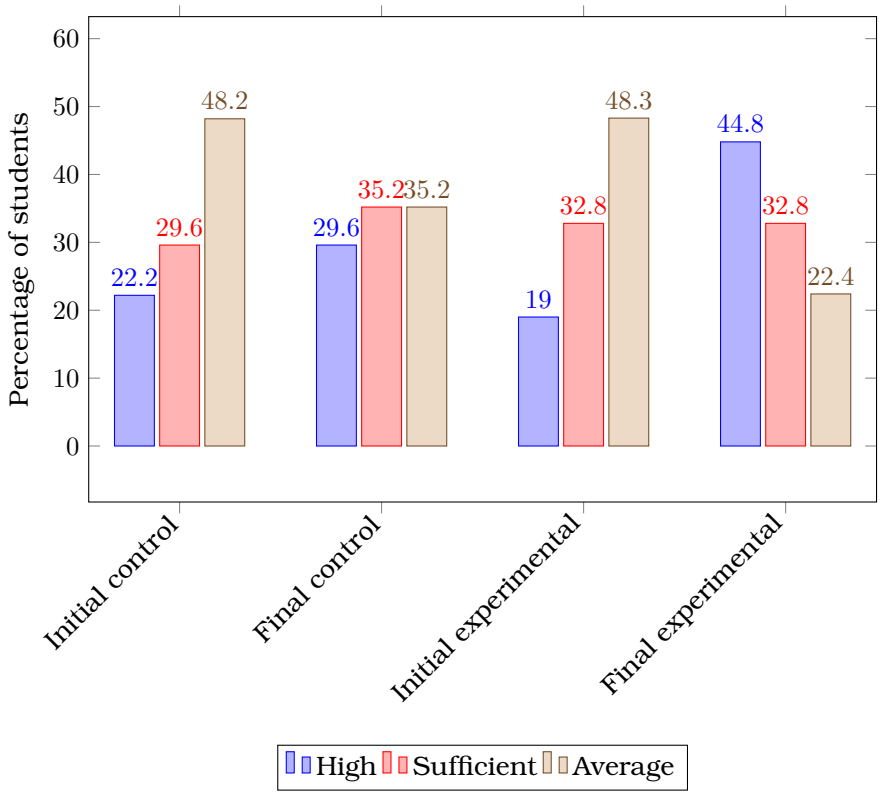

Figure 1: Dynamics of formation of the cognitive component of ID competence.

changes, with just a 1.8 percentage point increase at the high level (from 20.4% to 22.2%) and a 3.8 percentage point decrease at the average level (from 48.2% to 44.4%).

Similarly significant differences emerged in the value component (figure 3). The experimental group showed a dramatic increase of 38 percentage points in students at the high level (from 17.2% to 55.2%) and a corresponding decrease of 34.5 percentage points at the average level (from 44.8% to 10.3%). Notably, the control group actually showed a decrease of 3.7 percentage points in the high level (from 24.1% to 20.4%), with a modest 5.5 percentage point decrease at the average level (from 51.8% to 46.3%).

4.3. Statistical significance of the results

To determine whether the observed differences between the control and experimental groups were statistically significant, the chi-square criterion (χ^2) was applied. Using the formula for calculating the empirical value, $\chi^2 = 7.13$ was obtained. This value was compared with the critical value from statistical tables, yielding the ratio $\chi^2 = 7.13 > \chi^2_{0.05} = 5.99$, which indicates statistical reliability of the results at the $p < 0.05$ level.

This statistical confirmation reinforces the conclusion that the integrated approach to information and digital training had a significant positive impact on the formation of ID competence in future primary school teachers. The approach was particularly effective in developing the value component, where the experimental group showed the most dramatic improvements, followed by the operational and cognitive components.

4.4. Qualitative insights and COVID-19 context

Beyond the quantitative findings, the research revealed important qualitative insights into the effectiveness of the integrated approach. Notably, the COVID-19 pandemic provided an unexpected opportunity to observe how students applied their

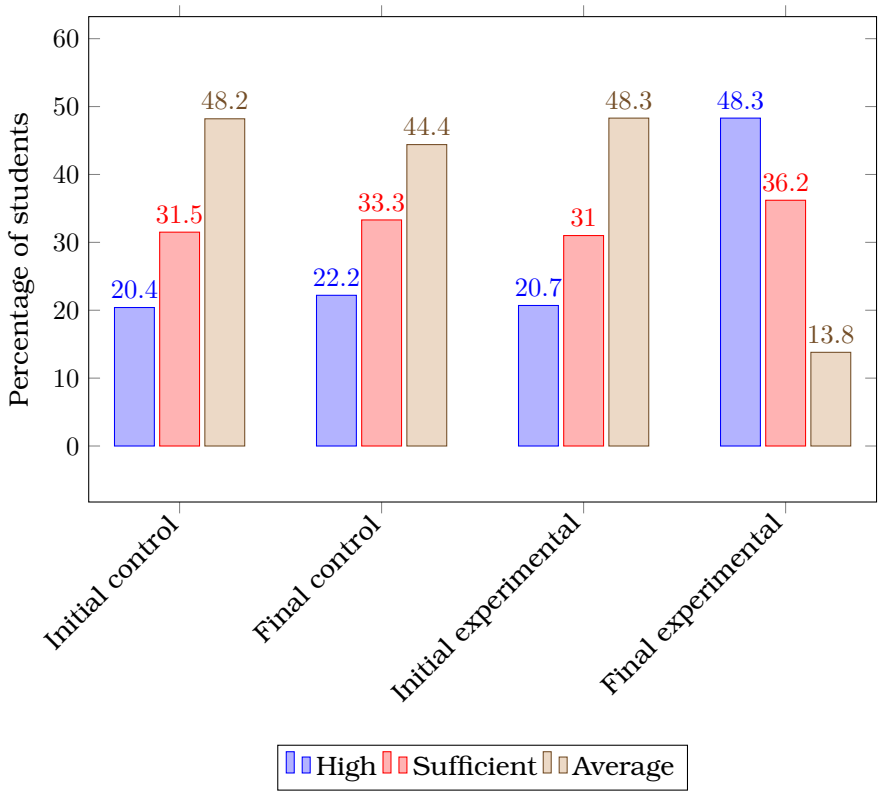

Figure 2: Dynamics of formation of the operational component of ID competence.

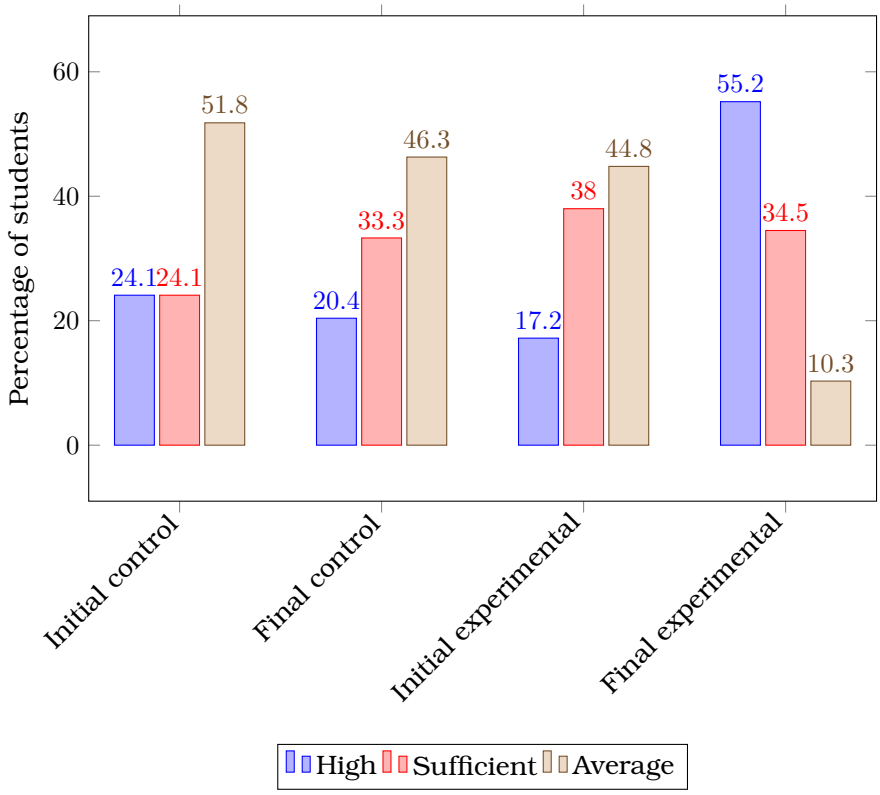

Figure 3: Dynamics of formation of the value component of ID competence.

digital competence in authentic crisis situations. Students in the experimental group demonstrated superior preparation for conducting online training of primary school

children under quarantine restrictions. They effectively organized online learning, helped teachers create and select appropriate tasks, provided assessment and feedback, and facilitated communication with primary students and their parents in the distance learning environment.

This real-world application of digital competence highlights the practical value of the integrated approach, particularly its emphasis on authentic learning experiences and the development of transferable skills. The ability of students in the experimental group to adapt their knowledge and skills to a sudden shift in educational modality suggests that the integrated approach fosters not only technical proficiency but also the flexibility and problem-solving capabilities essential for effective teaching in dynamic educational contexts.

5. Digital competence frameworks and educational policy context

5.1. Alignment with European digital competence frameworks

The integrated approach to ID training for future primary school teachers aligns conceptually with current European frameworks for digital competence development, particularly DigComp and DigCompEdu. This alignment is evident across several dimensions of these frameworks.

The cognitive component of ID competence, as conceptualized in this study, corresponds closely to the "Information and Data Literacy" and "Digital Content Creation" areas of DigComp, which emphasize knowledge and understanding of digital technologies and their applications [26]. The operational component aligns with the "Problem Solving" and technical aspects of DigComp, focusing on practical skills in using and implementing digital tools. The value component relates to the "Safety" and ethical dimensions of digital use emphasized in European frameworks.

DigCompEdu's emphasis on pedagogical application of digital technologies, rather than merely technical proficiency, is particularly well-represented in the integrated approach. The framework's areas of "Teaching and Learning", "Assessment", and "Empowering Learners" [5] align directly with the focus in this study on preparing future teachers to implement digital technologies in their professional practice and to develop their students' digital literacy.

This alignment with established European frameworks provides additional validation for the integrated approach and situates it within broader international discourse on digital competence development in education.

5.2. Educational policy implications

The findings of this study have several implications for educational policy, particularly in the context of ongoing educational reforms in Ukraine and broader European integration processes.

First, the demonstrated effectiveness of the integrated approach suggests that policy frameworks should emphasize comprehensive, cross-curricular integration of digital competence development rather than isolated courses or modules. The National Strategy for Education Development in Ukraine and the New Ukrainian School Concept could be further strengthened by explicitly promoting such integrated approaches to digital training in teacher education programs.

Second, the study highlights the importance of authentic, practice-oriented learning experiences in developing digital competence. Policy directives should encourage partnerships between teacher education institutions and primary schools to provide future teachers with opportunities to apply digital technologies in real educational settings. The current emphasis on teaching practice in Ukrainian educational policy could be expanded to specifically address digital practice experiences.

Third, the role of specialized courses, such as the elective course implemented in this study, suggests that educational policies should leave room for targeted interventions within broader integrated approaches. While comprehensive integration across the curriculum is essential, dedicated spaces for in-depth exploration of digital technologies and their pedagogical applications also play an important role.

Finally, the COVID-19 experience underscores the importance of developing crisis-resilient digital competence that enables teachers to adapt to rapidly changing educational circumstances. Educational policies should explicitly address the development of such resilience and flexibility, preparing future teachers not only for normalized educational contexts but also for potential disruptions and transitions.

6. Theoretical implications for understanding digital competence development

6.1. Developmental trajectories and dimensions

The results of this study offer several theoretical insights into how digital competence develops in future primary school teachers. The differential development of cognitive, operational, and value components suggests that these dimensions may follow distinct developmental trajectories and respond differently to educational interventions.

The value component showed the most dramatic improvement in the experimental group, with an increase of 38 percentage points at the high level. This suggests that attitudinal and value-related aspects of digital competence may be particularly responsive to integrated educational approaches that embed digital technologies across multiple contexts. The formation of values and attitudes toward digital technologies appears to benefit substantially from seeing these technologies applied in varied settings and for diverse purposes.

The operational component, focusing on practical skills and abilities, showed the next most significant improvement. This finding aligns with research by Meyer et al. [13] suggesting that operational aspects of digital competence develop through authentic practice and application rather than theoretical instruction alone. The integrated approach, with its emphasis on practical application across various educational activities, seems particularly well-suited to developing this operational dimension.

The cognitive component, while showing substantial improvement, demonstrated the least dramatic change of the three dimensions. This may suggest that knowledge and understanding of digital technologies require more time or different types of interventions to develop fully. Alternatively, it could indicate that cognitive aspects of digital competence had already been partially developed through previous educational experiences.

These differential trajectories point to the complex, multidimensional nature of digital competence development. Rather than developing uniformly across all dimensions, digital competence appears to evolve in a more nuanced pattern, with different components responding distinctively to educational interventions. This understanding challenges simplistic models of digital competence that treat it as a unitary construct developing along a single trajectory.

6.2. Role of social and contextual factors

The study's findings also highlight the importance of social and contextual factors in digital competence development. The integrated approach created rich social contexts for learning, including collaborative group work, peer interaction, and authentic engagement with primary school environments. These social dimensions appear to have significantly influenced students' development, particularly in the value component of digital competence.

This social dimension of development aligns with sociocultural theories of learning [21], which emphasize the role of social interaction and cultural tools in cognitive development. Digital technologies, as cultural tools, are appropriated through social processes that involve not just individual practice but also shared meaning-making and collaborative engagement. The superior performance of the experimental group suggests that the integrated approach effectively leveraged these social dimensions of learning.

The contextual embedding of digital technologies across multiple educational settings also appears to have played a crucial role. By encountering digital technologies in lectures, practical classes, independent work, and teaching practice, students in the experimental group experienced these technologies as integrated aspects of educational practice rather than isolated tools or techniques. This contextual integration may have facilitated deeper understanding and more meaningful application of digital technologies.

These findings suggest that theoretical models of digital competence development should account for social and contextual dimensions, moving beyond individually focused, decontextualized approaches to recognize the embedded, situated nature of digital competence formation.

6.3. Relationship to general pedagogical development

An important theoretical insight from this study concerns the relationship between digital competence development and broader pedagogical development. The integrated approach did not treat digital competence as separate from general pedagogical preparation but rather as an integral aspect of it. This integration appears to have facilitated meaningful connections between digital and pedagogical knowledge, enhancing both dimensions.

This finding resonates with the TPACK framework (Technological Pedagogical Content Knowledge) developed by Xiong and Lim [27], which emphasizes the intersections between technological, pedagogical, and content knowledge. Rather than treating these as separate domains, the TPACK framework highlights the importance of their integration and interaction. The effectiveness of the integrated approach in this study provides empirical support for such theoretical models that emphasize integration rather than separation.

The study also suggests that digital competence development may contribute to broader pedagogical flexibility and adaptability, as evidenced by the experimental group's superior handling of the COVID-19 transition to online teaching. This indicates a potentially reciprocal relationship between digital competence and general pedagogical competence, where development in one domain enhances capacity in the other.

These insights suggest the need for theoretical models that conceptualize digital competence not as an isolated skill set but as an integrated aspect of pedagogical competence more broadly. Such models would better capture the complex interrelationships between digital practices and general teaching practices that appear to characterize effective primary teacher preparation.

7. Current educational challenges and future directions

7.1. Addressing digital transformation in education

The findings of this study are particularly relevant in the context of the ongoing digital transformation of education globally. This transformation, accelerated by the COVID-19 pandemic, has fundamentally altered educational practices at all levels and created new imperatives for teacher preparation [24]. The integrated approach

to digital competence development demonstrated in this study offers a promising response to these transformative pressures.

Digital transformation in education goes beyond simply introducing new technologies; it involves rethinking educational processes, relationships, and goals in light of digital possibilities [22]. The integrated approach aligns with this deeper conceptualization of transformation by emphasizing not just technical skills but also pedagogical innovation and value reorientation. By addressing cognitive, operational, and value dimensions of digital competence, this approach prepares future teachers to participate actively in shaping educational transformation rather than merely responding to it.

The effectiveness of the integrated approach in preparing students for online teaching during COVID-19 highlights its potential for developing the kind of adaptive expertise increasingly required in digitally transforming educational environments. As Arısoy [2] notes, digital transformation demands not just specific skills but also the capacity to continually learn and adapt as technologies and practices evolve. The integrated approach, with its emphasis on authentic application and reflective practice, appears well-suited to developing such adaptive expertise.

7.2. Addressing equity and access concerns

While digital transformation offers significant educational opportunities, it also raises serious concerns about equity and access. The digital divide – disparities in access to digital technologies and the skills to use them effectively – remains a pressing issue in education worldwide [16]. The integrated approach to digital competence development demonstrated in this study offers several promising avenues for addressing these equity concerns.

First, by embedding digital competence development across the curriculum rather than in isolated courses, the integrated approach may help democratize access to digital learning opportunities. Students who might lack personal digital resources outside the educational institution can still develop digital competence through their regular educational activities.

Second, the explicit attention to value dimensions of digital competence, which showed the most significant improvement in the experimental group, may help future teachers develop critical awareness of equity issues in digital education. This awareness is essential for creating more inclusive digital learning environments in their future practice.

Third, the emphasis on pedagogical application of digital technologies, rather than merely technical proficiency, prepares future teachers to make sound decisions about when and how to use digital tools based on educational goals rather than technological availability. This pedagogical focus may help mitigate tendencies to implement digital technologies in ways that exacerbate rather than ameliorate educational inequities.

These equity-enhancing aspects of the integrated approach align with current educational priorities focused on inclusive and equitable quality education, as articulated in international frameworks such as the UN Sustainable Development Goals and the European Digital Education Action Plan.

7.3. Future research directions

While this study provides compelling evidence for the effectiveness of the integrated approach to digital competence development, several areas warrant further investigation in future research.

First, longitudinal studies tracking students into their early teaching careers would provide valuable insights into the long-term impacts of the integrated approach. Such studies could examine how digital competence developed during initial teacher education translates into classroom practice and evolves over time in professional

settings.

Second, more fine-grained analysis of specific elements of the integrated approach could help identify which components contribute most significantly to digital competence development. By isolating and testing specific features of the approach, researchers could develop more targeted and efficient training interventions.

Third, comparative studies examining the implementation of the integrated approach across different educational systems and cultural contexts would help determine its generalizability and identify potential adaptations needed for diverse settings. Such cross-cultural research would contribute to the development of more universally applicable models of digital competence development.

Fourth, research exploring the relationship between digital competence development and broader educational outcomes would strengthen the case for prioritizing such development in teacher education programs. By demonstrating connections between digital competence and improved teaching effectiveness or student learning outcomes, such research would provide additional policy-relevant evidence.

Finally, studies examining how the integrated approach might be adapted for in-service teacher professional development would extend its potential impact beyond initial teacher education. As digital technologies continue to evolve, developing sustainable models for ongoing digital competence development throughout teachers' careers remains a critical challenge.

8. Conclusions

Based on the analysis of the research results, several key conclusions can be drawn regarding the effectiveness of the integrated approach to information and digital training of future primary school teachers:

1. The research has confirmed that ID training of students in higher pedagogical education institutions has a dual character. It serves both as a means of professional training and as a subject of comprehensive study for future professional use. This interconnectedness determines the formation of future primary school teachers' ability to use information and digital technologies effectively in the educational process, ultimately developing digital literacy in primary school children.
2. The educational and methodological support developed for the integrated approach to ID training proved effective across all major forms of the educational process. The experimental implementation demonstrated successful integration in curricula, lectures, practical classes, independent work, teaching practice, and assessment activities.
3. The experiment confirmed the effectiveness of the integrated approach in developing future primary school teachers' ID competence. This approach was based on the systematic use of information resources (media, video, audio, library, photo, graphics, educational portals, websites), telecommunications environments, and educational process management systems.
4. The elective course "Modern Information and Digital Technologies in the Educational Process of Primary School" functioned as a system-forming factor in the integration of knowledge, skills, and values. Its effectiveness was particularly evident during the COVID-19 pandemic, when students who had completed the course demonstrated superior ability to create distance learning materials and organize educational processes using digital platforms.
5. Statistical analysis of initial and final measurements of ID competence levels in the control and experimental groups confirmed the methodological effectiveness

of the integrated approach. During the experimental period, students in the experimental group showed significantly higher development across cognitive, operational, and value components of ID competence compared to the control group.

The statistical evaluation using the χ^2 criterion confirmed the reliability of these results, demonstrating the effectiveness of modernizing ID training for future primary school teachers through the integrated approach.

These findings contribute to our understanding of effective approaches to digital competence development in teacher education and provide a research-validated model for training digitally competent primary teachers in an increasingly digitalized educational landscape. As digital technologies continue to transform educational practices, such integrated approaches to digital competence development will become increasingly essential for preparing teachers who can effectively navigate and shape this transformation.

References

[1] Andriievska, V.M., 2019. *Teoretychni i metodychni zasady pidhotovky maibutnoho vchytelia pochatkovoi shkoly do vykorystannia informatsiino-komunikatsiinykh tekhnolohii u profesiinii diialnosti*. D.Sc. Dissertation. Kharkivskyi nats. ped. un-tet im. H. S. Skovorody, Kharkiv.

[2] Arısoy, B., 2022. Digitalization in education. *Cypriot Journal of Educational Sciences*, 17(5), pp.1799–1811. Available from: https://doi.org/10.18844/cjes.v17i5.6982.

[3] Barboutidis, G. and Stiakakis, E., 2023. Identifying the Factors to Enhance Digital Competence of Students at Vocational Training Institutes. *Technology, Knowledge and Learning*, 28(2), pp.613–650. Available from: https://doi.org/10.1007/s10758-023-09641-1.

[4] Biggins, D., Holley, D., Evangelinos, G. and Zezulkova, M., 2017. Digital Competence and Capability Frameworks in the Context of Learning, Self-Development and HE Pedagogy. In: G. Vincenti, A. Bucciero, M. Helfert and M. Glowatz, eds. *E-Learning, E-Education, and Online Training*. Cham: Springer International Publishing, *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*, vol. 180, pp.46–53. Available from: https://doi.org/10.1007/978-3-319-49625-2_6.

[5] Caena, F. and 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), pp.356–369. Available from: https://doi.org/10.1111/ejed.12345.

[6] Camino, L.G., Cruz, S.G.M. and Ana, G.V.M.R., 2021. Development of Digital Competence in primary and secondary students in three dimensions: fluency, learning-knowledge and digital citizenship [Desarrollo de la Competencia Digital en estudiantes de primaria y secundaria en tres dimensiones: fluidez, aprendizaje-conocimiento y ciudadanía digital]. *RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao*, 2021(44), pp.5–20. Available from: https://doi.org/10.17013/risti.44.5-20.

[7] Collado-Sánchez, M., García-Peñalvo, F.J. and Pinto-Llorente, A.M., 2023. Analysis, Progress and Comparative of the European Digital Competence Framework DIGCOMP. In: F.J. García-Peñalvo and A. García-Holgado, eds. *Proceedings TEEM 2022: Tenth International Conference on Technological Ecosystems for Enhancing Multiculturality*. Singapore: Springer Nature Singapore, Lec-

ture Notes in Educational Technology, pp.991–997. Available from: https://doi.org/10.1007/978-981-99-0942-1_104.

[8] Drokina, A.S., 2016. Improvement of the informational and methodological competence of students of pedagogical higher educational institutions by means of information and communication technologies. *Problems of Engineer-Pedagogical Education*, (52-53), pp.196–200. Available from: http://jped.uipa.edu.ua/index.php/JPED/article/view/119.

[9] Education in a multilingual world: UNESCO education position paper, 2003. Available from: https://unesdoc.unesco.org/ark:/48223/pf0000129728.

[10] Fashoto, S.G., Faremi, Y.A., Mbunge, E. and Owolabi, O., 2024. Exploring structural equations modelling on the use of modified UTAUT model for evaluating online learning. *Educational Technology Quarterly*, 2024(3), p.319–336. Available from: https://doi.org/10.55056/etq.734.

[11] Fernández-Sánchez, M.R. and Silva-Quiroz, J., 2022. Assessment of the Digital Competence of Future Teachers from a Gender Perspective [Evaluación de la competencia digital de futuros docentes desde una perspectiva de género]. *RIED-Revista Iberoamericana de Educacion a Distancia*, 25(2), pp.327–346. Available from: https://doi.org/10.5944/ried.25.2.32128.

[12] López García, C., Sánchez Gómez, M.C. and García-Valcárcel Muñoz-Repiso, A., 2022. Development of Digital Competence in primary and secondary students in three dimensions: fluency, learning-knowledge and digital citizenship [Desarrollo de la Competencia Digital en estudiantes de primaria y secundaria en tres dimensiones: fluidez, aprendizaje-conocimiento y ciudadanía digital]. *RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao*, 2022(E48), pp.501–517.

[13] Meyer, F., Dyan-Charles, C., Pelletier, C., Laporte, G. and Arguin, F., 2021. Sequences of change of university trainers in intersectoral training on digital competence in education [Séquences de changement de formatrices universitaires dans une formation intersectorielle sur la compétence numérique en éducation]. *Canadian Journal of Learning and Technology*, 47(1). Available from: https://doi.org/10.21432/cjlt27980.

[14] Natsionalna stratehiia rozvytku osvity v Ukraini na period do 2021 roky, 2013. Available from: https://zakon.rada.gov.ua/laws/show/344/2013#Text.

[15] Onishchenko, I.V., 2016. Vplyv informatyzatsii vyshchoi pedahohichnoi osvity na protses formuvannia informatychnykh kompetentnostei maibutnikh uchyteliv pochatkovykh klasiv. *Bulletin of the Cherkasy Bohdan Khmelnytsky National University. Series "Pedagogical Sciences"*, (7), pp.31–37. Available from: http://ped-ejournal.cdu.edu.ua/article/view/1592.

[16] Petrusevich, D.A., 2020. Modern trends in the digitalization of education. *Journal of Physics: Conference Series*, 1691(1), p.012223. Available from: https://doi.org/10.1088/1742-6596/1691/1/012223.

[17] Petukhova, L.Y., 2009. *Teoretyko-metodychni zasady formuvannia informatychnykh kompetentnostei maibutnikh uchyteliv pochatkovykh klasiv*. dys. ... d-ra ped. nauk : 13.00.04. Pivdennoukrainskyi derzhavnyi pedahohichnyi universytet imeni K. D. Ushynskoho, Odesa.

[18] Pro skhvalennia kontseptsii realizatsii derzhavnoi polityky u sferi reformuvannia zahalnoi serednoi osvity "Nova ukrainska shkola" na period do 2029 roku, 2016. Available from: https://osvita.ua/legislation/Ser_osv/54258/.

[19] Pro zatverdzhennia Derzhavnoho standartu pochatkovoi osvity, 2018. Available from: https://www.kmu.gov.ua/ua/npas/pro-zatverdzhennya-derzhavnogo-standartu-pochatkovoyi-osviti.

[20] Pro zatverdzhennia Kontseptualnykh zasad rozvytku pedahohichnoi osvity v Ukraini ta yii intehratsii v yevropeiskyi osvitnii prostir, 2004. Available from:

http://osvita.ua/legislation/Vishya_osvita/3145/.

[21] Røkenes, F.M. and Krumsvik, R.J., 2014. Development of student teachers' digital competence in teacher education. *Nordic Journal of Digital Literacy*, 2014(4), pp.250–280. Available from: https://doi.org/10.18261/issn1891-943x-2014-04-03.

[22] Steriu, I. and Stănescu, A., 2023. Digitalization in education: navigating the future of learning. *Proceedings of the International Conference on Virtual Learning*. vol. 18, pp.169–182. Available from: https://doi.org/10.58503/icvl-v18y202314.

[23] Sych, T.V., Khrykov, Y.M. and Ptakhina, O.M., 2021. Digital transformation as the main condition for the development of modern higher education. *Educational Technology Quarterly*, 2021(2), p.293–309. Available from: https://doi.org/10.55056/etq.27.

[24] Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S.V., Giannoutsou, N., Cachia, R., Monés, A.M. and Ioannou, A., 2023. Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and Information Technologies*, 28(6), pp.6695–6726. Available from: https://doi.org/10.1007/s10639-022-11431-8.

[25] Upatova, I.P., 2019. *Teoriia i praktyka metodychnoi pidhotovky maibutnikh uchyteliv pochatkovoi shkoly*. dys. ... d-ra. ped. nauk : 13.00.04. Kharkivskyi natsionalnyi pedahohichnyi universytet imeni H. S. Skovorody, Kharkiv.

[26] Vuorikari, R., 2022. DigComp Helping Shape the Education Ecosystem in Europe. In: T. Väljataga and M. Laanpere, eds. *Shaping the Digital Transformation of the Education Ecosystem in Europe*. Cham: Springer International Publishing, *Communications in Computer and Information Science*, vol. 1639, pp.137–143. Available from: https://doi.org/10.1007/978-3-031-20518-7_11.

[27] Xiong, X.B. and Lim, C.P., 2015. Curriculum Leadership and the Development of ICT in Education Competencies of Pre-service Teachers in South China. *Asia-Pacific Education Researcher*, 24(3), pp.515–524. Available from: https://doi.org/10.1007/s40299-015-0238-1.

[28] Yaroshenko, O.G., Samborska, O.D. and Kiv, A.E., 2020. An integrated approach to digital training of prospective primary school teachers. *CTE Workshop Proceedings*, 7, p.94–105. Available from: https://doi.org/10.55056/cte.314.