Cloud technologies in the educational process: development and implementation of a suite of online services for the professional activities of primary school teachers

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Abstract

The article explores the integration of cloud-based ICT, particularly online services, into the professional activities of primary school teachers. Grounded in systemic and competency-based approaches, an open suite of online services has been designed to support face-to-face, distance, and blended learning formats, reflecting the preferences of primary educators as identified through a longitudinal study. In alignment with the content and demands of professional teaching practice, particularly in fulfilling Job Function A under contemporary educational conditions, this suite comprises a structured system of services that enables teachers to both utilize ready-made digital learning tools and develop their own ICT-based instructional resources. Group I – services for creating interactive educational content; Group II – services for organizing and conducting an online lesson; Group III – services for creating a virtual classroom and an electronic journal. Based on the fact that this complex is open, a system of requirements for the selection of online services is presented. The effectiveness of the developed complex was experimentally proved during a pedagogical experiment on the basis of the Izmail State Humanitarian University. As a result of mastering the developed complex, students majoring in Primary Education demonstrated creative projects for organizing a mathematics lesson in primary school with the possible use of a set of online services

Keywords

ICT, a set of online services, primary school teacher, professional activity,

1. Introduction

Since 2019, in response to the COVID-19 pandemic, educational institutions in Ukraine have transitioned to a distance learning format [1, 2, 3]. In the post-pandemic period, beginning in February 2022, a substantial proportion of general secondary education institutions (GSEIs) in Ukraine have continued to operate in distance or blended learning modes [4, 5] due to the ongoing armed aggression of the Russian Federation [6, 7]. The continuity of the educational process under crisis conditions has been made possible through the rapid advancement and integration of cloud technologies within the educational ecosystem. Papadakis et al. [8] emphasize the importance of cloud technologies for open education, which provides access to educational resources and platforms regardless of the location of participants in the educational process.

Cloud technologies are the foundation for creating modern educational platforms that provide access to educational resources, tools and services regardless of the user's location [9, 10, 11, 12, 13]. This allows you to organize both distance and blended learning, increasing the flexibility and adaptability of the educational process [14]. In particular, cloud services (Google Workspace for Education, Microsoft

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Teams and others) provide teachers with the opportunity to create, store and distribute educational materials from any device with access to the Internet, which significantly increases flexibility in planning the educational process and organizing distance or blended learning.

Cloud platforms facilitate synchronous collaborative interaction between teachers and students in real time, enhancing interactivity, enabling immediate feedback, and improving the overall efficiency of the educational process. Furthermore, cloud technologies support the systematic collection and analytical processing of data on students' academic performance, thereby enabling educators to tailor instructional approaches and implement personalized learning trajectories for each student [8, 15].

The use of cloud platforms in primary education allows teachers and students to work with interactive materials, virtual laboratories, and collaborate on projects in real time [15]. The implementation of cloud services provides teachers with tools for developing interactive tasks, test materials, presentations and multimedia content (using resources such as Kahoot!, Quizlet, Padlet, Canva, etc.), which positively affects the motivation of students and the quality of learning. The synergy of cloud technologies and augmented reality (AR) opens up new opportunities for visualizing complex concepts, conducting simulation experiments and increasing student motivation [16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27]. Papadakis et al. [15] show that such integration significantly expands the capabilities of the educational environment and contributes to the development of students' creative potential.

In the context of crisis challenges faced by Ukrainian education, cloud technologies demonstrate their potential as an effective means of ensuring the continuity of the educational process. Cloud technologies are an integral part of information and communication technologies (ICT), as they provide access to modern digital educational resources, tools and services that significantly expand the didactic potential of the educational process and increase its effectiveness.

Research by Ukrainian scholars [28, 29, 30, 31, 32] and international researchers [33, 34, 35, 36, 37, 38] demonstrates the widespread implementation of ICT in professional teaching practice.

Bulgarian researchers Terzieva et al. [39] documented significant changes in ICT usage in Bulgarian schools over the past decade, noting diverse digital tools including interactive whiteboards, computers, educational games, and augmented and virtual reality technologies .

A comprehensive survey by Terzieva et al. [35] involving 1,600 teachers and approximately 7,000 students revealed:

1. Most teachers preferred applying ICT for instructional activities, exercises, supplementary material research, and project work, while considering ICT less suitable for assessment and motivation.
2. Teachers primarily created presentations, instructional videos, electronic textbooks, specialized software, and supplementary electronic resources. They experienced difficulties with electronic testing, educational games, virtual laboratories, and simulations.
3. Regarding self-assessment of ICT competence, 33% rated themselves "excellent," 27% "very good," 20% "good," 13% "insufficient," and 7% reported no competence.

Teachers attributed low ICT competence to insufficient appropriate ICT courses, noting that available training lacked practical application. A survey of 192 primary school teachers in Jordan indicates a need for knowledge on integrating digital technologies into teaching practices and engaging children in ICT-based activities [40]. Slovak researchers Záhorec et al. [37] identified comparable issues, finding that most accredited courses focused on basic or advanced technical skills rather than pedagogical application. A similar situation was observed in the Czech Republic, with researchers concluding that teachers require methodological rather than technological assistance in ICT implementation, including guidelines and specific examples of ICT application in particular subjects.

During the COVID-19 pandemic, significant challenges were identified in the implementation of distance learning precisely due to the insufficient level of digital competence of teachers [41]. Teachers used various technological tools to continue teaching students, but it turned out that not all of them had the proper training to conduct online classes. In fact, the lack of digital literacy prevented many teachers from continuing their work without the support of colleagues [42]. The main challenges included: adapting teaching materials, technical access restrictions, and increasing workload [43]. The

study and analysis of research by Ukrainian and foreign scholars on the state of readiness of primary school teachers to use ICT in their professional activities [44] have shown the need to develop teachers' ICT competence.

A study by Spanish scholars Paños-Castro et al. [45] revealed an insufficient level of training of primary school teachers to use ICT during the pandemic, despite the presence of appropriate educational policies. Most respondents indicated that they had mastered ICT skills independently and expressed interest in continuous learning programs using Google Classroom, Google Sites, Google Meet and other services.

At the same time, Portuguese researchers Henriques et al. [46] found more positive dynamics – 67.7% of primary and secondary school teachers surveyed – as of 2021 already had adequate training in the use of digital resources and learning environments.

The insufficient level of digital skills among teachers does not create conditions for the effective use of cloud technologies in teaching. According to the results of international studies, in particular Papadakis et al. [15], the combination of cloud platforms with innovative tools, such as augmented reality, allows not only to expand access to quality education, but also to increase the efficiency of teaching through interactivity and collaboration. This is especially important for Ukraine, where cloud services can compensate for the limited material and technical base and facilitate the implementation of modern pedagogical approaches [14].

Augmented reality technologies can use cloud services to expand their capabilities. Brazilian researchers Lotthammer et al. [36] concluded that augmented reality on tablets in first-grade classrooms enhanced students' focus on learning material, facilitated effective assimilation, and positively influenced children's motivation for discovery.

Spanish researchers Villena Taranilla et al. [34] confirmed the potential of virtual reality in primary education as an emerging educational technology offering immersive learning, interactivity, creativity, and meaningful learning engagement. Their studies demonstrated statistically significant differences in motivation and academic performance favoring students taught using virtual reality.

Similar results were obtained in studies examining augmented reality in primary mathematics education using HP Reveal to enhance learning material perception. However, augmented reality implementation must be justified and appropriately limited to prevent cognitive overload in primary school students [47].

It should be noted that Li's [48] analysis of 1366 publications on the use of ICT in education indicates a conservative approach to the study of tools, with limited coverage of emerging ICTs (e.g. VR or AI), focusing mostly on traditional tools, while emerging or immersive technologies [49] remain largely unexplored. This study provides insight into the areas of study of ICT in education, with general issues of ICT use prevailing (62%). The author concluded that there is insufficient focus on specific educational content, tools and scenarios for ICT use in the classroom.

According to Li [48] on the training of teachers to use ICT in the process of teaching students, despite the urgent need, from 2009 to 2024 only 13% of studies were devoted to this issue, although 34% of studies directly emphasize the need to develop curricula for teachers. This indicates that the practical use of ICT in the teaching process, although mentioned, is not the central theme of most studies.

Despite the wide international representation in the analytical review of Li [48] (47 countries), studies are dominated by Turkey and the USA, while Eastern European countries are practically not represented [48]. Our attempts to analyze publications on the use of ICT by teachers in the process of teaching students also indicate their small number, which emphasizes the need to study the use of ICT in the teaching process specifically in this region, in particular in Ukraine.

In conclusion, international research demonstrates that teachers understand the importance of ICT integration in education but require professional support to enhance their ICT competence, particularly regarding methodological implementation strategies rather than purely technical skills. Based on the studies of Bulgarian [39, 35], Slovak [37], Czech [50], [38], Romanian [33] and Ukrainian [51, 52, 44] researchers, it was found that teachers need help in using ICT not only in using hardware, but also in practice-oriented training on the material of individual subjects with specific samples professional activity. Therefore, there is a need to familiarize teachers with services that help organize learning in

face-to-face, distance and blended forms, namely, to create a virtual classroom, an electronic journal, interactive learning content, including virtual whiteboards, as well as services for conducting online lessons, and thus with digital resources that will greatly facilitate the organization of face-to-face, distance and blended learning.

Research purpose: To theoretically substantiate and experimentally verify the effectiveness of using a complex of online services in the professional activities of primary school teachers for organizing face-to-face, distance, and blended learning.

Research objectives:

1. To analyze the readiness of teachers to use ICT in their professional activities before and after the COVID-19 pandemic.
2. To investigate the dynamics of usage and self-assessment of ICT competence levels among primary school teachers.
3. To determine the criteria for selecting online services for organizing various forms of learning in primary school.
4. To develop and scientifically substantiate a complex of online services for the professional activities of primary school teachers.
5. To experimentally verify the effectiveness of the developed complex of online services in the process of training future primary school teachers.
6. To develop methodological recommendations for implementing the complex of online services in the professional activities of primary school teachers, taking into account their needs for methodological support.

Taking into account the already described needs of the educational process, the components of this complex of online services for organizing face-to-face, distance (synchronous and asynchronous) and blended learning are as follows:

1. Services for creating interactive learning content;
   A. Services for creating interactive exercises;
   B. Services for creating interactive video;
   C. Services for creating virtual whiteboards;
   D. Interactive simulation services;
2. Services for organizing and conducting an online lesson;
3. Services for creating a virtual classroom and an electronic journal.

2. Analysis of the state of ICT use by primary school teachers in Ukraine

Based on a series of studies (2019-2021) conducted at Izmail State Humanitarian University and other educational institutions, the state of ICT usage in the professional activities of primary school teachers in Ukraine was established [44].

2.1. Research methodology

The presented study was organized as a series of interrelated stages of data collection and analysis during 2019-2021. The study represented longitudinal monitoring with elements of comparative analysis. A mixed methodology was used with a predominance of quantitative data collection methods and their qualitative interpretation.

2.2. Data collection stages

2.2.1. Initial survey (spring 2019)

The sample consisted of 30 primary school teachers from the Odessa region who completed paper questionnaires containing 6 questions. The purpose of the study was to determine the general state of ICT use in professional activities [53]. Paper questionnaires contained closed-ended questions with the ability to add one's own option. A five-point scale was used for self-assessment of ICT proficiency level.

2.2.2. Extended questionnaire (March 2020)

55 primary school teachers from the city of Izmail and the Izmail district participated in a survey based at the Izmail City Teacher's House. The questionnaire questions focused on ways of acquiring ICT competence, problems of ICT implementation, frequency of use, and types of digital resources [54]. In addition to closed-ended questions, these questionnaires contained open-ended questions regarding teachers' use of online services.

Primary school teachers participated in the survey; the age range was from young specialists to experienced teachers (average age 42 years), with work experience ranging from 1 to 48 years (average experience ∼19 years) and qualification categories from "specialist" to "higher category specialist". The geography of the study covered urban (80%) and rural (20%) schools of the Odessa region.

2.2.3. Online survey (autumn 2020)

The sample consisted of at least 119 teachers from the closed Facebook group "Mathematics 'Morning'. Pilot". The research method was an online questionnaire with the possibility of multiple choice. The focus of the survey was on primary school teachers' awareness of online services for creating interactive exercises, educational videos, and virtual boards. The questionnaire was presented in Google form and provided for the possibility of multiple choice and adding one's own options. The study adhered to the principles of academic ethics and ensured the anonymity of respondents when processing and presenting the results [47].

2.2.4. Online survey (autumn-winter 2021)

The online survey was conducted from November to December 2021 to determine the most popular online services among teachers. 232 primary school teachers in Ukraine participated in it by filling out a questionnaire presented in a Google form and posted in professional groups on social networks [55].

2.2.5. Analysis of all-Ukrainian research (2020-2021)

At this stage, the data of the all-Ukrainian online survey of the National Academy of Educational Sciences of Ukraine (607 respondents) were studied; a comparative analysis was conducted with the results of studies by Burda and Vasylieva [56]; comparison with the study of Skvortsova et al. [57].

3. Research results

3.1. Pre-pandemic period (2019-early 2020)

According to the results of a survey of 30 primary school teachers in 2019:

- 100% of respondents owned a computer and had experience using ICT.
- The highest self-assessment was given to skills for working on the Internet (80% – 5 points) and with e-mail (90% – 4 points).
- Lower scores were found for skills related to working with the file system, text editors, presentations, and graphics.

- The lowest results were found for skills for working in professional online networks (50% – 1 point) and creating websites (90% – 1 point).

Regarding the sources of acquiring ICT competence: 10% acquired it during their studies at higher education institutions, 50% – through participation in seminars and trainings, 40% – independently.

The subsequent study (March 2020) involving 55 teachers demonstrated:

- An increase in the number of teachers who acquired ICT competence in higher education institutions (from 10% to 22%).
- 84% of teachers worked independently to improve their ICT skills.
- The main obstacles to ICT implementation were: insufficient knowledge of technologies (70%), lack of time (64%), problems with classroom material provision (66%).
- 78% of respondents constantly used ICT in their professional activities.

According to the results of the survey of teachers before the COVID-19 pandemic, teachers used ICT as follows:

- 93% printed materials for classes.
- 96% searched for educational information on the Internet.
- 98% conducted lessons using computer technology.
- Only 24% created educational and gaming content using online resources.

3.2. Pandemic period (2020-2021)

During the pandemic and distance learning:

- The most popular means of communication were Viber (88.2%), the school website (62.7%), and Google Classroom (45.5%).
- The most frequently used resources for preparing and conducting lessons were “Na Urok” (74.4%), author’s lessons on YouTube (75.8%), and “Vseosvita” (64.6%).
- The LearningApps service became the most popular for creating interactive exercises (82% of teachers knew about it, 21% used it).
- To present educational content on a virtual board, 50% of teachers were aware of Padlet, but only 16% used it.

As a result of the transition to distance learning, there was a positive trend in the use of digital platforms. Comparison 2020-2021 showed an increase in the popularity of the platforms:

- “Na Urok” from 63.6% to 80.7%.
- “Vseosvita” from 44.3% to 60.5%.
- LearningApps from 25.1% to 41%.

To create interactive exercises in mathematics, teachers use various services, including LearningApps, Liveworksheets, Wizer.me, H5P, and others. At the same time, 17.7% of respondents did not create interactive exercises for lessons.

Compared to the 2020-2021 academic year, there was a positive trend in the choice of services for creating interactive materials. In particular, the use of Liveworksheets increased from 4% to 44.6%, and Wizer.me from 0.8% to 8.8%.

Regarding the creation of educational videos, 62.4% of teachers used MS Power Point, 46.8% – Zoom, 26.3% – screen recording programs. However, 50% of respondents noted that they did not create interactive videos, although there was a positive trend in the use of relevant services: Learnis (from 2% to 20.2%), H5P (from 0.8% to 4%).

The use of virtual whiteboards increased significantly: Padlet was chosen by 66.8% of respondents compared to 16% in the previous academic year. The use of Lino.it increased from 4% to 8.3%. At the same time, 26.3% of teachers did not use virtual whiteboards.

3.3. Dynamics of ICT competencies formation among Ukrainian teachers

The results of the self-assessment of teachers' ICT competence showed that 12.4% of respondents gave themselves the maximum score, 4 points – 28.4%, 3 points – 22.2%, 2 points – 9.8%, 1 point – 5.7%, 0 points – 21.6%.

A comparative analysis of the results of the study before and during the pandemic shows that during the pandemic, primary school teachers identified gaps in the use of ICT and assessed their own level of ICT competence more objectively. There was an increase of 2.1% in the number of teachers with a good level of ICT competence and 6.6% with an average level (table 1).

Table 1
Dynamics of ICT competencies formation among Ukrainian teachers in the pre-pandemic and post-pandemic periods based on self-assessment judgments of respondents.

Level	High (5 points), %	Good (4 points), %	Average (3 points), %	Insufficient (2 points), %	Missing (1 point / 0 points), %
Pre-pandemic period	15.5	26.3	15.5	20.0	22.7
Pandemic period	12.4	28.4	22.1	9.8	27.3
Increase	-3.1	+2.1	+6.6	-10.2	+4.6

Regarding material and technical support, as of 2021, 88.1% of general secondary education institutions in Ukraine had computer science classrooms with over 202 thousand workplaces. However, the issues of updating computer equipment (57% of computers were purchased more than five years ago) and providing high-quality Internet connection (40% of schools do not have proper connection) remain problematic [56].

A comparative international analysis showed that Ukrainian teachers demonstrate a higher level of readiness for advanced training in the field of ICT than their Mexican colleagues. According to 2021 research, 77.3% of Ukrainian teachers have mastered at least one electronic course on the use of ICT [55], while 40.7% of Mexican teachers have never attended such courses [58].

The study confirms that the forced transition to distance learning due to the COVID-19 pandemic had a positive impact on the development of ICT competence of primary school teachers, stimulating the mastery of new digital tools for creating interactive educational content.

Analysis of Ukrainian and foreign studies shows that primary school teachers actively use ICT in their professional activities. The forced transition to distance, online, and blended learning stimulated them to improve their ICT competence, often independently mastering the tools through webinars and master classes.

Teachers' self-development in the field of ICT was aimed at mastering the basic tools necessary for organizing distance learning (Google Meet, Zoom, Google Classroom, ClassDojo, etc.). Most teachers stopped at this stage, choosing a basic set of services. However, some teachers expanded this set to include services for creating interactive and non-interactive content, which requires deeper knowledge in the field of ICT and relevant technical and methodological skills. This emphasizes the need to train teachers to use ICT while still studying in higher education.

The focus of attention of primary school teachers is on organizing the educational process (face-to-face, distance, blended) using ICT, saturating lessons with video and interactive content. For distance learning, services that offer the creation of an electronic journal and a virtual classroom, with the possibility of filling it with educational materials, interactive tasks, and tests, are useful. During face-to-face education, the teacher can offer students interactive exercises and tests, interactive videos, and meet the needs of modern students – representatives of the digital generation.

Recently, virtual environments and laboratories for students' educational research [**?**], services for creating virtual reality, and chatbots [59, 60, 61], in particular GPT, have been rapidly developing. In virtual laboratories, students can explore facts and patterns, practice methods of action, and then practice skills in a game form. Chatbots are useful both for teachers during lesson preparation and for students during project activities, for searching for information and generating questions. It is obvious that the issue of organizing face-to-face and distance lessons using ICT should be part of the training

of future primary school teachers. Therefore, it is advisable to include modules on mastering online platforms and services in courses of methodological disciplines or elective disciplines during studies in higher education institutions.

4. A set of online services for organizing face-to-face, distance and blended learning

Analysis of research by Ukrainian and foreign scientists indicates the need to develop ICT competence of primary school teachers. It has been established that teachers need help not only in using hardware but also in practice-oriented training on the material of individual subjects. It is important to familiarize teachers with services for organizing face-to-face, distance and blended learning, such as creating a virtual classroom, electronic journal, interactive content, virtual whiteboards, as well as services for conducting online lessons.

Given the preferences of primary school teachers and the positive dynamics of their mastery of online services, it is advisable to provide for familiarization of future teachers with the use of ICT in the process of teaching individual subjects or integrated courses. The components of the complex of online services for organizing face-to-face, distance (synchronous and asynchronous) and blended learning are:

1. Services for creating educational interactive content:
    - Services for creating interactive exercises;
    - Services for creating interactive video;
    - Services for creating virtual whiteboards;
    - Services-interactive simulators.
2. Services for organizing and conducting an online lesson.
3. Services for creating a virtual classroom and an electronic journal.

The selection of online services was carried out taking into account the results of a longitudinal study of the preferences of primary school teachers in Ukraine. Each of them already has a Ukrainian-language library that the teacher can use without further development.

Therefore, within the framework of methodological disciplines it is advisable to familiarize future teachers with a set of online services for organizing face-to-face, distance (synchronous and asynchronous) and blended learning. This set of online services is open and can be modified and supplemented in accordance with constantly changing conditions.

4.1. Services for creating interactive educational content

We proceed from the interpretation of "educational content" as a set of content elements that are the subject of study by students. By interactive learning content we mean: 1) educational content that provides for certain actions with its elements and requires active participation of the student in the process of working with it; 2) a tool for teacher-student interaction by offering the student certain educational digital products, with the possibility of feedback in the form of an assessment of the results of learning activities 3) a set of all elements (content elements and control elements that allow moving through the content array) with which the student interacts directly or indirectly.

As the practice of modern primary school shows, there are different forms of interaction with interactive learning content; we are talking about passive, active, and research. In a passive form of interaction, a student does not change the content but only views or listens to interactive content in order to understand and memorize educational information, performing only management functions (starting and finishing work, scrolling, etc.). For example, a passive form of interaction can be observed when a student watches an instructional video prepared in advance by a teacher.

The active form of interaction involves changing the content by performing certain actions with it; in this case, the interactive learning content has two states – the original (created by the teacher) and the transformed (modified by the student). For example, when watching an interactive educational video that includes pauses for exercises, the learner is forced to apply the knowledge or methods of action gained while watching the video fragment – we have an active form of interaction with interactive content.

The exploratory form of interaction involves not just modifying content elements according to a plan or algorithm that is set externally, as in an active form of interaction, but studying an object by changing conditions while freely manipulating it. For example, when working in the PhET Interactive Simulations virtual laboratory and studying fractions, a student can set numerical values for the numerator and denominator and observe the corresponding value of the whole.

The use of interactive educational content in the learning process allows you to organize interaction with the student: present educational material, organize feedback, instantly evaluate the results of students' learning, and provide a certain amount of assistance if the student has difficulties.

Interactive content includes interactive exercises, tests, videos, virtual whiteboards, online simulations, etc. It should be noted that any learning content can be interactive if it is based on interaction with the learner.

Given the above features of the cognitive processes of the learner's personality as a representative of the digital generation, to improve the perception, understanding and memorization of educational information, visualization and clarification of educational material is required, which can be realized through the use of ICT tools, creating interesting, vivid and dynamic interactive content. The most popular interactive content among Ukrainian teachers is interactive exercises.

4.2. Services for creating interactive exercises

An interactive learning exercise is a task made in a certain online service using templates of this service, which is launched when a student logs in and is completed when he or she logs out. Interactive exercises can involve both the teacher entering the correct answer (and therefore create the possibility of instant automatic verification of the result of the student's performance of this task) and the student's open answer (in which case the teacher checks the correctness of the task himself).

In any case, an interactive exercise contains the following elements: instructions on how to perform it, how to record the result; the actual task condition; the solution and the answer (if the task is performed in a template with automatic verification, the teacher writes down the correct answers during its preparation).

It should be noted that interactive exercises performed in a template that provides automatic verification of correctness allow students to immediately receive feedback on the result of their performance, thus satisfying the need of students of the digital generation for instant gratification, as they do not want to wait for a remote result.

By creating interactive exercises in services that also include an electronic journal, the teacher receives information about each student's completion of all tasks and can monitor their progress. Of course, services that include an electronic journal allow a teacher to organize a virtual classroom by inviting students to it and offering assignments to students through this classroom. Of course, this option is useful for organizing distance and blended learning.

Online services for creating interactive exercises offer the creation of tasks in a whole range of templates that can be combined into groups. These are templates for creating tasks that require the following steps to enter the correct answer: 1) selecting and clicking on the correct answer – pointing exercises; 2) moving the elements of the task – manipulative exercises; 3) writing the correct answer – keyboard exercises; 4) naming the answer – speech exercises.

Pointing and manipulative types of exercises, in some cases also keyboard exercises, involve automatic verification of the correctness of the task by the service. It should be noted that keyboard tasks may contain an open answer followed by a teacher's check. All of the above may also apply to test tasks.

When selecting online services for creating interactive exercises, we adhered to certain requirements: Group I – requirements for creating interactive exercises; Group II – requirements for controlling their implementation and monitoring student performance.

The first group of requirements for creating interactive exercises and test tasks includes: 1) the ability to create exercises for all sections of the subject; 2) the availability of a sufficient number of platforms to diversify interactive exercises; 3) the ability to brightly design interactive exercises through the use of pictures, graphs, diagrams, audio and video materials, etc.; 4) the availability of animations, dynamism and special effects in interactive exercises; 5) the ability to create differentiated exercises by level of difficulty; 6) the ability to present a series of interactive exercises by level of advancement, where the student sees how many exercises he or she needs to complete to move to a higher level; 7) a clear and simple algorithm for students to complete interactive exercises; 8) a simple algorithm for teachers to create interactive exercises.

The second group of requirements for controlling the implementation of interactive exercises and monitoring student performance includes: 1) avoiding the possibility of students acting at random when choosing an answer; 2) availability of the function of instant and step-by-step control of the course of students' performance of a particular exercise, a series of exercises, accumulation of data on students' performance and their analysis and generalization, which allows to track the results.

We have already identified the most popular online services among Ukrainian teachers for creating interactive exercises. Here are the services we have selected: LearningApps, LiveWorksheets, and Wizer.me, H5P, Google Forms, Classtime.

4.3. Services for creating interactive video

Interactive video is a special video format that involves interaction with video content through the use of various tools. Interactive learning videos integrate additional elements into the video, such as video pauses that prompt students to complete a task and embedded hotspots that encourage students to work through the necessary learning material presented through text, images, graphs, or hyperlinks to a relevant web page.

An interactive training video is created on the basis of a ready-made training video, which is supplemented with hotspots and stops. Therefore, we believe that it is methodologically justified to adhere to the following groups of requirements when choosing online services for creating interactive video: Group III – requirements for creating an educational video; Group IV – requirements for creating "hot spots" and stops with interactive tasks, as well as monitoring the results of interactive tasks.

The third group of requirements for creating an educational video includes 1) the ability to create a video based on a multimedia presentation; 2) the ability to create a live video; 3) the ability to create a video based on a ready-made script; and 4) the duration of the created video.

The fourth group of requirements includes 1) the convenience of adding interactive content; 2) a variety of templates for creating interactive exercises; 3) control over the correctness of interactive exercises; and 4) the ability to view the current and final results of an interactive video.

So, to create a training video, we suggest choosing Microsoft Powerpoint, Canva, Renderforest, Zoom, and Microsoft Teams, and to create an interactive video, H5P and LearningApps.

4.4. Services for creating virtual whiteboards

Using online services to demonstrate educational material on a virtual whiteboard, it is possible to introduce students to organized interactive learning content on a particular topic or lesson.

Virtual whiteboard services will help teachers not only organize and conduct remote lessons in asynchronous mode but also organize and conduct educational projects. On a virtual whiteboard, a teacher can vividly and clearly present both the structural elements of a distance lesson and structural elements of the educational project and a plan for working on it. A virtual whiteboard makes it possible to visualize the course of a distance lesson by presenting the content units of the lesson in a schematic form or in the form of notes. The virtual whiteboard also helps the teacher organize and conduct a

presentation (defense) of the project asynchronously in the form of students uploading videos and/or other materials and evaluating them, in particular in Padlet.

Given the purpose of distance learning, educators are mostly interested in virtual interactive whiteboards for organizing collaborative work with various content with the possibility of joint editing – Educreations, Lino.it, Padlet, Popplet. Realizing that virtual whiteboards are available on the web from IDroo, Whiteboard Fox, Padlet, NoteBookCast, Conceptboard, Groupboard, Classroomscreen, Ziteboard, Lino.it, and others, and their list is constantly expanding. Therefore, when choosing virtual whiteboards, we suggest focusing on the following group of requirements: 1) the availability of various virtual whiteboard templates; 2) the ability to present material of various formats on a virtual whiteboard; 3) the ability to involve students in viewing publications; 4) the ability for students to publish their own posts.

In accordance with our requirements, we propose to use the Padlet and Lino.it virtual whiteboard services.

4.5. Interactive simulation services

We consider interactive simulators as a digital service that creates visualization capabilities through the use of models of abstract objects that are studied and researched. In this way, abstract objects/concepts, processes, and situations are modeled in a virtual environment, the study and research of which leads to a significant learning outcome in the form of discovering patterns, modes of action, rules, generalizations, etc. These simulations not only provide purely educational content but also have a shell for implementing the educational experience and provide a game format. Thus, we consider interactive simulations to be resources for teaching with simulations, as well as those that involve the use of immersive technologies – virtual and augmented reality.

We divide interactive simulators into two groups: virtual laboratories and augmented and virtual reality.

When choosing virtual laboratories, we suggest taking into account the following requirements: 1) the possibility of observing a new concept or method of action by setting certain conditions by the student; 2) the possibility of visualizing the result in different formats; 3) bringing students to the generalization of a concept or method of action; 4) the possibility of developing a skill or skill in applying a new method of action; 5) the possibility of applying a new method of action when performing tasks from simple to complex; 6) the possibility of organizing the study of a new concept or method of action both in symbolic and visual form. In accordance with these requirements, we suggest using such services as PhET and GeoGebra.

The teacher can create and/or use AR and VR with the help of Google Art, and H5P.

Unlike VR, which helps to immerse oneself in an artificial and simulated world and act in it, AR is more connected to the real physical world. AR is a technology in which the user's perception of the real world is enhanced and supplemented with additional information from computer models, allowing the user to stay connected to the real environment. It is known that the main difference between AR and VR is that in VR the user is completely immersed in the artificial world and is separated from the real world, and in AR the system brings the digital device to the user's real working environment as an auxiliary tool for a comprehensive study of the object [62].

To effectively use VR in teaching younger students, teachers need special equipment and paid programs that are not available in all educational institutions. A simplified option that allows teachers to demonstrate VR elements is virtual tours. The issue of the didactic possibilities of virtual tours in teaching junior schoolchildren is studied by Vasiutina [63]. The author proposes to use the Google Art and Culture application for younger students to view the expositions of the world's best museums [63].

In our opinion, virtual tours are not the only possible example of VR use. For example, lessons can be "emotionally embellished" by incorporating certain AR elements when working on learning tasks. For example, to create a positive emotional background in math lessons, in order to help students visualize the situation described in the task, you can create a link to the corresponding video fragment that illustrates the plot of the task.

AR can also be used as a means of implementing a differentiated approach: by pointing the device at a certain mark, a student can receive either instructions for solving a problem, a detailed algorithm of actions, or a ready-made solution and analyze it or test themselves, or, conversely, receive a task of a higher level of complexity.

With A-Frame and H5P, teachers can create their own AR, depending on the topic and content of the learning tasks, in the following ways: by overlaying images, audio and video materials, 3D models on a real image that may be contained in textbooks, workbooks, or individual drawings.

4.6. Services for organizing and conducting an online lesson

Synchronous distance learning is impossible without services for organizing real-time video conferencing. Based on the preferences of teachers in choosing services for organizing online lessons, we suggest that you meet the following requirements: 1) the ability to schedule a meeting in advance and synchronize it with the calendar; 2) the duration of the conference and the maximum number of participants; 3) the ability to demonstrate the screen; 4) the availability of the whiteboard tool; 5) the ability to record the conference; 6) the ability to communicate in chat; 7) the ability to create virtual rooms for organizing group work.

So, for online lessons, we suggest using Zoom, Google Meet, and Microsoft Teams. These services, chosen on the basis of our surveys of teachers, correlate with the results of the study by Burda and Vasylieva [56], who argue that teachers use Zoom most actively; Skype was second in 2020 (over 20%), and in 2021 it was replaced by Google Meet (54.2%).

4.7. Services for creating a virtual classroom and electronic journal

We understand a virtual classroom as the organization of the educational process on an appropriate platform using tools that create certain opportunities. These include: connecting students to the virtual classroom; filling it with educational materials and interactive content; uploading students' work; checking uploaded work by the teacher; recording the results of students' learning activities in an electronic journal: both recording the results of interactive tasks automatically checked by the service and tasks checked by the teacher; organizing and conducting video conferences.

When choosing services, we suggest that you meet the following requirements: 1) the ability to create a virtual classroom: selection of exercises or a series of exercises for a given lesson and a given class; 2) the availability of a bank of interactive exercises that can be used at any time without creating your own; 3) the ability of the teacher to further work with the results in an electronic journal.

Taking into account the results of a survey of teachers on the choice of services for creating a virtual classroom and an electronic journal, we have chosen LearningApps, Google Classroom, Padlet, ClassDojo, Classtime, Wizer.me, Liveworksheets. It should be noted that Google Classroom has all of the above tools that allow for a holistic presentation of a virtual classroom, and the services (LearningApps, Padlet, ClassDojo, Classtime, Wizer.me, Liveworksheets) help teachers focus on one or more aspects of creating a virtual classroom that requires the use of other services.

5. Results of experimental verification of the complex

5.1. Experimental research methodology

The experimental base included 157 applicants for the bachelor's degree, including 78 people at Izmail University and 79 people at the Bohdan Khmelnytsky National University of Cherkasy (hereinafter referred to as ChNU). The experimental work took place in two stages: ascertaining and formative.

5.2. The ascertaining stage

The purpose of the ascertaining stage was to determine the level of readiness of future primary school teachers to use ICT in the process of teaching younger schoolchildren who are candidates for higher

education in the specialty 013 Primary Education, for the selection of control and experimental groups. Since the experimental work lasted for three academic years (2020-2023), the ascertaining experiment was held every year before the implementation of experimental training. The implementation of the aim of the ascertaining experiment involved surveying students on the state of awareness of online services.

The survey of students of the 3rd and 2nd (shortened term of study) courses of the Izmail University was conducted before studying the module "ICT in teaching mathematics to younger schoolchildren" within the framework of the normative discipline "Methodology of teaching mathematics in primary school" and students of the ChNU during the 2020-2021 academic year, 2021-2022 academic year and 2022-2023 academic year.

The ascertaining experiment was implemented using diagnostic tools, in particular, surveying students on their awareness of online services. The results obtained indicate that students are familiar with the most popular services (LearningApps, Padlet, Canva, etc.) and with those with which they interact during distance learning in higher education institutions (Google Meet, Google Classroom, Google Forms, Zoom, Microsoft Teams); an insufficient level of formation of the skills of higher education applicants to use the outlined services was established.

The student survey was conducted during the 2020-2021 academic year, 2021-2022 academic year and 2022-2023 academic year in two series: 1) students of the 3rd and 2nd (shortened term of study) courses of the Izmail University before studying the module "ICT in teaching mathematics to younger schoolchildren" within the framework of the normative discipline "Methodology of teaching mathematics in primary school" and students of the ChNU; 2) students of subgroups I and II of the 4th year of study at Ushynsky University at the beginning of mastering free choice disciplines.

1. In 2020-2021, 100% of students of Izmail University and ChNU were knowledgeable to use ICT in teaching younger students. However, only 33% of IDGU students and 32% of ChNU felt the need to use online services. Only 25% of Izmail University students and 24% of ChNU were directed to finding new digital tools and varying digital resources. Students were familiar with such services as LearningApps, Google Forms, Classtime, Canva, Padlet, GeoGebra, Google Arts and Culture, Zoom, Google Meet, Microsoft Teams, ClassDojo and Google Classroom. The level of skills in these services was assessed as high (0%), sufficient (17% of Izmail University, 16% of ChNU), average (58% of Izmail University, 60% of ChNU), low (25% of Izmail University, 24% of ChNU). Skills were acquired during studies at higher education institutions (42% of Izmail University, 52% of ChNU) and independently (58% of Izmail University, 48% of ChNU).
   The results of our study are generally consistent with those of Villena Taranilla et al. [34], who surveyed Spanish students – future primary school teachers and found that their mastery of educational ICT tools is only at the "satisfactory" level. At the same time, they revealed a positive attitude towards ICT: students are aware of the importance of digital skills for their future profession and seek to develop them. The authors emphasize the need to strengthen the development of this competence in curricula, especially through the integration of pedagogical and technological knowledge.
2. In 2021-2022, 100% of Izmail University and ChNU students were oriented towards using ICT. However, only 45% of Izmail University students and 42% of ChNU felt the need for online services. 34% of Izmail University students and 38% of ChNU were directed towards finding new digital tools. The list of services remained unchanged. The level of skills in services was assessed as high (0%), sufficient (21% of Izmail University, 19% of ChNU), average (55% of Izmail University, 58% of ChNU), low (24% of Izmail University, 23% of ChNU). Skills were acquired during studies at higher education institutions (48% of Izmail University, 46% of ChNU) and independently (52% of Izmail University, 54% of ChNU).
3. In 2022-2023, 100% of Izmail University and ChNU students were oriented towards using ICT. 68% of Izmail University students and 64% of ChNU felt the need for online services. 48% of Izmail University students and 46% of ChNU were directed towards finding new digital tools. The list of services remained unchanged. The level of skills in working with services was assessed as high

(0%), sufficient (24% of Izmail University, 25% of ChNU), average (56% of Izmail University, 57% of ChNU), low (20% of Izmail University, 18% of ChNU). Skills were acquired during studies at higher education institutions (40% of Izmail University, 43% of ChNU) and independently (60% of Izmail University, 57% of ChNU). Based on the data, it was found that the level of skills in using online services of Izmail University and ChNU students is approximately the same. The study participants were combined into experimental (EG1, EG2, EG3) and control groups (CG1, CG2, CG3). The homogeneity of the level of students' readiness to use ICT was proven using the χ^2-Pearson criterion. The null hypothesis of no differences between the distributions of readiness levels of students of Izmail University and ChNU was accepted (χ^2-Pearson = 0.67, p = 0.967).

5.3. The formative stage

The developed complex has been implemented in the methodological training of students majoring in Primary Education at the Izmail University.

Students of Izmail University mastered the developed complex while studying a separate module "ICT in Teaching Mathematics to Primary School Students" as part of teaching of the normative discipline "Methods of teaching mathematics in primary school".

Experimental training allowed students to explore the possibilities of using a set of online services at different stages of a primary school mathematics lesson. They gained experience in delivering a remote math lesson in Google Classroom/ClassDojo or on the Padlet/Lino.it virtual whiteboard. It should be noted that these virtual classrooms or virtual whiteboards contain or provide links to interactive exercises, simulations, and instructional videos. It should be emphasized that even if a link to a video or task is provided, the student automatically goes to a certain service and sends the results of his or her work to the teacher in the form of a screenshot of the page where the work has already been evaluated. It is also possible that the teacher can view the results of individual tasks directly in the service in which the task was created, provided that interactive tasks are sent through the virtual classroom of this service (LearningApps, Classtime, and Liveworksheets). It should be noted that the acquired competencies in organizing face-to-face, distance and blended learning using a set of online services were applied by students during the simulation of future professional activities in seminars and laboratories.

Pedagogical practice shows that over the past two years, teachers have mostly used real-time distance learning to conduct online lessons. The most common services for online math lessons are Google Meet, Zoom, and MS Teams. These lessons also involve interactive exercises that can be posted in the above services, and therefore the option of feedback from the teacher may be the same.

As a result of mastering this module, students were able to complete creative projects – to create tasks using online services in accordance with the peculiarities of the structure of a combined mathematics lesson in primary school. In completing the assignments, students demonstrated awareness of using online services and templates for creating interactive exercises of these services, understanding the features of selecting appropriate service templates for a particular task; the possibility of combining online services when organizing a distance lesson, compensating for the disadvantages of certain services with the advantages of others. Students posted their completed assignments in the Google Classroom.

The purpose of the formative stage of the study was to determine the effectiveness of special training of future primary school teachers to work with the above complex of online services.

In the control groups (CG1-3), the training of future teachers to use ICT was limited to studying the issue "Teaching aids" within the topic "Organization of mathematics teaching in primary school". In the experimental groups (EG1-3), the training involved mastering the module "ICT in teaching mathematics to younger schoolchildren", which included the following topics: 1) Services for creating educational interactive content in mathematics (1 seminar, 1 laboratory session); 2) Services for creating a virtual classroom and an electronic journal (1 lecture); 3) Online services for organizing a distance lesson (1 seminar session).

Particular attention was paid to the educational material prepared on the basis of electronic courses

from the Zmist.ua website. The following organizational and pedagogical conditions were implemented: 1) updating the content of the work programs of methodological disciplines and elective courses with modules related to ICT; 2) training teachers to use ICT.

At the formative stage of the experiment, the following tasks were solved:

1) researching the capabilities of online services for creating interactive content, organizing online lessons, creating a virtual classroom and working with an electronic journal;
2) demonstrating a system for organizing a mathematics lesson with a combination of online services;
3) implementing individual creative projects;
4) determining the level of readiness of future teachers to use ICT;
5) analyzing students' motivation to use online services and reflecting on the acquired competence.

Results of mastering the module "ICT in teaching mathematics to younger schoolchildren" Students of EG1-3 successfully completed creative projects, creating tasks using online services in accordance with the structure of a combined mathematics lesson in primary school. They demonstrated awareness of using online services, understanding the selection of appropriate templates and the possibility of combining services for organizing a distance lesson. The completed tasks were placed in the virtual environment of Google Classroom, which indicates the creation of an educational environment in higher education institutions by introducing ICT in the training of future teachers.

Students of CG also completed projects to create interactive mathematics exercises without special training in the use of online services. Students of EG1-3 actively participated in student conferences, reporting on the use of ICT in mathematics lessons in primary school. The results of the implementation of creative projects are summarized in table 2.

Table 2
Results of students' creative projects.

School year	Groups	Level				Total
		low	average	sufficient	high	
2020–2021	EG_1 Abs.val	3	11	7	3	24
	EG_1 %	12.5	46	29	12.5	100
	CG_1 Abs.val	6	15	4	0	25
	CG_1 %	24	60	16	0	100
2021–2022	EG_2 Abs.val	4	12	10	3	29
	EG_2 %	14	41	35	10	100
	CG_2 Abs.val	5	15	5	1	26
	CG_2 %	19.2	58	19	3.8	100
2022–2023	EG_3 Abs.val	2	11	9	3	25
	EG_3 %	8	44	36	12	100
	CG_3 Abs.val	4	15	7	2	28
	CG_3 %	14,3	53,6	25	7,1	100

To prove the differences in the results of the experimental and control groups of students of Izmail University and ChNU, the χ^2-Pearson criterion was used at the significance level $\alpha = 0.05$. Two hypotheses were formulated:

H0: there are no differences between the distributions of students of the experimental and control groups of the two universities by levels of creative projects.

H1: there are differences between the distributions of students of the experimental and control groups of the two universities by levels in the implementation of creative projects.

Calculation results: χ^2=8.407 at p=0.38 ($p \leq 0.05$). We accept the alternative hypothesis, which indicates the presence of differences between the distributions of students of the experimental and control groups of two universities by levels in the performance of creative projects. The V-Cramer index is 0.231, which for df=3 indicates the average effect size.

At the control stage, a comparative analysis of the research results was carried out using statistical data processing to assess the effectiveness of the experiment.

The summarized results of the implementation of the adaptive model of forming the readiness of future primary school teachers to use ICT are presented in the table 3.

Table 3
The effectiveness of the research-experimental approach: summarized research results.

School year	Groups	Level								Total
		low		average		sufficient		high		
		A	F	A	F	A	F	A	F	
2020–2021 s.y	EG_1 Abs. value	6	3	14	11	4	7	0	3	24
	EG_1 %	25	12.5	58	46	17	29	0	12.5	100
	CG_1 Abs. value	6	6	15	15	4	4	0	0	25
	CG_1 %	24	24	60	60	16	16	0	0	100
2021–2022 s.y	EG_2 Abs. value	7	4	16	12	6	10	0	3	29
	EG_2 %	24	14	55	41	21	35	0	10	100
	CG_2 Abs. value	6	5	15	15	5	5	0	1	26
	CG_2 %	23	19.2	58	58	19	19	0	3.8	100
2022–2023 s.y	EG_3 Abs. value	5	2	14	11	6	9	0	3	25
	EG_3 %	20	8	56	44	24	36	0	12	100
	CG_3 Abs. value	5	4	16	15	7	7	0	2	28
	CG_3 %	18	14.3	57	53.6	25	25	0	7.1	100

The reliability of the results was tested using the χ^2 Pearson criterion (significance level $\alpha = 0.05$) with the formulation of two hypotheses:

H0: there are no differences between the distributions of readiness levels in the experimental and control groups.

H1: there are statistically significant differences between the distributions of readiness levels in the studied groups.

The results of the calculations are presented in the table 4.

Table 4
Results of χ^2-Pearson calculations.

Pearson's χ^2	*df*	Asymptotic significance
8.685[a]	3	0.034
15.994[a]	3	0.001

According to the results of the calculations ($p \leq 0.05$ and $p \leq 0.001$), we reject the null hypothesis and take into account the alternative hypothesis: there are differences between the distributions of the levels of readiness of future primary school teachers to use ICT in teaching younger schoolchildren of the experimental and control groups.

The effect size was estimated using the V-Cramer index (table 5).

Table 5
Interpretation of the effect size of the V-Cramer index for df=3,

V Kramer	*df=3*	Effect size
0.235	0.17–0.28	average
0.250	0.17–0.28	average

Based on the presented data (figure 1), it was established that the implementation of the developed complex of online services demonstrates higher efficiency compared to traditional approaches. Experimental training in the use of a complex of online services statistically reliably provides better results in

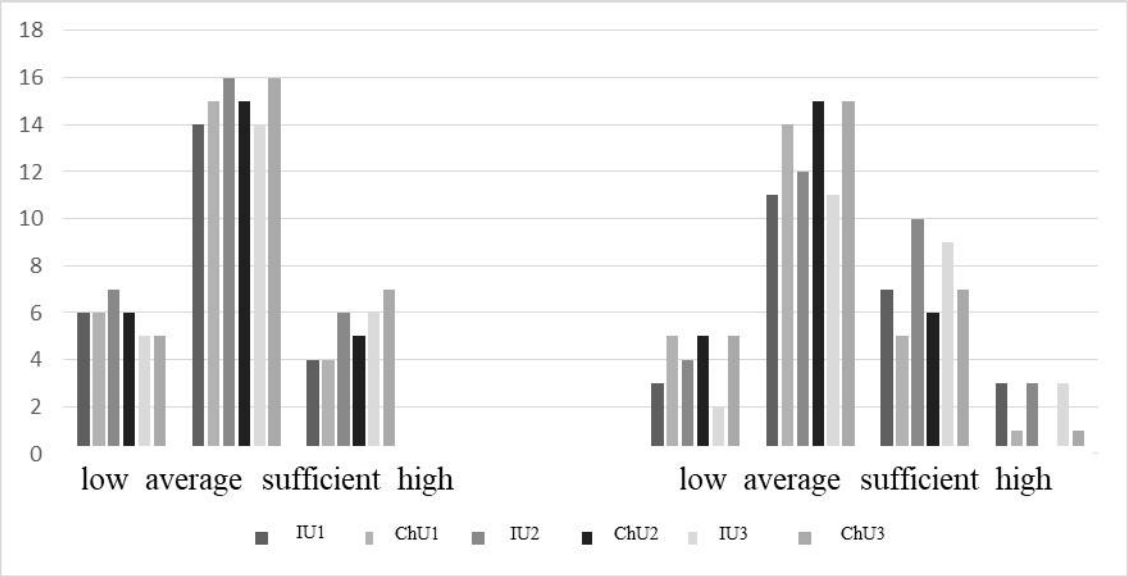

Figure 1: Dynamics of growth of quantitative characteristics of readiness levels of future primary school teachers to use ICT in teaching younger schoolchildren.

the formation of teachers' readiness to use information and communication technologies in professional activities.

6. Discussion of research findings and debatable issues

Based on the presented study regarding ICT usage in the professional activities of primary school teachers in Ukraine, several key conclusions:

1. Positive impact of the pandemic on ICT competency development – the forced transition to distance learning became a catalyst for the development of teachers' digital skills. This observation is supported by statistical data showing increased usage of various digital platforms and services.
2. Self-education as the primary path to ICT competency acquisition – the research shows that a significant portion of teachers (84%) work independently to improve their ICT skills rather than acquiring them during their studies at higher education institutions.
3. Deepening differentiation among teachers – some educators stopped at the basic level of ICT usage, while others expanded their arsenal of digital tools and began creating interactive content.
4. More objective self-assessment of competency levels – during the pandemic, primary school teachers more realistically evaluated their own skills, identifying gaps in their ICT usage.
5. Based on the results of a survey of teachers about their motivation for choosing online services and a comparative analysis of the services' capabilities, we selected the following services (LearningApps, Liveworksheets, Wizer.me, Classtime, Google Forms, H5P, Google Classroom, ClassDojo, Padlet, Lino.it, Renderforest, Canva, Zoom, Google Meet, Microsoft Teams, PhET, GeoGebra, Google Art), which form a set of online services for organizing full-time, distance and blended learning of open type, that is, in the process of professional activity, primary school teachers have the opportunity to modify it by adding new online services with greater educational opportunities. Therefore, there is a need for future teachers to master the complex of services in the process of professional training in higher education institutions, in particular when mastering methodological disciplines that develop the ability to use ICT in the educational process, taking into account the specifics of subjects and integrated courses.
6. The effectiveness of implementing the developed complex of online services was verified during a pedagogical experiment, which included ascertaining and formative stages. The ascertaining

stage was repeated over three academic years and demonstrated growth in the need for online services throughout the research period – there is a significant positive trend among students who felt the need to use online services: from 33% in 2020-2021 academic year to 68% in 2022-2023 academic year (Izmail University) and from 32% to 64% (ChNU).
7. Increased motivation to search for new digital tools – the percentage of students directed towards finding new digital tools increased from 25% to 48% (Izmail University) and from 24% to 46% (ChNU) over three years.
8. The results of the formative experiment convincingly demonstrate the effectiveness of specialized training for students in using online services in their professional activities. The results of creative projects demonstrate a significant difference between experimental and control groups, which is statistically confirmed using the χ^2-Pearson criterion.
9. Stable set of online services – the list of online services used by students remained unchanged throughout the study period, which may indicate the formation of a "core" of the most popular and convenient services. However, it should be noted that the conditions for using these services changed somewhat over the years of experimental work, which was emphasized to the students. Additionally, the list of services was supplemented with new ones, but the core services remained unchanged.

Debatable issues can be identified:

1. The research results show that teachers often master a basic set of services and stop at this level. This raises the question: what is more important in a rapidly changing digital environment – deep knowledge of a limited set of tools or superficial familiarity with a wide range of digital resources?
2. The study shows that only 22% of teachers acquired ICT competency in higher education institutions (although this is an increase from 10% in previous data). This raises the question: how effectively are higher education institutions preparing future teachers to use modern digital technologies? Should teacher training programs be revised considering the rapid digitalization of education? We are confident that teacher training programs should include not only individual modules on the use of ICT in methodological courses, but also separate disciplines aimed at equipping future teachers with digital competence.
3. The study does not answer the question: how sustainable are the ICT skills acquired during training? Will the level of proficiency in these skills decrease after course completion, and will students apply these skills in their future professional activities?
4. This the question: how ready are the higher education institution teachers themselves to implement ICT in the preparation of future teachers? What is their level of digital competency?

Overall, despite certain methodological limitations, the study provides valuable information about the dynamics of ICT competency development among Ukrainian primary school teachers and emphasizes the need for a systematic approach to implementing digital technologies in education.

7. Prospects for further research

The conducted study confirms the effectiveness of implementing a specialized ICT module in the training of future primary school teachers. However, it also reveals a number of unresolved issues that require further investigation. First, a longitudinal study is needed to assess the sustainability and practical application of acquired ICT competencies after graduation and during the initial stages of professional activity. Second, the digital competency of higher education instructors should be examined, particularly its influence on the development of students' ICT skills. Third, there is a need to develop and validate a model that effectively integrates formal education and self-directed learning in forming digital literacy. These directions will help to deepen understanding of ICT integration in teacher education and support the development of more effective training strategies aligned with the demands of modern education.

Declaration on Generative AI

Artificial intelligence or tools using artificial intelligence were not used in the preparation of the manuscript.

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