

A SET OF ONLINE SERVICES FOR ORGANIZING FACE-TO-FACE, DISTANCE, AND BLENDED LEARNING

SVITLANA SKVORTSOVA, TETIANA BRITSKAN, TETYANA SYMONENKO,
KIRA HNEZDILOVA, RUSLANA ROMANYSHYN*

*Corresponding author: ruslana.romanyshyn@cnu.edu.ua

Abstract. The article presents the results of a study on the use of ICT, specifically online services, in the professional activities of primary school teachers. The research was conducted from 2018 to 2024. Taking into account the preferences of primary school teachers, which were identified through a longitudinal study (2019-2022), an open set of online services for organizing face-to-face, distance (in synchronous and asynchronous modes), and blended learning was developed. The set includes: Group I – services for creating interactive educational content (A. Services for creating interactive exercises; B. Services for creating interactive videos; C. Services for creating virtual whiteboards; D. Interactive simulation services); Group II – services for organizing and conducting online lessons; Group III – services for creating a virtual classroom and managing electronic gradebook. Considering the content of the teacher's professional activity and the implementation of labor function A (according to the professional standard for teachers), the developed set includes services that allow the teacher to either use ready-made or create their own ICT-based learning tools. Since this set is open and components of each group may change, the article provides a system of criteria for selecting online services. The set was implemented in the training of future primary school teachers during a pedagogical experiment conducted at the South Ukrainian National Pedagogical University named after K.D. Ushynsky, Izmail State University of Humanities, and Bohdan Khmelnytsky National University of Cherkasy. The results of the pedagogical experiment demonstrate the effectiveness of the developed set of online services, which prepares future primary school teachers to use ICT in teaching integrated courses to young learners. The novelty of the study lies in developing a flexible, criteria-based approach to selecting online services that can be adapted to changes in the digital educational environment. The findings have practical implications for teacher education institutions and professional development programmes, as they provide methodological guidance on integrating ICT into primary education and may serve as a basis for further research aimed at enhancing teachers' digital competence.

Keywords: ICT, set of online services, primary school teacher, professional activity, teacher education, interactive educational content.

1. INTRODUCTION

Considering the characteristics and needs of modern primary school students, who are representatives of the digital generation, it is fundamentally important for a primary school teacher to possess a sufficient level of ICT competence/digital competence. This requirement is regulated by the Professional Standard for the professions of "Primary School Teacher in General Secondary Education," "Teacher of General Secondary Education," and "Teacher with an Associate Degree in Primary

Education” in Ukraine. According to the EU’s 2018 Digital Education Action Plan, the extensive use of digital technologies for teaching and learning is envisaged. Therefore, the National Report on the State and Prospects of Education Development in Ukraine (2021) emphasizes the relevance of research in “digital humanistic pedagogy and digital didactics, the use of open information and digital resources, networks, and systems,” as well as “the use of digital technologies for assessment,” “designing learning environments using augmented and virtual reality tools, primarily in general secondary education,” and “developing methodological systems for using digital technologies in teacher training and professional development, subject-specific teaching methodologies, and the use of digital technologies by students, especially those in general secondary education” (National Academy of Pedagogical, 2021, pp. 131-132).

The importance of using ICT in a teacher’s educational activities has significantly increased since 2020 when domestic schools switched to online learning due to the Covid-19 pandemic. Since 2022, because of Russia’s full-scale aggression against Ukraine, schools have been forced to return to distance or blended learning.

This study is grounded in two complementary theoretical frameworks. First, the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) provides a lens for understanding how teachers integrate technology into subject-specific pedagogy. TPACK posits that effective technology integration requires the intersection of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). In the context of this study, the developed set of online services represents TK resources that teachers must learn to combine with their PK and CK for effective mathematics instruction in primary schools.

Second, the European Framework for the Digital Competence of Educators (DigCompEdu; Redecker, 2017) provides a structured approach to defining the specific digital competences that educators need. DigCompEdu identifies six areas of competence, including digital resources, teaching and learning, assessment, and empowering learners. The set of online services developed in this study aligns with these competence areas: services for creating interactive content correspond to the ‘Digital Resources’ and ‘Teaching and Learning’ areas, while assessment tools (electronic gradebooks, monitoring features) align with the ‘Assessment’ area.

The SAMR model (Puentedura, 2013) is also relevant as a descriptive lens for categorizing how the selected online services transform pedagogical practice, ranging from substitution (e.g., using digital worksheets instead of paper) to redefinition (e.g., creating interactive simulations that enable exploratory learning impossible without technology). Together, these frameworks provide the theoretical justification for the selection criteria developed in this study and inform the interpretation of experimental results.

International research consistently demonstrates that primary school teachers require structured, practice-oriented training to develop digital competence (Tondeur et al., 2012; Ertmer & Ottenbreit-Leftwich, 2010; Voogt et al., 2013). Meta-analysis indicates that technology integration courses are most effective when they combine theoretical knowledge with hands-on experience using specific digital tools within authentic pedagogical contexts (Tondeur et al., 2020). The UNESCO ICT Competency Framework for Teachers (UNESCO, 2018) further emphasizes the need for systematic approaches to ICT in teacher education that go beyond isolated tool training.

Studies from Central and Eastern Europe provide relevant regional context. Bulgarian researchers (Terzieva et al., 2020; Terzieva et al., 2018), Slovak scholars (Záhorec et al., 2019), Czech researchers (Klement & Klementová, 2016; Neumajer, 2012), and Romanian scholars (Popa & Bucur, 2015) have established that teachers require practical, subject-specific ICT training. Ukrainian studies (Skvortsova et al., 2023; Ovcharuk, 2023; Ovcharuk & Ivaniuk, 2020; Burda & Vasylyeva, 2021) confirm these findings in the national context. Recent research by Falloon (2020) highlights that digital competence development in pre-service teachers is most effective when embedded within subject-specific methodology courses rather than standalone ICT courses, which aligns with the approach taken in the present study.

However, while individual studies have examined specific digital tools or platforms, there remains a gap in research that provides a systematized, criteria-based approach to selecting and organizing online services across the full spectrum of teaching activities (face-to-face, distance, and blended), particularly in the context of emergency remote teaching and post-pandemic education. This study addresses this gap.

Therefore, the development of a substantiated set of online services for organizing face-to-face, distance (in synchronous and asynchronous modes), and blended learning, which can be used by primary school teachers in their professional activities, is a relevant issue.

The aim of this research is to: (1) develop and justify the selection of online services for each component of the set based on theoretically grounded criteria; (2) conduct experimental training for future primary school teachers on the use of the selected services; and (3) present the results of the pedagogical experiment. Specifically, the study addresses the following research question: Does structured training using a systematized set of online services significantly improve pre-service primary teachers' readiness to integrate ICT into their professional activities compared to traditional instruction?

Based on the teacher's professional needs and the longitudinal study of Ukrainian primary school teachers' ICT preferences (Skvortsova et al., 2023), an open set of online services was developed, organized into three groups.

Taking into account the teacher's needs in organizing the educational process (Skvortsova et al., 2020; Skvortsova et al., 2021; Skvortsova et al., 2022; Skvortsova et al., 2023), the components of the aforementioned set of online services for organizing face-to-face, distance (in synchronous and asynchronous modes), and blended learning include tools/services and platforms:

1. for creating interactive educational content;
 - A. for creating interactive exercises;
 - B. for creating interactive videos;
 - C. for creating virtual whiteboards;
 - D. for interactive simulation;
2. for organizing and conducting online lessons;
3. For creating virtual classrooms and managing electronic gradebooks.

As a result of a longitudinal study on the preferences of Ukrainian primary school teachers (Skvortsova et al., 2023) regarding their ICT needs and usage in the educational process, online services were selected for each component of the set. In this way, we outlined the range of online services used by primary school teachers in Ukraine, and each of these services already includes a Ukrainian-language library that teachers can use without further modification. It should be noted that the proposed set of services is open and can be modified – new services may be added according to the requirements outlined below.

The selection criteria were informed by the TPACK framework, ensuring that each service supports the intersection of technological, pedagogical, and content knowledge. A detailed description of each service category and the rationale for specific tool selection is provided in Skvortsova et al. (2020), Skvortsova et al. (2021), Skvortsova et al. (2022), Britskan (2023); below we present a condensed overview.

We define “educational content” as a set of substantive elements that are the subject of study for students. Interactive educational content includes:

1. Educational content that involves specific actions with its elements, requiring active participation from the student while working with it.
2. A tool for interaction between the teacher and the student by offering certain educational digital products, with feedback in the form of student performance assessment, and, specifically, providing guidance on the student's progress based on the obtained results.
3. A set of all elements (content elements and navigation elements) that the student interacts with, either directly or indirectly (Britskan, 2023, p. 133).

In practice, various forms of interaction with educational interactive content are possible in modern elementary schools: passive, active, and exploratory. Passive interaction involves students not altering the content but simply viewing or listening to the interactive content to understand and memorize educational information, only performing operational functions (starting and finishing tasks, scrolling, etc.). An example of this is when a student watches a pre-prepared educational video. However, active interaction entails changing the content by performing certain actions with it. Here, the content has two states: the original (created by the teacher) and the transformed (modified by the student). For instance, if a student watches an interactive educational video with pauses for exercises, they must apply the knowledge gained during the video to complete the tasks. Exploratory interaction involves not merely modifying the content based on a plan or algorithm, but exploring the object by changing the conditions through free manipulation. For example, in the PhET Interactive Simulations virtual lab, students can study fractions by adjusting the numerator and denominator and observing the whole value. Using interactive content in education allows for student engagement, feedback provision, immediate assessment of learning outcomes, and support when students encounter difficulties. Interactive content includes exercises, tests, videos, virtual boards, and online simulators. Any educational content can be interactive if it is based on student interaction.

Students of the digital generation are primarily visual learners, so visualizing and illustrating educational material is necessary to improve understanding and retention. This can be achieved using ICT tools, creating engaging, dynamic, and colorful interactive content. Among Ukrainian teachers, interactive exercises are the most popular type of content. An interactive educational exercise is a task created using specific online service templates. It starts when the student logs into the system and ends when they log out (Britskan, 2023). These tasks can either allow for automatic feedback (with pre-set answers) or open responses, which the teacher checks manually. Each interactive exercise typically includes the following elements: instructions on how to perform the task, the task itself, and solutions/answers (with automatic checks, the teacher inputs the correct answers during setup). Similar assignments with automatic checking provide immediate feedback, which is essential for digital-native students who prefer instant gratification. Services with built-in electronic journals enable teachers to monitor each student's progress and manage their learning activities. These tools are particularly useful for blended and distance learning.

Online services for creating interactive exercises offer various templates that can be grouped into: point-and-click exercises: selecting the correct answer; manipulative exercises: moving elements within the task; keyboard exercises: typing in answers; oral exercises: speaking responses. Some services offer automatic checking for the first three types, while open-response tasks require manual assessment by the teacher.

When selecting services for creating interactive exercises, we considered two main criteria groups: *Group I* (Creation criteria): allows for exercises across all subjects, diverse templates, multimedia enhancements (e.g., images, charts), animations, and differentiated exercises based on difficulty levels. *Group II* (Monitoring criteria): ensures prevention of random guessing, provides instant feedback, tracks progress, and allows for data analysis of student success.

Based on these criteria, the most popular services among Ukrainian teachers include LearningApps, Liveworksheets, Wizer.me, H5P, Google Forms, and Classtime (Skvortsova et al., 2020; Skvortsova et al., 2021; Skvortsova et al., 2022; Skvortsova et al., 2023; Britskan, 2023).

Interactive video is a special format that enables interaction with video content using various tools. Educational interactive videos engage students by embedding pauses, tasks, and "hot spots" with additional materials such as text, images, and hyperlinks. Educational interactive videos are based on pre-recorded videos, supplemented with interactive elements. When selecting services for creating interactive videos, we followed two additional criteria groups: *Group III* (Video creation criteria): includes creating videos from multimedia presentations, using real footage, and producing videos based on ready-made scripts. *Group IV* (Interactive content criteria): includes ease of adding interactive

elements, various templates, monitoring results, and checking the correctness of tasks.

Considering these requirements, the services selected for creating educational videos include Microsoft PowerPoint, Canva, Renderforest, Zoom, Microsoft Teams for video creation, and H5P and LearningApps for interactive videos (Skvortsova et al., 2021; Skvortsova et al., 2022; Britskan, 2023).

It is possible to acquaint students with structured educational interactive content on a specific topic or lesson using online services for demonstrating educational material on a virtual whiteboard. Virtual whiteboard services will help the teacher not only during the organization and conduct of distance lessons in asynchronous mode, but also during the organization and conduct of educational projects. The teacher on the virtual board can vividly and visually present both the structural elements of the remote lesson and the structural elements of the educational project and the plan of work on it. The virtual board makes it possible to visualize the progress of the remote lesson by presenting the content units of the lesson in a schematic form or in the form of notes. In addition, a virtual board supports teachers in organizing and assessing the asynchronous presentation and defense of educational projects, allowing students to upload videos and other project materials, as exemplified by Padlet. Given the purpose of distance learning, among virtual interactive whiteboards, educators are mostly interested in virtual whiteboards for organizing joint work with various content with the possibility of joint editing – Educreations, Lino it, Padlet, Popplet. Understanding that the services IDroo, Whiteboard Fox, Padlet, NoteBookCast, Conceptboard, Groupboard, Classroomscreen, Ziteboard, Lino.it, etc. are available on the network, and their list is constantly expanding. Therefore, when choosing virtual boards, we suggest focusing on the following group of requirements: 1) availability of various virtual board templates; 2) the ability to present material of various formats on the virtual board; 3) the possibility to involve students in reviewing publications; 4) the possibility for schoolchildren to publish their own posts. In accordance with the requirements formulated by us, we suggest using the services - virtual boards Padlet and Lino.it. The rationale for choosing these services is given in the works of the authors (Britskan, 2023).

We consider interactive simulators as a digital service that creates visualization opportunities 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 the virtual environment, the study and research of which leads to a significant educational result in the form of the discovery of regularities, methods of action, rules, generalizations, etc. These simulators not only provide educational content but also incorporate edutainment elements and present learning activities in a game-based format. Thus, interactive simulators are resources for teaching with simulations, as well as those that involve the use of immersive technologies - virtual and augmented reality (AR, VR) (Britskan, 2023). Interactive simulators are divided into two groups: virtual laboratories; 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 independently setting certain conditions for the student; 2) the possibility of visualizing the result in various formats; 3) bringing students to the generalization of a concept or method of action; 4) the opportunity to practice a skill or skill in applying a new method of action; 5) the possibility of using 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 in both symbolic and visual form. In accordance with the outlined requirements, we have chosen such services as PhET and GeoGebra for teaching mathematics to junior high school students. The rationale for choosing these services is given in the works of the authors (Britskan, 2023). With the help of Google Art, HP Reveal and H5P, the teacher can create and/or use AR, VR. Unlike VR, which helps you mostly immerse yourself in an artificial and simulated world and act in it, AR is more related to the real physical world. AR is a technology in which the user's perception of the real world is enhanced and augmented with additional information from computer models, allowing the user to stay in touch with the real environment. As you know, 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, while in AR the system

brings a digital device to the real working environment of the user as an aid for comprehensive exploration of the object (Melnik et al., 2018). For the effective use of VR in the education of younger students, the teacher needs special equipment and paid programs, which are not available in all educational institutions. A simplified option that allows the teacher to demonstrate the elements of VR is virtual tours. T. Vasyutina (2020) investigates the didactic possibilities of virtual excursions in the education of younger schoolchildren. The author suggests using the Google Art and Culture application for younger schoolchildren to view exhibits of the world's best museums (Vasyutina, 2020).

In our opinion, virtual tours are not the only possible use case for VR. We strongly suggest lessons can be "emotionally embellished" if you include certain AR elements while working on educational tasks. For example, to create a positive emotional background in mathematics lessons, in order for students to imagine the situation described in the problem, you can create a call to the appropriate video fragment that illustrates the plot of the problem. AR can also be used as a means of implementing a differentiated approach: by pointing the device at a certain mark, the student can receive either instructions for solving the task, or a detailed algorithm of actions, or a ready-made solution and analyze it or test himself, or, conversely, - receive tasks of a higher level of complexity. Investigating the problem of the interaction of participants in the educational process when using VR and AR, S. Litvynova and N. Soroko (2023) obtained the following survey results: the interaction of participants in the educational process using virtual reality needs improvement, methodological recommendations and research on the organization of this environment for various purposes, for example, research students of new educational materials, performance of laboratory work, joint work of students on research, instructions on the activities of the teacher in working with students in virtual reality, etc.; the interaction of the participants of the educational process using augmented reality provides opportunities for mutual understanding between teachers and students, in addition, they use both ready-made AR technologies and self-created ones (Litvynova & Soroko, 2023). Following S. Litvinova and N. Soromko (2023), we believe that VR and AR provide unique opportunities for the interaction of participants in the educational environment, and therefore deserve the attention and mastery of teachers. Therefore, we suggest using the HP Reveal and H5P services. In the specified services, the teacher can create his own AR, depending on the topic and content of educational tasks, in the following ways: by superimposing images, audio and video materials, 3D models on a real image that can be contained in textbooks, educational notebooks, or individual drawings.

Distance learning in synchronous mode is impossible without services for organizing video conferences in real time. Given the content of teachers' professional activities, when choosing services for organizing online lessons, we suggest following the following requirements: 1) the possibility of planning a meeting in advance and synchronizing it with the calendar; 2) the duration of the conference and the maximum number of participants; 3) the ability to demonstrate the screen; 4) availability of the "Board" tool; 5) the possibility of recording the conference; 6) the possibility of communication in the chat; 7) the possibility of creating virtual rooms for organizing group work. Zoom, Google Meet, and Microsoft Teams, the most popular services for conducting online lessons among teachers and university professors, meet the above requirements (Skvortsova et al., 2022; Britskan, 2023). We note that this set of services was chosen by us taking into account teachers' preferences (Skvortsova et al., 2023), correlates with the results of a study by M. Burda and D. Vasylieva (2021), who claim that teachers use Zoom most actively; second place in 2020 was taken by Skype (more than 20%), and in 2021 it was replaced by Google Meet (54.2%).

We understand the virtual class as the organization of the educational process on the appropriate platform using tools that create certain opportunities. Namely: inclusion of students in the virtual class; filling it with educational materials and interactive content; uploading the works done by students; checking of uploaded works by the teacher; recording the results of students' educational activities in the electronic journal: both recording the results of interactive tasks automatically checked by the service and tasks checked by the teacher; organization and holding of video conferences. When choosing services, we proceeded from

the following requirements: 1) the possibility of creating a virtual class: selection of exercises or a series of exercises for the specified lesson and the corresponding class; 2) availability of a bank of interactive exercises that can be used at any time without creating your own; 3) the possibility of the teacher to further work with the results in the electronic journal. Based on the submitted requirements and taking into account the results of the teachers' questionnaire regarding the choice of services for creating a virtual class and electronic journal (Skvortsova et al., 2023), we chose LearningApps, Google Classroom, Padlet, ClassDojo, Classtime, Wizer.me, Liveworksheets. The justification for choosing these services in accordance with the specified requirements is presented in the works of the authors (Skvortsova et al., 2022; Britskan, 2023). At the same time, we note that Google Classroom has all the above-mentioned tools that allow you to present a virtual class holistically, and services (LearningApps, Padlet, ClassDojo, Classtime, Wizer.me, Liveworksheets) help the teacher focus on one or more aspects in creating a virtual class. work that requires the use of other services. It should be noted that the proposed set of services is open, it can be modified – supplemented with new services, in accordance with the above requirements.

2. RESEARCH METHODS

This study employed a quasi-experimental pre-test/post-test design with non-equivalent control groups (Campbell & Stanley, 2015). The quasi-experimental design was chosen because random assignment of students to groups was not feasible in the university setting; instead, intact groups at different institutions and within different course tracks served as experimental and control groups. The study was conducted over three consecutive academic years (2020–2021, 2021–2022, 2022–2023) in two parallel research cycles, providing replication across time and institutional contexts.

The total sample comprised 412 bachelor's degree students in specialty "Primary Education" from three Ukrainian universities: South Ukrainian National Pedagogical University named after K.D. Ushynsky (Ushynsky University; $n=255$), Izmail State University of Humanities (Izmail University; $n=78$), and Cherkasy National University named after B. Khmelnytskyi (ChNU; $n=79$). Convenience sampling was used, with institutional assignment determining group allocation. The homogeneity of experimental and control groups was verified statistically prior to the intervention (see Section 4.1).

Research cycle 1: Students of Izmail University (EG1–3, $n=78$ total) and ChNU (CG1–3, $n=79$ total) were assigned to experimental and control conditions, respectively. Research cycle 2: Fourth-year students at Ushynsky University were divided into subgroups based on their elective course selection: those who chose "Methodology of Teaching Problem Solving" formed the experimental groups (EG4–6, $n=134$ total), while those who chose "Ethics and Aesthetics" formed the control groups (CG4–6, $n=121$ total).

Two main instruments were used: (1) ICT Readiness Questionnaire: A researcher-developed questionnaire (Britskan, 2023, pp. 180–195) assessed students' readiness to use ICT across three criteria: motivational (attitudes toward ICT use in teaching), content-related (knowledge of available online services and their pedagogical applications), and operational (practical skills in using online services). The questionnaire comprised 25 Likert-scale items and 10 multiple-choice items. Content validity was established through expert review by five educational technology specialists. Internal consistency was assessed using Cronbach's alpha ($\alpha=0.82$ for the motivational subscale, $\alpha=0.79$ for content-related, $\alpha=0.85$ for operational).

(2) Creative Project Assessment Rubric: Students' creative projects (designing ICT-based mathematics lessons) were evaluated using a standardized rubric with four performance levels: Low (0–5 points), Intermediate (6–10 points), Sufficient (11–15 points), and High (16–20 points). The rubric assessed: (a) awareness of online services and their templates (0–5 points); (b) appropriateness of service-template selection for specific tasks (0–5 points); (c) ability to combine multiple services in lesson design (0–5 points); (d) compensating limitations of one service with advantages of another (0–5 points). Inter-rater reliability was established through double-blind assessment by two evaluators (Cohen's $\kappa=0.78$).

The study proceeded in three stages:

Diagnostic stage: Prior to the intervention, all participants completed the ICT Readiness Questionnaire to establish baseline levels and verify group homogeneity.

Formative stage (intervention): In experimental groups, students completed a specially designed ICT training module integrated into their methodology courses. In Research cycle 1, EG students completed a module "ICT in the Teaching of Mathematics" (1 seminar, 1 laboratory session, 1 lecture, 1 seminar) within the compulsory course "Methodology of Teaching Mathematics in Primary School." In Research cycle 2, EG students completed the module "Using ICT in Teaching Problem Solving" (5 lectures, 5 practical classes) within the elective course. Control group students followed standard curricula without specialized ICT training using the developed set of services. All students completed creative projects at the end of the intervention.

Assessment stage: Creative projects were assessed using the standardized rubric. Post-intervention questionnaire data were collected.

Categorical data (performance levels) were analyzed using Pearson's chi-square test (χ^2) to compare distributions between experimental and control groups. The significance level was set at $\alpha=0.05$. Effect sizes were estimated using Cramér's V coefficient. All statistical analyses were performed using IBM SPSS Statistics (Version 27).

The study was conducted in accordance with the ethical guidelines of the participating institutions. All participants provided written informed consent prior to participation. Participation was voluntary, and students were informed that their decision to participate or not would have no impact on their academic standing. Data were anonymized during analysis.

3. RESULTS AND DISCUSSION

The developed complex is implemented in the methodical training of students of specialty "Primary education" of the Southern Ukrainian National Pedagogical University named after K.D. Ushynsky (hereinafter – Ushynsky University), Izmail State University of Humanities (hereinafter Izmail University) and Cherkasy National University named after Bohdan Khmelnytskyi (hereinafter – ChNU). The experimental base included 412 bachelor's degree holders, including 78 people at IDSU, 255 people at Ushynsky University, and 79 people at ChNNU.

It is obvious that before the beginning of experimental training, future teachers may have certain knowledge and experience in using online services that the teacher can use in professional activities. Therefore, prior to the experimental training, a baseline assessment was conducted. Its purpose was to find out the awareness of future teachers about online services, how they can be used in professional activities, and their attitude towards the use of ICT in the process of teaching mathematics students. At this stage, student questionnaires were used.

The pedagogical experiment had two research cycles. The first one provided for the inclusion of a separate module "ICT in the teaching of mathematics of junior high school students" in the content of the compulsory course "Methodology of teaching mathematics in primary school", and the second - the inclusion of the module "ICT in teaching problem solving" in the content of the elective course chosen by students "Teaching methodology problem solving". Each of these research cycles lasted three academic years – 2020-2021; 2021-2022; and 2022-2023).

The results of the ascertainment experiment. The student survey was conducted during 2020-2021 and 2021-2022. and 2022-2023 AD In the first research cycle of the experiment, students of III and II (reduced study period) courses of Izmail University were involved before studying the module "ICT in teaching mathematics of junior high school students" within the compulsory course "Methodology of teaching mathematics in primary school" and students of ChN University before studying this regulatory discipline. To the second research cycle – students I (those who chose the course "Problem Solving Learning Methodology") and II (those who did not choose the course "Problem Solving

Learning Methodology”) of subgroups of the 4th year of study at Ushynsky University at the beginning of mastery the elective course.

The analysis of the results of the student questionnaire proved that the awareness of the availability of online services and the ability to use some of them in the process of education of junior high school students among the applicants of IDSU and ChNU are approximately at the same level.

In view of the above, the research participants were conditionally combined into experimental EG1 (24 students of Izmail University in 2020-2021), EG2 (29 students of Izmail University in 2021-2022), EG3 (25 students in 2022-2023 AD) and control groups CG1 (25 students of ChNU in 2020-2021), CG2 (26 students of ChNU in 2021-2022), CG3 (28 students of ChNU in 2022-2023).

Homogeneity according to the indicated feature – awareness of the availability of online services for performing the professional activities of an primary school teacher, willingness to use them and available experience among students of Izmail University and ChNNU, proved with the help of mathematical statistics methods, in particular the χ^2 -Pearson test. The statistical hypothesis that there are no differences between the distributions of students of the two higher education institutions (Izmail University and CHNU) according to the determined criteria (motivational, substantive and operational) was tested at the $\alpha=0.05$ significance level. Calculations were carried out using IBM SPSS, a software product for analyzing statistical data.

We formulated null and alternative hypotheses:

H0: there are no differences between the distributions of the levels of readiness of future primary school teachers to use ICT in the process of teaching junior high school students of two higher educational institutions (Izmail University and ChNU).

H1: there are differences between the distributions of the levels of readiness of future primary school teachers to use ICT in the process of teaching junior high school students of two higher education institutions (Izmail University and ChNU).

According to the results of the calculations, it was established: the value of the Pearson's χ^2 criterion is 0.67 at $p=0.967$ ($p>0.05$). And therefore, we accept the null hypothesis, according to which there are no differences between the distributions of the levels of readiness of future primary school teachers to use ICT in the process of teaching junior high school students of two higher education institutions (Izmail University and ChNU).

The second research cycle began with a baseline assessment where the participants were surveyed in two subgroups at Ushynsky University before studying the elective course. The obtained results were predictable for us and indicate that the students of I (those who chose the course “Problem Solving Learning Methodology”) and II (those who did not choose the course “Problem Solving Learning Methodology”) of subgroups of Ushynsky University are motivated to the use of ICT, are aware of online services in the teacher's professional activity and are able to use the outlined services at approximately the same level. The study participants were conditionally divided into experimental EG4 (44 students in 2020-2021), EG5 (44 students in 2021-2022), EG6 (46 students in 2022-2023) and control groups CG4 (42 students in 2020-2021), CG5 (44 students in 2021-2022), CG6 (35 students in 2022-2023).

Also, as in the case of the first research cycle and experimental work, we proved the homogeneity of the experimental and control groups according to the specified feature. We applied the χ^2 -Pearson test at the $\alpha=0.05$ significance level. Two hypotheses are formulated – null and alternative:

H0: there are no differences between the distributions of the levels of readiness of future primary school teachers to use ICT in the process of teaching junior high school students of the two subgroups of Ushynsky University.

H1: there are differences between the distributions of the levels of readiness of future primary school teachers to use ICT in the process of teaching junior high school students of two subgroups of Ushynsky University.

According to the results of calculations, it was established: $\chi^2 = 0.18$ with $p=0.991$ ($p>0.05$). And therefore, we accept the null hypothesis (H0), according to which there are no differences between the

distributions of the levels of readiness of future primary school teachers to use ICT in the process of teaching junior high school students of the two subgroups of Ushynsky University.

Like the baseline assessment stage, the formative stage of the experiment was conducted over three consecutive academic years and comprised two parallel research cycles.

According to the first research cycle in the control groups (CG1-3), the special training of future teachers for the use of ICT was limited to the study of the issue of "Teaching tools" within the topic "Organization of mathematics education in primary school" according to the working curriculum. In the experimental groups (EG1-3), the process of preparing future students for the use of ICT involved mastering the developed module "ICT in the teaching of mathematics of junior high school students", which contained the following topics: Topic 1. Services for creating educational interactive content in mathematics (1 seminar, 1 laboratory occupation). Topic 2. Services for creating a virtual class and an electronic journal (1 lecture). Topic 3. Online services for organizing a distance lesson (1 seminar). The educational material for teaching the specified module is presented on Google Disk (https://drive.google.com/drive/folders/1wxirjWullPIkqSN1bGXoaqFnPfvfHRx_), which was prepared on the basis of electronic courses posted on the Zmist.ua website (authors: S. Skvortsova, T. Britskan).

As a result of mastering the specified module, EG1-3 students completed creative projects - created tasks with the help of online services in accordance with the structure of the combined mathematics lesson in primary school. While completing the task, students demonstrated awareness of using online services and templates for creating interactive exercises of these services, understanding the peculiarities of selecting appropriate service templates for the implementation of a certain task; the possibility of combining online services when organizing a distance lesson, compensating the disadvantages of certain services with the advantages of others. Completed tasks were placed by students in the virtual environment of Google Classroom. It should be noted that the students of CG also performed projects that involved the creation of interactive exercises in mathematics, but without special training in the use of the specified set of online services.

The results of creative projects are summarized in Table 1.

In order to prove the differences in the performance results of the students of the experimental and control groups of the two higher educational institutions (Izmail University and ChNNU), the χ^2 -Pearson test was used at the significance level of $\alpha=0.05$. We formulated two hypotheses – null (H_0) and alternative (H_1):

H_0 : there are no differences between the distributions of students of the experimental and control groups of the two higher education institutions according to the levels in the performance of creative projects.

H_1 : there are differences between the distribution of students of the experimental and control groups of the two higher education institutions according to the levels in the execution of creative projects.

Calculation results: $\chi^2=8.407$ with $p=0.038$ ($p\leq 0.05$). Based on these results, we accept an alternative hypothesis. So, it can be stated that it is statistically proven: there are differences between the distributions of students of the experimental and control groups of the two higher education institutions according to the levels in the execution of creative projects. The V-Kramer index, equal to 0.231, was used to estimate the effect size. For $df=3$, we have an average effect size.

According to the second research cycle of the formative stage in the control groups (CG4-6) who chose the elective course "Ethics and Aesthetics", the special training of future teachers for the use of ICT was limited to the study of general issues of the methodology of teaching mathematics in primary school according to the working curriculum.

Tab. 1

Results of creative projects by students (1 series)

Academic year	Group		Level				Total
			Low	Intermediate	Sufficient	High	
2020-2021	EG ₁	absolute value	3	11	7	3	24
		%	12.5	46	29	12.5	100
	CG ₁	absolute value	6	15	4	0	25
		%	24	60	16	0	100
2021-2022	EG ₂	absolute value	4	12	10	3	29
		%	14	41	35	10	100
	CG ₂	absolute value	5	15	5	1	26
		%	19.2	58	19	3.8	100
2022-2023	EG ₃	absolute value	2	11	9	3	25
		%	8	44	36	12	100
	CG ₃	absolute value	4	15	7	2	28
		%	14.3	53.6	25	7.1	100

Source: authors' own research

In the experimental groups (EG4-6), the preparation of future students for the use of ICT involved mastering the developed module "Using information technologies in teaching problem solving" within the framework of the optional discipline "Methodology of teaching problem solving".

Features of the use of ICT in teaching problem solving are reflected in the content module No. 4, which involves 5 lectures and 5 practical classes. Classes in the course "Methodology of teaching problem solving" were conducted according to the following topics: Topic 1. Creating a virtual class and an electronic journal (Google Classroom, Classtime, LearningApps, ClassDojo). Topic 2. Online services for creating interactive math tasks (LearningApps, Classtime, Liveworksheets, Wizer.me). Topic 3. Online services for creating an educational video (Renderforest, H5P, Microsoft PowerPoint). Topic 4. Online services for organizing a distance class (Padlet, Lino it, Zoom, Teams).

The results of creative projects are summarized in Table 2.

The developed module "Features of the use of ICT in teaching problem solving" interested students and motivated them to further work with online services in their future professional activities. Using the χ^2 -Pearson test at the significance level of $\alpha=0.05$, the difference in the distribution of students by levels (low, average, sufficient and high) of the experimental and control groups of Ushynsky University in the performance of creative projects was statistically proven. Two hypotheses are formulated – null (H0) and alternative (H1):

H0: there are no differences between the distributions of students of the experimental and control groups of Ushynsky University by level in the performance of creative projects.

H1: there are differences between the distribution of students of the experimental and control groups

of Ushynsky University according to the levels in the execution of creative projects.

Tab. 2

Results of creative projects by students (series 2)

Academic year	Group		Level				Total
			Low	Intermediate	Sufficient	High	
2020-2021	EG ₄	absolute value	5	21	13	5	44
		%	11	48	30	11	100
	CG ₄	absolute value	8	24	8	2	42
		%	19	57.2	19	4.8	100
2021-2022	EG ₅	absolute value	4	20	15	5	44
		%	9.1	45.5	34.1	11.4	100
	CG ₅	absolute value	9	26	8	1	44
		%	20.5	59.1	18.1	2.3	100
2022-2023	EG ₆	absolute value	4	20	16	6	46
		%	9	43	35	13	100
	CG ₆	absolute value	7	20	8	0	35
		%	20	57	23	0	100

Source: authors' own research

Calculation results: $\chi^2=18.05$ at $p=0.001$ ($p \leq 0.001$). Based on these results, we accept an alternative hypothesis. So, it can be stated that it is statistically proven: there are differences between the distributions of students of the experimental and control groups of the Ushynsky University according to the levels in the execution of creative projects. The V-Kramer index, equal to 0.266, was used to estimate the effect size. For $df=3$, we have an average effect size.

In view of all the above, we have reason to state that special training of future primary school teachers in the use of the proposed set of online services allows to prepare them for work in conditions of face-to-face, distance and mixed education better than in the case of traditional education. At the control stage of the experiment, a comparative analysis and interpretation of the research results was carried out; statistical processing of the received data was carried out to determine the effectiveness of the experimental work.

In the research process, the reliability of the obtained results was checked using the χ^2 -Pearson test at the $\alpha=0.05$ significance level. For this, the null and alternative hypotheses were put forward:

H0: there are no differences between the distributions according to the levels of readiness of future primary school teachers to use ICT in the education of younger schoolchildren in the experimental and control groups.

H1: there are differences between the distributions according to the levels of readiness of future primary school teachers to use ICT in the education of younger schoolchildren of the experimental and

control groups. The results of the calculations are given in Table 3.

Tab. 3

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

Source: authors' own research

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 according to the levels of readiness of future primary school teachers to use ICT in the education of younger schoolchildren of the experimental and control groups. Table 4 shows the estimation of the effect size using the V-Kramer index.

Tab. 4

Effect size interpretation 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

Source: authors' own research

It was found that the EG representatives – both the 1st and 2nd research cycles have more opportunities in creating interactive educational content and combining online services, they show persistent aspirations for this. At the same time, no significant differences were found in the results of research cycles I and II.

So, the experimental test (Fig. 1-2) confirmed the effectiveness of the developed complex of online services, which is the content of the training of future primary school teachers for the use of ICT in teaching junior high school students subjects (integrated courses). Statistical processing of the results using the χ^2 -Pearson test and the V-Kramer index revealed a significant difference in the results of EG compared to CG.

The findings of this study demonstrate that structured training using a systematized set of online services significantly improves pre-service primary teachers' ICT readiness compared to traditional instruction. Both experimental research cycles yielded statistically significant differences with medium effect sizes ($V=0.235-0.250$), suggesting that the intervention had a meaningful practical impact.

These results are consistent with the TPACK framework (Mishra & Koehler, 2006), which predicts that technology integration is most effective when technological knowledge is developed in conjunction with pedagogical and content knowledge. The experimental modules in this study were embedded within subject-specific methodology courses (mathematics teaching), allowing students to develop TPACK rather than isolated technical skills. This interpretation aligns with findings by Tondeur et al. (2020), who demonstrated through a meta-analysis that teacher education programs integrating technology within authentic pedagogical contexts produce stronger outcomes than standalone ICT courses.

The finding that criteria-based selection of digital tools enhances training effectiveness extends prior work by Ertmer and Ottenbreit-Leftwich (2010), who argued that teachers need not only access to technology but also a structured understanding of how to select appropriate tools for specific pedagogical goals. The system of selection criteria developed in this study operationalizes this principle by providing explicit requirements for each category of online service, aligned with the DigCompEdu competence areas (Redecker, 2017).

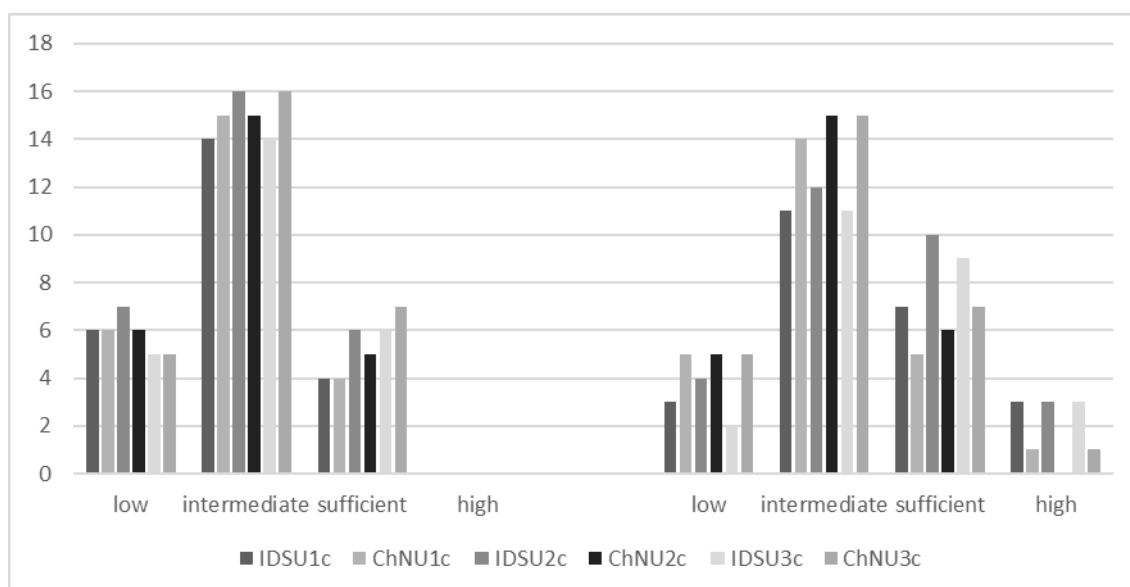


Fig. 1. Growth dynamics of the quantitative characteristics of the levels of readiness of future primary school teachers for the use of ICT in the education of younger schoolchildren (research cycle 1)

Source: authors' own research

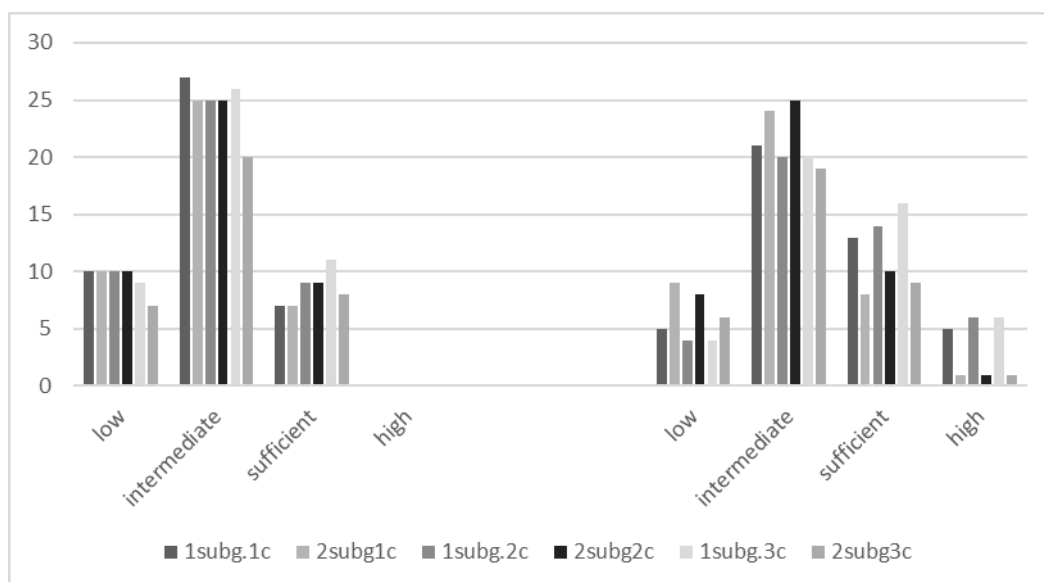


Fig. 2. Growth dynamics of the quantitative characteristics of the levels of readiness of future primary school teachers for the use of ICT in the education of younger schoolchildren (research cycle 2)

Source: authors' own research

Our results are also consistent with the Ukrainian context studies. Ovcharuk (2023) found that teachers who received structured ICT training during wartime conditions demonstrated higher digital readiness, and Burda and Vasylyeva (2021) documented the rapid adoption of videoconferencing tools (particularly Zoom and Google Meet) among Ukrainian educators – the same tools included in our set of services.

Several limitations should be acknowledged. First, the quasi-experimental design with convenience sampling introduces potential threats to internal validity: differences between institutions (curricula, instructors, resources) may have contributed to the observed effects alongside the intervention itself. Future research should employ randomized designs where possible. Second, the assessment relied primarily on creative project evaluation, which, while ecologically valid, captures a limited snapshot of

ICT readiness. Longitudinal follow-up studies are needed to determine whether the training effects persist into professional practice. Third, the study was conducted in the specific context of Ukrainian higher education during a period of extraordinary disruption (pandemic and wartime), which may limit generalizability to other contexts. Fourth, the sample was limited to primary education students studying mathematics methodology; replication across other subject areas would strengthen the findings.

The study has several practical implications. For teacher education institutions, the findings suggest that ICT training should be integrated into subject-specific methodology courses rather than offered as separate technology courses. The developed set of online services with explicit selection criteria can serve as a practical tool for curriculum designers and teacher educators internationally, adapted to local contexts and available tools. For educational policy, the results support the inclusion of structured digital competence development in teacher education standards, consistent with the DigCompEdu framework recommendations.

4. CONCLUSIONS

This study developed, implemented, and validated a comprehensive, open set of online services for organizing face-to-face, distance, and blended learning in primary education. Grounded in the TPACK and DigCompEdu frameworks, the set is organized into three groups (interactive content creation, online lesson delivery, and virtual classroom management) with explicit, theoretically informed selection criteria for each category.

This set supports the development of teachers' professional competence for the full realization of their labor function. The outlined set includes:

1. Services for creating interactive learning content:

- Services for creating interactive exercises (LearningApps, Liveworksheets, Wizer.me, H5P, Google Forms, Classtime, etc.);
- Services for creating interactive videos (LearningApps, H5P based on educational videos that can be created in MS PowerPoint, Canva, and Renderforest, etc.);
- Services for creating virtual boards (Padlet, Lino.it, etc.);
- Interactive simulator services (PhET, GeoGebra, Google Arts and Culture, HP Reveal, H5P, etc.);

2. Services for organizing and conducting online lessons (Zoom, Google Meet, Microsoft Teams, Skype, etc.);

3. Services for creating virtual classrooms and electronic journals (Google Classroom, ClassDojo, Padlet, Classtime, Liveworksheets, Wizer.me, LearningApps, etc.).

The developed set of online services is open and allows for adjustments according to the needs of teachers. To ensure the possibility of its enhancement, requirements for selecting online services have been developed based on the structural elements of the set. We have established that expanding the set of online services is possible by adhering to a system of requirements. The system of requirements for creating interactive learning content includes requirements for the services: 1) for creating interactive exercises; 2) for creating interactive videos; 3) for creating virtual boards; 4) for selecting interactive simulator services. The system of requirements for interactive exercises contains two groups of requirements.

Group I of requirements for creating interactive exercises:

1. Possibility of creating exercises for all sections of the subject;
2. Availability of a sufficient number of platforms to diversify interactive exercises;
3. Possibility of vibrant design of interactive exercises through the use of images, graphs, charts, audio and video materials, etc.;
4. Presence of animations, dynamics, and special effects in interactive exercises;
5. Possibility of creating differentiated exercises by levels of complexity;

6. Possibility of presenting a series of interactive exercises by advancement levels, where the student sees how many exercises they need to complete to move to a higher level;

7. Clear and straightforward algorithm for students to perform interactive exercises;

8. Uncomplicated algorithm for teachers to create interactive exercises.

Group II of requirements for monitoring the performance of interactive exercises and student performance:

1. Avoiding the possibility of random actions by students when choosing an answer;

2. Availability of the function for instant and step-by-step monitoring of students' exercise completion and accumulating data on their success.

When selecting services for interactive video, it is also advisable to adhere to two groups of requirements:

Group I – Requirements for creating video:

1. Ability to create video based on a multimedia presentation;

2. Ability to create real-life video;

3. Ability to create video based on a ready script;

4. Duration of the created video.

Group II – For creating “hot spots” and stops with interactive tasks, as well as monitoring the results of completing interactive tasks:

1. Ease of adding interactive content;

2. Variety of templates for creating interactive exercises;

3. Control of the correctness of completing interactive exercises;

4. Possibility of viewing current and final results of interactive video completion.

When choosing services for creating virtual boards, we believe it is reasonable to consider the following:

1. Availability of various templates for the virtual board;

2. Ability to present materials of different formats on the virtual board;

3. Possibility of involving students in viewing publications;

4. Ability for students to publish their own posts.

When expanding the set of interactive simulator services (virtual laboratory services), it is advisable to consider:

1. Possibility of observing a new concept or method of action by allowing the student to set certain conditions independently;

2. Possibility of visualizing the result in different formats;

3. Guiding students to generalize the concept or method of action;

4. Ability to practice a skill or technique in applying a new method of action;

5. Ability to apply a new method of action when completing tasks from simple to complex;

6. Possibility of organizing an exploration of a new concept or method of action in both symbolic and visual forms.

For organizing and conducting online lessons, we base our requirements on the choice of services for organizing video conferences: the ability to plan meetings in advance and synchronize with a calendar; the duration of the conference and the maximum number of participants; the ability to share screens; availability of a “Board” tool; the possibility of recording the conference; the possibility of chatting; the ability to create virtual rooms for organizing group work.

The following group of requirements for selecting services for creating a virtual classroom and electronic journal: the ability to create a virtual classroom: selecting exercises or series of exercises for the specified lesson and corresponding class; the availability of a bank of interactive exercises that can be used at any time without creating one's own; the teacher's ability for further work with the results in the electronic journal.

Thus, considering the developed system of requirements for selecting online services, over three

years of the pedagogical experiment, each of the structural elements of the set was expanded with new services and adjusted according to the new capabilities of known services.

The quasi-experimental study (N=412, three universities, three academic years) demonstrated that pre-service teachers who received structured training using the developed set showed significantly higher ICT readiness and creative project performance compared to control groups ($p=0.038$ and $p=0.001$ for the two series, with medium effect sizes). These findings contribute to the growing body of evidence that systematic, criteria-based approaches to ICT integration in teacher education are more effective than ad hoc exposure to individual digital tools. The system of selection criteria developed for each service category ensures that the set remains open and adaptable as new technologies emerge. Future research should examine the long-term impact of the training on graduates' professional practice, extend the approach to other subject areas and educational levels, and explore the integration of emerging technologies such as AI-powered educational tools. The theoretical analysis of the characteristics of children—representatives of the digital generation, the problem of preparing future primary school teachers for using ICT in their professional activities, the study of the experience of universities in Ukraine in this direction, and the results of the pedagogical experiment convincingly demonstrate the need for creating a set of online services and mastering it by students specializing in 013 Primary Education during their methodological training.

The scientific novelty of the study lies in the development of a flexible, criteria-based approach to selecting online services that can be adapted to the changing digital educational environment. The findings have practical significance for teacher education institutions and professional development programs, as they provide methodological guidance for integrating ICT into primary education and may serve as a basis for further research on improving teachers' digital competence.

The conducted research does not exhaust all aspects of the problem of preparing future primary school teachers for applying ICT. The prospects for further research may be related to expanding the set of online services for organizing in-person, distance (in synchronous and asynchronous modes), and blended learning with new resources, including neural networks, which are currently rapidly developing.

Author Contributions:

Conceptualization: S. Skvortsova.

Data curation: T. Britskan.

Formal analysis: S. Skvortsova, K. Hnezdilova.

Investigation: S. Skvortsova, T. Britskan.

Methodology: S. Skvortsova.

Project administration: R. Romanyshyn.

Supervision: R. Romanyshyn.

Validation: K. Hnezdilova.

Visualization: K. Hnezdilova.

Writing – original draft: T. Symonenko.

Writing – review & editing: T. Symonenko.

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Svitlana Skvortsova, Doctor of Pedagogical Sciences, Professor, Corresponding Member of the National Academy of Pedagogical Sciences of Ukraine, Professor of the Department of Mathematics and its Teaching Methods, The State Institution “South Ukrainian National Pedagogical University named after K.D. Ushynsky”, Odesa, Ukraine;
ORCID ID: 0000-0003-4047-1301

Address: The State Institution “South Ukrainian National Pedagogical University named after K.D. Ushynsky”, 26, Staroportofrankivska St., Odesa, 65020, Ukraine.

E-mail: Skvortsova.SO@pdpu.edu.ua

Tetiana Britskan, PhD, Senior Lecturer of the Department of Preschool and Primary Education, Izmail State University of Humanities, Izmail, Ukraine;

ORCID ID: 0000-0001-7277-4169

Address: 12, Repina str, Izmail, 68610, Ukraine

E-mail: britskan@idgu.edu.ua

Tetyana Symonenko, Doctor of Pedagogical Sciences, Professor, Professor of the Department of Teaching Methods, Stylistics and Culture of the Ukrainian Language at Bogdan Khmelnytsky National University of Cherkasy, Research Professor at WU Universität (Wien), Director of the Center of Ukrainian Researchers in Austria, Vienna, Austria;

ORCID ID: 0000-0001-5963-0451

Address: Bogdan Khmelnytsky National University of Cherkasy, 81 Shevchenko Boulevard, Cherkasy, 18000, Ukraine.

E-mail: irinka200888@vu.cdu.edu.ua

Kira Hnezdilova, Doctor of Pedagogical Sciences, Professor, Professor of the Department of Primary and Special Education, Bogdan Khmelnytsky National University of Cherkasy, Cherkasy, Ukraine;

ORCID ID: 0000-0002-5226-840X

Address: Bogdan Khmelnytsky National University of Cherkasy, 81 Shevchenko Boulevard, Cherkasy, 18000, Ukraine

E-mail: kiiirra@vu.cdu.edu.ua

Ruslana Romanyshyn, Doctor of Pedagogical Sciences, Professor, Head of the Department of Primary Education and Educational Innovations, Vasyl Stefanyk Carpathian National University, Ukraine;

ORCID ID: 0000-0001-8480-2702

Address: Vasyl Stefanyk Carpathian National University, 57 Shevchenko Str., Ivano-Frankivsk, 76018, Ukraine.

E-mail: ruslana.romanyshyn@cnu.edu.ua

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Скворцова Світлана, Бріцкан Тетяна, Симоненко Тетяна, Гнезділова Кіра, Романишин Руслана. Комплекс онлайн-сервісів для організації очного, дистанційного і змішаного навчання. *Журнал Прикарпатського університету імені Василя Стефаника*, 13 (3) (2026), 73-92.

У статті презентовано результати дослідження проблеми використання ІКТ, зокрема онлайн-сервісів, у професійній діяльності вчителя початкової школи, яке тривало з 2018 року по 2024 рік. Врахувавши уподобання учителів початкової школи, що були з'ясовані в результаті лонгітюдного дослідження (2019-2022 рр.), розроблено відкритий комплекс онлайн-сервісів для організації очного, дистанційного (у синхронному й асинхронному режимі) і змішаного навчання: I група – сервіси для створення навчального інтерактивного контенту (А. Сервіси для створення інтерактивних вправ; Б. Сервіси для створення інтерактивного відео; В. Сервіси для створення віртуальних дошок; Г. Сервіси-інтерактивні симулятори); II група – сервіси для організації та проведення онлайн-уроку; III група - сервіси для створення віртуального класу та електронного журналу. З огляду на зміст професійної діяльності вчителя для реалізації трудової функції А (за професійним стандартом вчителя), розроблений комплекс містить сервіси, за допомогою яких учитель може або використовувати готові, або створювати власні засоби навчання на основі ІКТ. Виходячи з того, що даний комплекс є відкритим, а тому складники кожної з груп можуть змінюватись, в статті подано систему вимог щодо відбору онлайн-сервісів. Розроблений комплекс впроваджено в практику підготовки майбутніх учителів початкової школи під час педагогічного експерименту на базі ДЗ «Південноукраїнський національний педагогічний університет ім. К.Д. Ушинського», Ізмаїльського державного гуманітарного університету та Черкаського національного університету імені Богдана Хмельницького. Результати педагогічного експерименту свідчать про ефективність розробленого комплексу онлайн-сервісів, який є змістом підготовки майбутніх учителів початкової школи до застосування ІКТ у навчанні молодших школярів предметів (інтегрованих курсів). Наукова новизна дослідження полягає в розробці гнучкого, критеріального підходу до вибору онлайн-сервісів, які можна адаптувати до змін у цифровому освітньому середовищі. Результати мають практичне значення для навчальних закладів педагогічної освіти та програм професійного розвитку, оскільки вони надають методичні рекомендації щодо інтеграції ІКТ у початкову освіту та можуть слугувати основою для подальших досліджень щодо підвищення цифрової компетентності вчителів.

Ключові слова: ІКТ, комплекс онлайн-сервісів, учитель початкової школи, професійна діяльність, навчальний інтерактивний контент.