Developing the Professional Competence of Future Chemistry Teachers through Digital Technologies: A Case Study of Kazakhstan

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***Abstract*—Developing professional competence among future teachers is a key aspect of the modern education system, especially in the context of the rapid advancement of digital technologies. Since the early 1990s, the European Union has paid special attention to the education and training of highly qualified educators capable of effectively utilizing modern teaching methods. The report "Europe and the Global Information Society" emphasized the need for integrating new technologies into the educational process. This research project focuses on a relatively unexplored area—the use of digital technologies to develop future chemistry teachers' competencies in Kazakhstan. The research aims to enhance understanding of the effective application of digital technologies in chemistry education and provide practical recommendations to improve the quality of education. The study utilized various methods, including theoretical analysis, online surveys, modeling, experiments, and the analysis of test results. Survey results among students confirmed the importance of using digital technologies to develop the professional competence of future chemistry teachers. A pedagogical experiment using digital technologies revealed the effectiveness of educational and methodological support specifically designed to enhance the professional skills of future chemistry teachers. Monitoring results indicated a significant increase in the professional competence of experiment participants. These findings are crucial for the developing curriculum aimed at preparing future chemistry teachers and contribute to the improvement of education quality in this field. The conclusions drawn can be used to further enhance teaching methods in chemistry using digital technologies in Kazakhstan and other countries.**

***Keywords*—professional competence, information technologies, digital literacy, game-based learning technology, level-based learning technology, virtual laboratory**

I. Introduction

In recent decades, Information and Communication Technologies (ICT) have brought significant changes to the social, economic, and cultural spheres of society, substantially improving the quality of life and the dynamics of societal development. An integral part of this process is the field of education, where ICT can significantly impact the formation of professional competencies for future educators. In this context, since 1993, the European Union has actively advocated for the need to train and enhance the level of ICT literacy among teachers, as emphasized in the report "Europe and the Global Information Society" [1].

To meet the growing demands for digital literacy among citizens and improve educational systems, the European Commission adopted the "Europe 2020" strategy in 2010. This strategy is aimed at addressing Europe's key priorities in the areas of economy, knowledge, and innovation. One fundamental aspect of the strategy is ensuring the presence of well-prepared teachers capable of adapting to new teaching methods and effectively using ICT to enhance learning outcomes and student employability [2].

Two recent initiatives undertaken by the European Commission, "Rethinking Education" and "Opening up Education," underscore the importance of having well-prepared, motivated, and entrepreneurial teachers [2]. In this context, it is crucial not only to improve the educational level of teachers but also to integrate pedagogy and technology [3, 4].

Despite the importance of professional development, it is also necessary to ensure technological competence among the teaching staff [5]. In this context, the significance of continuous development of professional competence in the training of future teachers is increasing. However, despite a considerable volume of research dedicated to the digital competence of teachers, issues related to the effective use of educational technologies in teacher training require further exploration [5–9].

In this context, our article aims to justify possible ways of using digital technologies to enhance the competencies of future chemistry teachers' modern education settings. The professional competence of future teachers, including the ability to effectively utilize digital technologies in the educational process, is a key aspect of this research. The goal of our study is to contribute to understanding the effectiveness of incorporating digital technologies in the training of future chemistry teachers and developing specific strategies to enhance the quality of their education. To achieve this goal, tasks were outlined, including exploring the potential of digital technologies, assessing the level of professional competence, creating educational materials, and conducting an experiment to evaluate the effectiveness of digital technologies in the professional training of future chemistry teachers. The results of this study can provide insight into the effectiveness of utilizing digital technologies in the preparation of chemistry teachers and will make a

significant contribution to the current discourse on the development of professional competence in education [10–17].

II. Literature Review

In recent years, Information and Communication Technologies (ICT) have significantly influenced social, economic, and cultural changes in society, leading to an improvement in the quality of life for individuals and communities. However, the potential of ICT in education is still evolving. The scientific literature review on this topic encompasses a range of studies, articles, and publications examining various aspects of developing the professional competence of future chemistry teachers through the use of digital technologies, with a focus on the context of Kazakhstan.

Shagataeva *et al.* [18] provided an analysis of the integration of digital technologies into the chemistry education system in Kazakhstan. The authors emphasized the impact of using virtual laboratories, electronic textbooks, and other digital resources on the development of the competence of future chemistry teachers. At the same time, Salimzyanova *et al*. [19] explored challenges and opportunities for preparing chemistry teachers in Kazakhstan in the digital age. They analyzed the current state and proposed strategies for the effective use of digital technologies in the professional training of future teachers. Some later Ergashovich [20] aimed to identify the perspectives of using digital technologies in chemistry education in Kazakhstan. The author conducted surveys of chemistry students, revealing their opinions on the role of digital technologies in developing their professional competence. Moreover, Trenova *et al.* [21] focused on developing competencies for chemistry teachers in the digital era, drawing from the experience in Kazakhstan. The authors analyzed the effectiveness of using digital technologies in teaching chemistry and their impact on the preparation of future teachers.

Abdigapbarova and Zhiyenbayeva [22] discussed innovative approaches to chemistry education in Kazakhstan with an emphasis on the use of digital technologies. They highlighted the role of digital resources in developing key competencies for chemistry teachers.

Furthermore, it is crucial for future teachers to have a clear understanding of concepts such as professionalism, professional culture, and professional identity, which can be incorporated into a broader understanding of professional competence. It is expected that a modern teacher will possess a range of qualities, including generosity, professional mastery, self-improvement, theoretical knowledge, practical skills, and a positive cultural outlook. Professional competence is a vital component of effective teaching and is defined as a combination of knowledge, skills, abilities, beliefs, and moral values [23–25]. Then Struyven and Meyst in their systematic review [26] found that professional competencies are often grouped as "professional/technical knowledge", "subjective competencies", "pedagogical competencies", "skills", or "attitudes". Voogt *et al*. [27] proposed a broader definition of professional competence that includes not only the knowledge and skills necessary for effective classroom teaching but also the ability to interact and collaborate with colleagues within and beyond the school community. Additionally, ethical commitments contribute to student learning and professional growth. They emphasized that achieving professional competence is a lifelong process that begins with Initial Teacher Education (ITE). Bennett *et al*. [28] noted that professional competence is a complex concept encompassing various aspects of teaching, and Ivannikova *et al*. [29] suggested that additional research is needed to understand the developmental trajectories of different aspects of teacher competence.

Many researchers have proposed components and criteria for assessing the level of professional competence of future teachers. For instance, studies by Krumsvik [30, 31] and Kay [32] indicated that subject matter knowledge is a fundamental component in assessing the professional competence of chemistry teachers. They included knowledge of fundamental concepts, theories, and principles of chemistry, as well as the ability to apply them in practice. The assessment of students' learning achievements is also highlighted as crucial in evaluating the professional competence of chemistry teachers. This criterion involves the ability to develop and conduct assessment tasks and analyze assessment results to enhance the teaching process.

Also, it should be noted that Ferrari [33] emphasized the importance of an orientation component in the use of modern teaching methods. This component includes the ability to use research and problem-solving teaching methods, as well as employing modern technologies to enhance the teaching process. Krumsvik [34] underscored the importance of considering chemistry teachers' ability to reflect and self-assess for evaluating their professional competence. This criterion involves the ability to analyze one's work and the teaching process, identify strengths and weaknesses, and develop strategies for professional improvement. Generally, the concept of pedagogical digital competence was introduced by Krumsvik *et al*. [35] as a set of skills, abilities, and perspectives that teachers should possess for the effective integration of digital technologies into their practice and professional development. Additionally, Mutekwe [36] noted that digital competence requires both technological knowledge and didactic application. Therefore, a teacher's digital competence includes the responsibility not only to develop their own digital competence but also to contribute to the development of digital competence among their students [37].

Similarly, United Nations Educational, Scientific and Cultural Organisation (UNESCO) [38] has developed its own dimensions, indicators, and levels to measure the development of teachers' digital competence. Recognizing digital competence as an essential set of skills reflects the importance of technology in contemporary society and education. Teachers who are competent in digital technologies can better prepare their students to navigate and succeed in the digital age.

Therefore, it is crucial to develop the digital competence of future teachers, and there are numerous ways to teach digital literacy, which is the first step in this direction. However, the authors emphasize that it is essential not only to focus on technical skills but also to cultivate innovative thinking and

creativity in the digital environment. For instance, International Society for Technology in Education [39] suggested employing a gamified approach in teaching digital literacy to enhance students' skills with various digital tools and stimulate their creative thinking.

Some researchers also indicates that the use of gaming technologies can be an effective method for teaching digital literacy. For example, in the study of Lund *et al*. [40], the use of gaming simulations helped students improve their digital literacy and critical thinking skills. In another study by Instefjord and Munthe [41], the use of gaming technologies aided students in developing communication and collaboration skills.

Another crucial aspect of effective digital literacy education is the use of a personalized approach to teaching, considering the individual needs and interests of students. For instance, Rohman and Sajo [42] used personalized learning to help students enhance their digital literacy skills and increase motivation for learning.

In conclusion, it is important to note that effective education in digital literacy should also include teaching ethical behavior in the digital environment. This involves providing educational materials and practices related to data privacy, digital violence, and other ethical issues associated with the use of digital technologies [43–48].

III. Research Background

The development of professional competence among future chemistry teachers is a significant undertaking, given the complexity and unique characteristics of this discipline. Understanding fundamental research and concepts, is crucial, making the development of professional skills paramount. In the field of chemistry, a deep understanding and application of modern teaching methods are necessary. This development allows teachers to effectively convey knowledge and inspire students, generating interest in a challenging subject [49, 50]. This, in turn, contributes to progress in science, industry, and society as a whole. Therefore, ensuring a high level of education in chemistry and shaping successful professionals in this field places the development of professional competence among future chemistry teachers as an essential and critical task [51].

Analytical chemistry, as one of the key areas in the field of chemistry, holds strategic importance in various research and production areas. This scientific field involves the development and study of analytical methods, as well as the creation of new approaches to determine the composition and properties of substances. The role of analytical chemistry extends to pharmaceuticals, the food industry, medical diagnostics, environmental science, and other significant areas of research and production.

Currently, analytical chemistry is included in the curriculum for students in grades 8–11 according to updated standards. The curriculum consists of laboratory sessions and practical assignments covering both qualitative and quantitative courses. Despite the importance of integrating analytical chemistry into the educational process, it is crucial to focus on effective teaching methods and create a motivational environment to stimulate students' interest in the subject. Therefore, developing of the professional competence of future chemistry teachers in the field of analytical chemistry becomes a critical factor in ensuring high-quality education and the formation of qualified professionals.

In higher education institutions, analytical chemistry is taught to second-year students, covering sections such as "Qualitative Analysis" and "Quantitative Analysis." The course includes lectures, practical sessions, and laboratory work, providing students with the necessary knowledge and practical skills to work with modern analytical methods. However, challenges may arise in teaching qualitative analysis due to the duration and complexity of laboratory work, as well as a shortage of reagents and equipment. Addressing these issues involves the use of modern teaching methods, including virtual laboratories, and ensuring access to contemporary technologies and equipment. This not only aids in understanding the theoretical concepts of analytical chemistry but also develops skills in working with modern technologies. Additionally, a focus on group projects and assignments contributes to the development of teamwork skills, which is a key aspect of preparing future professionals in the field of analytical chemistry [52].

IV. Research Methods

With the aim of enhancing the professional competence of future chemistry teachers through digital technologies, an electronic textbook on the topic of "Qualitative Analysis" in analytical chemistry was developed and tested (see Fig. 1). This tool not only deepens students' knowledge but also enhances their digital competence by integrating modern technologies into the learning process. The electronic textbook, aligned with the curriculum, includes lectures, practical sessions, and laboratory work, providing numerous self-study assignments, including quizzes, reports, and test tasks.

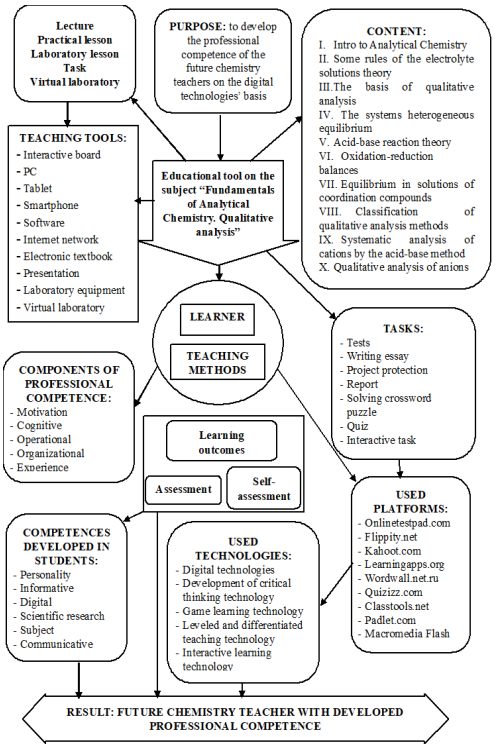

Fig. 1. Electronic textbook model developed for the subject "Analytical Chemistry".

Additionally, to improve students' knowledge and skills, a methodology for conducting practical sessions using "competitive gaming" and "differentiated learning levels" technologies is proposed. This approach aligns with the principles of developmental and level-differentiated learning, fostering innovative thinking, creativity, critical thinking, and digital literacy. Moreover, at the conclusion of each lecture, assignments utilizing digital technologies are given for independent completion to further enhance students digital competence [53].

A self-assessment methodology was employed for the electronic textbook, where students received scores based on their performance level in each task. This approach not only allows for assessment but also fosters the development of students' professional competence, building the necessary skills to apply acquired knowledge in their future professional endeavors. Thus, the creation of this electronic textbook using digital technologies contributes to the improvement of education quality, provides an effective and interactive learning process, and facilitates the development of the professional competence of future chemistry teachers [54].

In the academic year 2021–2022, a descriptive experiment was conducted at the South Kazakhstan State Pedagogical University. An online survey was administered among students of the Chemistry Faculty specializing in Chemistry Education and Chemistry-Biology Education. The aim was to assess the level of development of both professional and digital competencies among future chemistry teachers. Google Forms was utilized to survey 121 students, providing both qualitative and quantitative data for analysis (refer to Fig. 2). The survey link is provided below: (https://forms.gle/1RCvvsK5cb7PjBnVA).

Fig. 2 reveals the distribution of responses provided by respondents to each question as follows:

- Question 1: 68.6% of respondents indicated a need for further learning and improvement, while 31.4% expressed complete confidence in their professional competence.
- Question 2: Responses were categorized as 7.4% low, 60.3% medium, and 32.2% high regarding confidence levels.
- Question 3: The majority, constituting 82.6% of respondents, affirmed belief in the efficacy of digital technologies for enhancing the learning process. Conversely, 7.5% favored traditional teaching methods, and 9.9% expressed openness to employing any effective teaching method.
- Question 4: Frequency of technology utilization varied among respondents, with 22.3% reporting daily usage, 44.6% a few times a week, 24.8% once a week, 4.2% rarely, and 3.1% never.
- Question 5: Perceived benefits of technology included increasing the availability and variety of educational materials (38%), fostering active student participation (28.1%), improving interaction and communication between teachers and students (20.7%), and enhancing the level of understanding and memorization of material (13.2%).

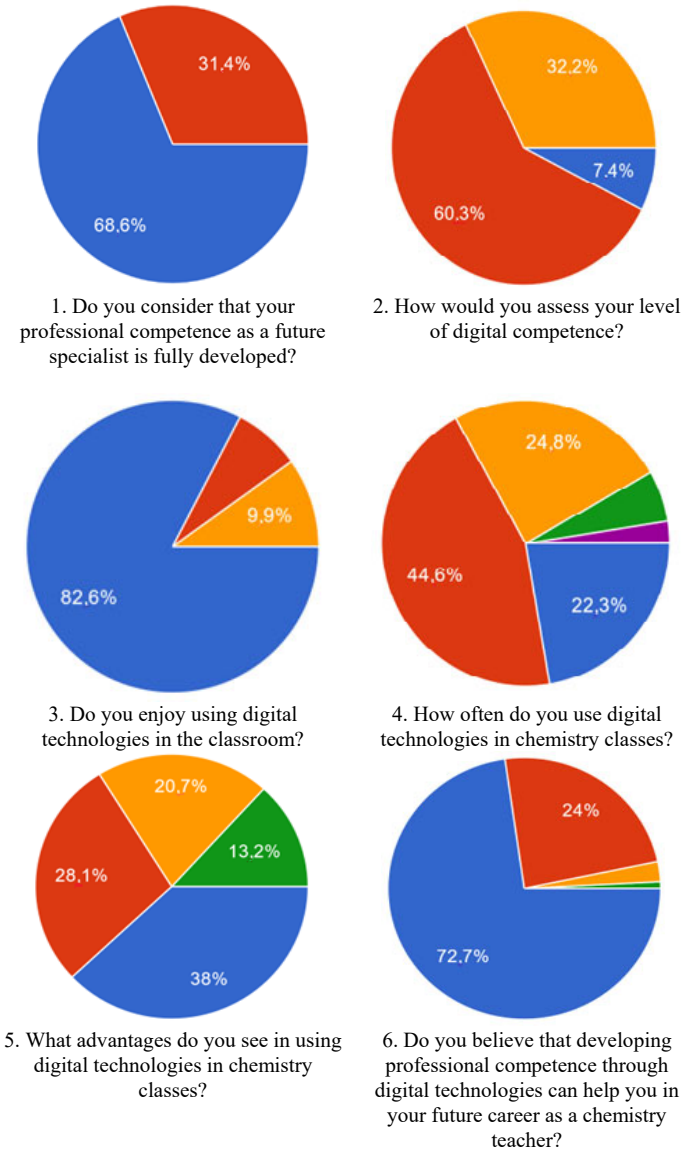

Fig. 2. Qualitative and quantitative analysis of the survey.

In the analysis of open-ended questions in the online survey, the following observations can be highlighted: 51.24% of participating students identified "professional skills" as important factors for successful work in the profession. They described the need for knowledge, experience, personal qualities, and skills for effective work in the professional field. 27.27% of respondents noted "fulfillment of professional tasks" as an important factor, describing the need for knowledge and skills for the successful completion of professional tasks. Thus, students demonstrated a correct understanding of professional skills.

In response to the question about the difficulties students face when transitioning from school to university, 62.81% pointed out difficulties in using new educational technologies and highlighted challenges related to the seamless use of digital technologies. During the survey, 26.44% of participants mentioned using mobile applications and various platforms, while 17.4% preferred virtual laboratories. Others most commonly mentioned presentation programs (such as PowerPoint) and interactive boards. The survey also showed that students rarely use various types of digital technologies to enhance their motivation and create a stimulating educational environment

For future chemistry teachers, it is crucial to develop not only their professional skills but also their digital literacy. To achieve this, it is necessary to introduce new teaching methods, actively use digital technologies in the educational process, teach students to use digital tools, and effectively integrate them into the educational process. Survey results indicate that digital technologies can become a significant element of the professional development of future chemistry teachers, and their use has a substantial impact on the quality of education and training [55].

In the first semester of the 2022–2023 academic year, a pedagogical-experimental study was conducted to assess the professional competence of future chemistry teachers according to specific criteria and to determine the effectiveness of the educational and methodological support prepared using digital technologies. The research involved students from the 2nd year of the South Kazakhstan Pedagogical University, specializing in chemistry and biology education. The experimental group consisted of students in the chemistry teacher specialty, while the control group comprised students in the chemistry-biology teacher specialty. There were 26 students in the experimental group and 25 students in the control group. One practical session on "Heterogeneous Equilibrium in Analytical Chemistry" was conducted in the experimental group, which was structured as a game-competition. Before the game, the student group was divided into subgroups using a generator on the classtools.net platform. By accessing the link https://www.classtools.net/random-name-picker/ and clicking the "edit" button, the names of the student group were recorded. The generator was activated to randomly assign student to different groups. This game consisted of three rounds, with points awarded for Tasks I, II, III of each round. All tasks were displayed on an interactive board and the group with the highest number of points at the end was declared the winner. Prizes were awarded to students in the winning group (Table 1).

Table 1. The content of the practical session organized in the form of a game competition

I Round—Quiz	II Round—Intellectual Competition "Leader of the 21st Century"	III Round—Test Tasks
In the first round, using the "random round" method on the wordwall.net platform, questions were presented, and students responded. A link was provided for their answers.	In this round, the online platform flippity.net was utilized for interactive intellectual tasks. Flippity.net promotes a deeper understanding of the study material, enhances motivation for learning, ensures long-term retention of knowledge, and reduces the time spent on education.	In the third round, multiple-choice test questions were presented, prepared using the Google test platform on google.com. This allows for the assessment of individual abilities and knowledge of each learner.
https://wordwall.net/ru/resource/52763462	https://www.flippity.net/qs.php?k=1O9VcTh7DzkpgMnseV69fNubQJWfB_VTiEllpx-V4dZo	https://forms.gle/sM87EjGATdwZ6mk66
According to the game rules, two groups took turns answering questions within a specified time frame by spinning a drum. The answer to a question was removed by clicking the "Remove" button. If one group couldn't answer, the next group provided their answer. 5 points were awarded for each correct answer, and at the end of the game, the scores were tallied.	According to the rules of the game, each group took turns selecting windows for 100, 200, 300, 400, and 500 points, revealing the topic of the question. The difficulty of the question was proportional to the number of points awarded for a correct answer. Each group answered the questions shown in the selected window, and if unable to answer, the next group had the opportunity to respond, with the points transferred to the answering group. After answering, the window was closed, and the correctness of the answer was checked. The points for each group were recorded. At the end of the game, the winning team was determined based on the total points earned.	Google Test provides an opportunity for additional testing, and at the end, each student can review their scores and correct answers. Thus, after taking the test, students can continue their work, retaining the provided material and enhancing their knowledge. To achieve a high score, it is necessary to thoroughly study the provided topics and prepare for them with due attention.

Following one of the experimental lessons (Table 1), testing was conducted with 8 students. Fig. 3 shows the test results.

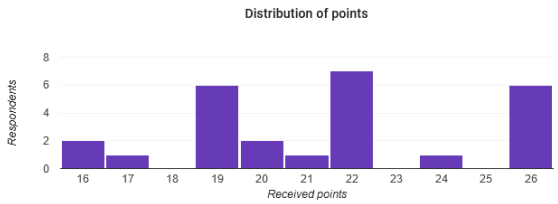

Fig. 3. Test results obtained at the conclusion of the lesson.

In Fig. 3, it is evident that satisfactory responses were given to 21.46 out of 26 points, with the median score obtained being 22 out of 26.

At the conclusion of this experimental lesson, Padlet was utilized for students to provide feedback. The teacher, who is registered on the Padlet.com platform, sends the link to the students. The Padlet board can be accessed on an interactive board, and each student can join using their smartphone via the link sent by the teacher to openly share their impressions of the lesson. To receive feedback on this lesson, the Padlet board is displayed on the interactive board at this link: https://padlet.com/aliyakarmanova/padlet-p7hodh9msfgbdlow). Students can also express their thoughts on the Padlet board by following this link All student communication can be viewed on the Padlet board.

Furthermore, an image has been provided representing a virtual laboratory showcasing reactions of cations from the fifth analytical class (Fig. 4). To access the virtual laboratory, press and hold the "Ctrl" key and click on the image.

This virtual experiment is presented in a non-animated form; students perform it manually with the help of prompts. This approach helps to maintain the flow of the work and understand the characteristics of cations and reactions.

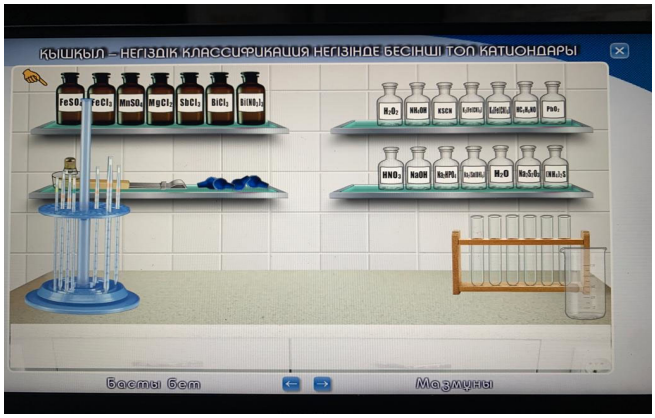

Fig. 4. Virtual laboratory of qualitative reactions of cations from the fifth analytical group.

V. Results and Discussions

An assessment of the professional competence of future teachers was conducted before and after the experiment, based on specific criteria. The results of the assessment are presented in Table 2.

Table 2. The Results of before and after experimental monitoring of future chemistry teachers (by levels)

The level of professional competence of future chemistry teachers	Control group				Experimental group			
	Before the experiment		After the experiment		Before the experiment		After the experiment	
	n=25	%	n=25	%	n=26	%	n=26	%
High	5	20%	8	32%	6	23.08%	15	57.69%
Medium	18	72%	16	64%	17	65.38%	11	42.31%
Low	2	8%	1	4%	3	11.54%	0	0

From the analysis of the presented data, it can be concluded that the pedagogical experiment significantly influenced the level of professional competence of future chemistry teachers in both research groups. The experimental group demonstrated a significant increase in the proportion of participants with a high level of competence, rising from 23.08% to 57.69% after the experiment. In the control group, there was also an increase in this indicator from 20% to 32%, but not as significant as in the experimental group. Both groups showed a decrease in the proportion of participants with a low level of competence, indicating the positive impact of the pedagogical experiment on the overall level of competence. These results confirm the effectiveness of educational and methodological support developed using digital technologies in enhancing the professional competence of future chemistry teachers.

The analysis of the research results allowed us to assess the impact of digital technologies on the development of the professional competence of future chemistry teachers and identify their advantages and limitations in an educational context. This study enables us to identify specific aspects where digital technologies can be effective, such as interactive electronic resources, virtual laboratories, modeling, and other tools [55, 56].

Currently, Kazakhstan's education system encompasses all levels of learning, from preschool to higher education. The Ministry of Education and Science of Kazakhstan regulates the educational process and develops curriculum standards, aiming to align with international educational standards. In recent years, there has been a focus on the development of Science, Technology, Engineering, and Mathematics (STEM) education to prepare students for modern challenges and labor market demands. Education reforms aim to improve the quality of teaching, introduce modern teaching methodologies, and integrate digital technologies into the learning process. However, challenges such as insufficient funding, uneven distribution of educational resources between urban and rural areas, and the need to train highly qualified teachers capable of effectively implementing innovative teaching methods persist. Overall, Kazakhstan is striving to develop a modern and high-quality educational system capable of providing students with all the necessary knowledge and skills for successful careers and personal development [56].

The obtained data can serve as a foundation for further development of instructional materials using digital technologies and adapting the educational program to the needs of learners. Exploring the potential of digital technologies for the development of professional competence in future chemistry teachers has allowed us to determine their potential and impact on teaching quality.

The research results confirm the effectiveness of digital technologies in the educational process, particularly in the realm of chemical education. This highlights the importance of incorporating digital technologies into upcoming chemistry teacher training programs to improve the quality of student education and cultivate their professional skills. As a result, it is essential to study and comprehend the potential of digital technologies as vital components in the enhancement and development of educational programs for future chemistry teachers. By analyzing the results and data gathered, effective methods can be identified to enhance students' professional competence and utilize digital technologies in the educational setting.

The development and provision of educational and methodological support through the use of digital technologies have contributed to enhancing of the professional competence of future chemistry teachers. The electronic textbook used in the experimental group had a positive impact on educational outcomes and the overall quality of education. The experiment enabled the assessment of the effectiveness of instructional materials developed with the use of digital technologies. The experimental group, which utilized digital technologies, achieved higher results compared to the control group. This indicates the positive influence of digital technologies on the development of professional skills and knowledge among future chemistry teachers.

The analysis of the research results confirms the importance of using digital technologies in preparing future chemistry teachers. Their use contributes to improving the quality of education and developing students' professional competence. Therefore, the article describes the development and implementation of an electronic textbook using digital technologies, as well as an experiment to assess its effectiveness. The results obtained show the positive impact of digital technologies on the development of the professional competence of future chemistry teachers.

VI. Conclusion

In conclusion, this research highlights the importance of integrating digital technologies into the education of future chemistry teachers. The observations and analysis results confirm that the use of interactive electronic resources, virtual laboratories, and other digital tools in the educational process contributes to the effective development of students' professional competencies. Digital technologies not only enhance the learning process but also contribute to improving the quality of education, adapting to the needs of modern learners. The importance of aspects such as interactivity, accessibility, and multifunctionality of digital tools for creating a more effective educational experience is emphasized. These research findings provide a foundation for integrating of digital technologies into educational programs for future chemistry teachers. They underscore the relevance and necessity of continuously refining educational methodologies, and striving to create innovative and technologically advanced pedagogical practices.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Aliya Karmanova conducted the research by developing the training model, research instruments, collecting data, and writing the paper. Others can be written to provide scientific input and suggestions for the collection and analysis of data during and after the survey and also interpret the results. All authors have approved the final version.

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