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DEVELOPMENT AND IMPLEMENTATION OF AN ONLINE CHEMISTRY COURSE: ADVANTAGES, CHALLENGES AND EXPERIMENTAL RESULTS

Abstract. The article explores issues related to the use of electronic educational resources (EER) in the educational process, with a particular focus on the study of Chemistry. It presents an analysis of both Ukrainian and international experiences in utilizing EER for organizing distance learning. The findings indicate that electronic educational resources create learning conditions in which students, through the use of digital technologies, become active participants in events and processes, fully interacting with a learning environment that simulates real-world objects and processes. The authors examine the specific features of developing and using an online course to study Chemistry in vocational education institutions. Such a course allows the integration of various electronic resources into a single platform, providing visualization and interactivity in learning a subject that is often challenging for students, as is the case with Chemistry. The article describes the experience of creating an online Chemistry course, detailing the algorithm for its design and course structure. Examples of educational materials, assignments, and the services used for their development are provided. This online course offers several didactic opportunities, such as the ability to dynamically update content, methods, tools, and training formats, demonstrate laboratory experiments, analyze virtual experiments and observations, and implement various types of knowledge assessment for students. The use of an electronic course meets the educational needs of modern students. The article also analyzes the results of initial and final surveys conducted among vocational and technical educational institution students who participated in the study and used the online course to learn chemistry. The analysis of initial survey results revealed that traditional textbooks were considered unengaging and lacking interactivity, whereas post-experiment surveys indicated that most students found the online course more interesting. The analysis of students' academic achievements showed positive progress in mastering the educational material. The main advantages and identified shortcomings of the online course are also discussed.

Keywords: electronic educational resources; ICT in education; online course; chemistry education; vocational and technical education institutions.

1. INTRODUCTION

The task of modern education is to form a holistic system of universal knowledge, skills, and abilities, as well as experience in independent activities and personal responsibility among students, which determines the quality of educational content. However, improving the quality of education should not be achieved by increasing the burden on students but through the enhancement of teaching forms and methods, the selection of educational content, and the implementation of new educational technologies that focus not on the transmission of readymade knowledge but on the development of a complex of personal qualities in students. One of the conditions for improving the education system is the organization and implementation of innovative activities in pedagogical practice aimed at ensuring the efficiency and quality of education. The goal of innovative activities in education is to ensure high-quality education and the development of a pedagogical system that meets the demands of the times and the needs of society. The implementation of innovative technologies enables the achievement of these goals through the application of the latest methods and approaches to teaching, the use of modern digital technologies, and the development of a creative approach to the education and upbringing of youth.

One of the innovations of modern education is the process of digitalization. According to the Regulation "On Electronic Educational Resources" [1], electronic educational resources (EER) are an integral part of the educational process, have educational and methodological purposes, and are used to support the learning activities of students. They are considered one of the main elements of the information-educational environment. EERs gained particular significance in Ukraine during the period of distance learning, initially prompted by the COVID-19 pandemic and subsequently by military actions. As a result, all levels of education – from preschool, school, and vocational and technical education institutions to higher education – face challenges in organizing learning under these conditions, ensuring the quality of education, and maintaining the interest of learners. This problem is especially acute in the Natural Sciences, particularly in the study of Chemistry, including in vocational and technical education institutions.

The state of students' cognitive motivation for mastering academic subjects, particularly Chemistry, and for conscious professional self-determination can be enhanced through the proper organization of the educational environment during online or blended learning and the use of highly interactive information technologies in the educational process. Such information technologies include electronic educational resources, which create learning conditions where students, through the use of computers, become direct participants in events and processes, fully interacting with a learning environment that models real-world objects and processes.

Analysis of recent studies and publications. In recent years, the issue of using ICT in education has become one of the most relevant topics in both domestic and international scientific literature [2, 3, 4, 5, 6, 7], as digital technologies support and expand a number of important directions and functions of education:

- expand the possibilities for collecting, storing, transmitting, transforming, and analyzing diverse information;
- increase the accessibility of education and the variety of educational formats;
- ensure the continuity of education throughout life;
- promote the development of personalized learning;
- contribute to the improvement of the organizational support of the educational process;
- enhance the activity of participants in organizing the educational process;
- facilitate the creation of a unified information-educational environment;
- ensure the independence of the educational process from place and time of learning;
- provide opportunities for choosing an individual learning trajectory;
- foster the development of independent research activities and more.

The actual state of the problem, which is associated with the use of digital tools by teachers for the organization and implementation of distance learning in Ukraine, is substantiated by researchers in the works [8, 9]. The concept of electronic educational resources has been considered in a number of works, including those by M. Tukalo, S, Lytvynova, V. Bykov and O. Melnyk [10, 11, 12].

According to [1], electronic educational resources (EER) are educational, scientific, informational, and reference materials and tools developed in electronic form and presented on any type of media or hosted on computer networks. They are reproduced using electronic digital technologies and are essential for the effective organization of the educational process, particularly in terms of providing high-quality educational and methodological materials. These resources include educational films, audio recordings, video demonstrations, and modern next-generation educational resources that feature well-structured nonlinear navigation systems in the form of hypertext and consist of visual or auditory fragments. Educational materials are presented through various methods, including graphics, photos, videos, animations, and sound.

A distinctive feature of these resources is the incorporation of cutting-edge pedagogical tools such as interactivity, multimedia, modelling, communicativeness, and productivity. Interactivity fosters active learning forms by presenting subject matter through manipulable learning objects and processes that students can engage with independently. Multimedia allows for the representation of learning objects in various ways – through graphics, photos, videos, animations, and sound – providing a realistic presentation of objects and processes. Modeling simulates reactions typical of the study of objects and processes being studied.

Communicativeness facilitates direct interaction, timely provision of information, and rapid access to educational resources available online. Productivity enhances the speed of information retrieval and increases the effectiveness of educational activities. Next-generation educational resources, which constitute the information-technology component, are open modular multimedia systems composed of three types of electronic modules: informational, practical, and testing. The modularity of these modern educational resources allows for the utilization of new pedagogical technologies and enables educators to create custom instructional courses and individualized learning trajectories for students.

Researchers have explored various aspects of using electronic educational resources in the study of chemistry. For instance, in the work [13], the formation of natural science competence during the study of Chemistry with the help of ICT is argued. The study emphasizes using ICT tools such as educational modelling resources, software-methodical complexes, and virtual Chemical laboratories capable of simulating chemical phenomena and processes. The article examines multimedia software-methodical tools used in high school Chemistry lessons to visually represent atomic structures, electronic shells, molecular composition and spatial structures, as well as chemical properties and methods of substance production. The authors [14, 15] have analyzed the directions for using digital resources in Chemistry classes, describing the capabilities and advantages of various online tools for effectively acquiring knowledge in Chemistry. The works by [16, 17, 18] examine the theoretical and practical aspects of using augmented and virtual [19] reality in Chemistry education. Additionally, the use of smartphones and mobile applications in Chemistry learning has been discussed in [20, 21].

Particular attention should be given to the characteristics of Chemistry as a science. One of the reasons students find Chemistry to be a challenging subject is that it requires them to rapidly transition between different levels of abstraction: the macroscopic level (experiments and observations), the submicroscopic level (electrons, atoms, and molecules), and the symbolic level (formulas, equations, and computer models) – the idea that underlies Johnstone's famous chemical triple [14]. Visualization is crucial for addressing this issue. Attempting to visualize three-dimensional molecules and reactions can be pretty complex, but it is essential for understanding molecular structure, stereochemical features, and reaction mechanisms.

The research goal. Creating a holistic online course for studying Chemistry allows for integrating various electronic resources in one place, providing both visualization and interactivity [22, 23]. However, as the analysis of scientific literature reveals, while considerable attention has been given to the study of individual educational resources, there is a lack of focus on creating and utilizing integrated online courses for studying Chemistry that combine various online services, including in vocational and technical education institution.

Given the prospects for development in Ukraine, the use of electronic courses in the educational process is increasing. This growth enhances students' acquisition of essential knowledge, strengthens social interaction mechanisms among all participants in the educational process, and creates an information-communication environment. Therefore, the aim of our work was to conduct a comprehensive study of the development and implementation of an online Chemistry course in a vocational and technical education institution, as well as to identify its advantages and disadvantages.

2. RESEARCH METHODOLOGY

The study presents the results of developing an online course in Chemistry and its use in the educational process. The following methods were used in the study.

An examination and synthesis of pedagogical experience and scientific-pedagogical literature on the use of electronic educational resources in the educational process were conducted to understand the problem's current state and the research objectives. An analysis of several online digital resources suitable for teaching chemistry was carried out to determine their accessibility and functionality.

The experiment was conducted during the 2023-2024 academic year. An online course was developed based on available online resources for studying Chemistry by first-year students of the State Educational Establishment "Sumy Professional High School of Building and Avtotransport " in the speciality "Food product Controller (meat and fish production). Food product Controller (dairy production). Chemical-bacteriological analysis laboratory technician". For these students, studying Chemistry is a crucial component of their professional training and serves as the foundation for subsequent courses in their field of specialization. The pedagogical experiment was conducted based on the material of the chemistry course for the 10th grade, namely during the study of the topics "Oxygen-containing organic compounds" and "Nitrogen-containing organic compounds". In the practical part of the research, student interviews and observations of students using the online course while studying the Chemistry course were conducted. Twenty-eight students took part in the study.

Work on the article material was carried out within the framework of the scientific topic of the Department of Chemistry and Methods of Teaching Chemistry of the Sumy State Pedagogical University named after A. S. Makarenko "Methodological support for training a chemistry teacher in the context of reforming higher education".

3. THE RESULTS AND DISCUSSION

To create a digital educational resource, the use of online platforms and services is essential. There is a wide range of digital tools available for developing informational products to support the educational process:

– web platforms for distance learning: Google Classroom, Moodle, Human;
– online services for creating scribing: PowToon, Sparkol VideoScribe, Moovly, GoAnimate;
– online services for working with virtual online boards: Jamboard, Padlet, Linoit, Flinga, Limnu, Trello, Miro, Twiddla, etc;
– online services for creating online tests and questionnaires: Classtime, Google Forms, Na Urok, Quizalize, Quizizz, Kahoot, LearningApps, Google Forms, ClassMarker, Online Test Pad, Formative, Testmoz;
– online services for creating infographics: Canva, Genially, Infogram;
– online services for creating interactive posters: ThingLink, Genially, Smore, Glogster;

- online services for creating interactive worksheets: Wizer.me, LiveWorksheets, Formative, Classkick;
- online services for creating interactive presentations: Genially, Canva, Prezi, Emaze, Google Presentations, Wepik, Visme, Nearpod;
- online services for creating interactive didactic exercises, quizzes, puzzles, crosswords and other tasks: LearningApps, Genially, Wordwall, Quizlet, StudyStack, Flippity, Rebus1.com, ProProfs, WordMint, Purpose Games, Quizlet, Jigsaw Planet, Crossword Generator, Sporcle, StudyStack;
- online services for creating word clouds: WordArt, Wordcloud.pro, Word It Out, Word Cloud Generation, Word Clouds, AnswerGarden;
- online services for creating webquests: Genially, Google Sites, Vseobrazovanie, Moi kvest, Blogger;
- online services for creating interactive videos: Edpuzzle, PlayPosit, H5P, VIZIA, YouTube Video Annotation Tools, TED Ed;
- telecommunication technologies for video communication: Zoom, Google Meet, Microsoft Teams, Skype, etc.

The implementation of e-learning through electronic courses is based on information and electronic technologies. It impacts the methods for selecting and structuring content, as well as the methods for implementing instructional strategies and organizational forms of learning. At the same time, both the teacher and the learner must remain engaged in an active dialogue.

3.1. Creating an online course

Our survey, which was conducted at the beginning of the design phase of the online course "Chemistry", provided evidence that the use of digital content generates interest and enhances motivation among learners (Fig. 1). The implementation of electronic courses through digital technologies enables educational institutions to effectively respond to the challenges posed by the current wartime conditions and ensure a high level of organization in the educational process based on modern digital technologies.

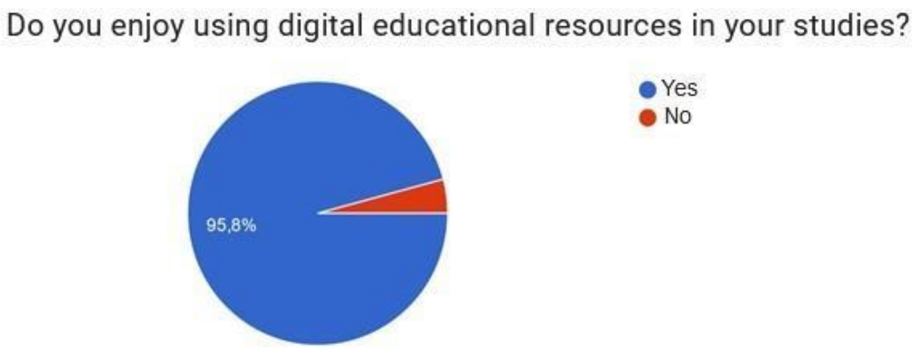

Figure 1. Survey results of students

The design of the online course "Chemistry" involved the following stages:

1. Organizational and preparatory stage:

- analyzing the relevance of developing the electronic course,
- surveying students to determine their attitudes towards traditional versus EER-based learning,
- defining the goals and objectives of the course,
- identifying all possibilities for course creation,
- creating a course implementation plan.

2. Design stage:
- planning course work and developing sections (topics),
- researching sources and methods for gathering information,
- studying and selecting technologies, forms, and methods of instruction,
- choosing the educational platform for the electronic course,
- selecting digital educational resources,
- choosing lesson materials,
- familiarizing with the themes of the educational materials to be created.

3.Technological stage:
- creating scribing content for the electronic course (using PowToon),
- developing a virtual tour to the "Academic Virtue" country (using Padlet),
- creating educational materials and selecting video content (demonstrations) for the "I Learn" section,
- developing interactive exercises and tasks for the "I Apply" section (using LearningApps, WordWall, Kahoot!, Jigsaw Planet, Quizlet, and Genially),
- adding engaging information to the "I Discover" section (using Canva, Genially, Infogram),
- creating tasks for the "I Check" section (using Canva, WordWall),
- setting up online reflection boards in the "I Analyze" section (using Padlet),
- developing online tests (using Online Test Pad, All Education),
- creating digital lessons (using Padlet),
- assembling the online course "Chemistry" on the Google Classroom platform.

4. Final stage:
- presenting the online course to students on the Google Classroom platform,
- analyzing the effectiveness of the course development,
- evaluating the effectiveness of the online course "Chemistry" in the context of distance and blended learning,
- surveying students for feedback on the online course.

To develop the online course "Chemistry", the following prerequisites must be met:
- availability of educational technology with internet access (personal computers, laptops, tablets, etc.),
- all participants in the educational process must have a Google account,
- digital competence of both the instructor and the learners,
- pedagogical experience, with the teacher possessing a range of traditional and modern teaching methodologies.

The online course "Chemistry" is designed for distance and blended learning using the Google Classroom platform. Google Classroom is an internet platform developed by Google for educational institutions to facilitate simplified and rapid online teaching. It allows for course creation, webinars, and learner testing. Google Classroom integrates various tools, including Google Drive for task creation and sharing, Google Docs, Sheets, and Slides for document preparation, Gmail for communication, Google Calendar for scheduling, and other web services. On the Google Classroom platform, a separate folder is created on Google Drive for each user, where assignments are submitted and evaluated by the instructor. Mobile applications available on iOS and Android allow students to take photos and attach them to assignments, share files from other apps, and access information offline. This offline access is crucial and appealing in the current context. The teacher can monitor each learner's progress and, after evaluating their work, return it with comments. Creating the course required following a specific algorithm (Fig. 2).

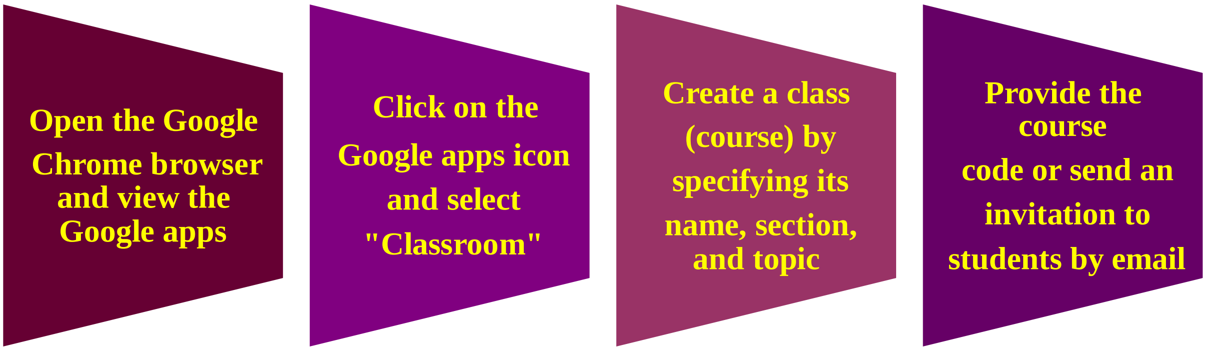

Figure 2. Algorithm for creating the online course "Chemistry"

The online course "Chemistry" is designed for students. To use the electronic course effectively, students need to:

- create a Google Account,
- join the electronic course via an invitation link or enter the course code;
- follow the teacher’s announcements on the Google Classroom platform;
- carefully read the instructions before starting each lesson,
- work through lesson materials in the specified order.
- submit assignments and other work to the teacher in a timely manner for review.

The online course "Chemistry" is designed to facilitate interactive learning, promote understanding of the learning process, offer flexibility in pace and timing, provide feedback, and include a combination of educational content. In the top horizontal menu of the course, there are four tabs: Feed, Tasks, Users, Grades.

Feed: the feed allows for posting announcements for students, sharing links for online lessons in a distance learning environment, and discussing topics and questions. Access to this feature is configured manually.

Tasks: this tab contains materials for the "Chemistry" course. The online course is structured and includes "Introduction". In the "Introduction" section, students can learn about the course author and structure of the course by watching a scribe video, available on YouTube at (https://www.youtube.com/watch?v=oS8D10_mwgA). Additionally, they can take a virtual journey to the "Country of Academic Virtue" (Fig. 3).

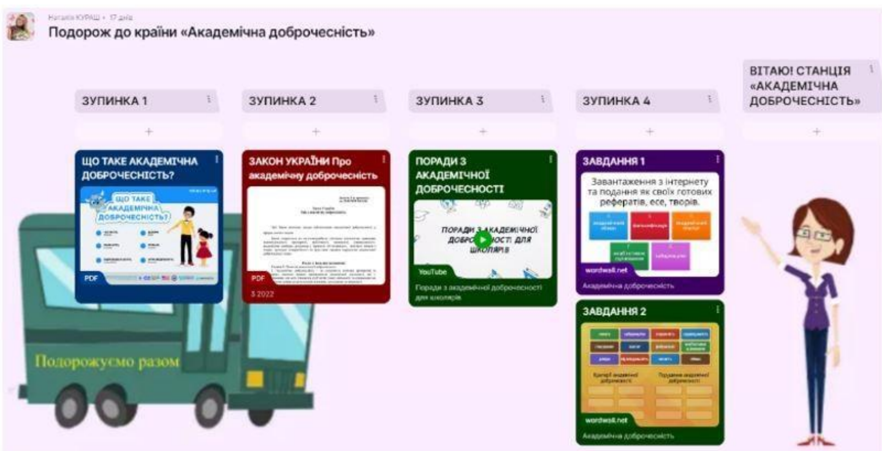

Figure 3. Screenshot of the section "Journey to the Country of Academic Virtue"

The course topics include digital lessons created using the Padlet online service. All educational materials can be viewed by single-clicking with the left mouse button. In the "Users" tab, information about students and the teacher who can join the electronic course is displayed. The "Grades" tab organizes and displays the performance of each student by lesson topics. The online course "Chemistry" consists of digital lessons that encourage students to actively participate during lessons, gain knowledge through personal experience, and collaborate effectively during group work. Moreover, lessons utilizing digital educational technologies offer several advantages:

– activation of students' cognitive activity
– increased motivation for learning
– conducting lessons at a high aesthetic and emotional level
– high degree of differentiated instruction
– increased amount of work completed during lessons
– improvement of knowledge control
– increased lesson effectiveness
– development of research and investigative skills.

Using digital services allows for the application of various e-learning system tools and communication means for feedback, surveys, discussions, and collaboration, as well as the utilization of digital tools to support learning, reinforcement, and assessment of students' knowledge. The materials for the digital Chemistry lessons are created using electronic tools and organized with the online service Padlet. The lessons in the online course follow a structured sequence, reflecting their order of execution (Fig. 4).

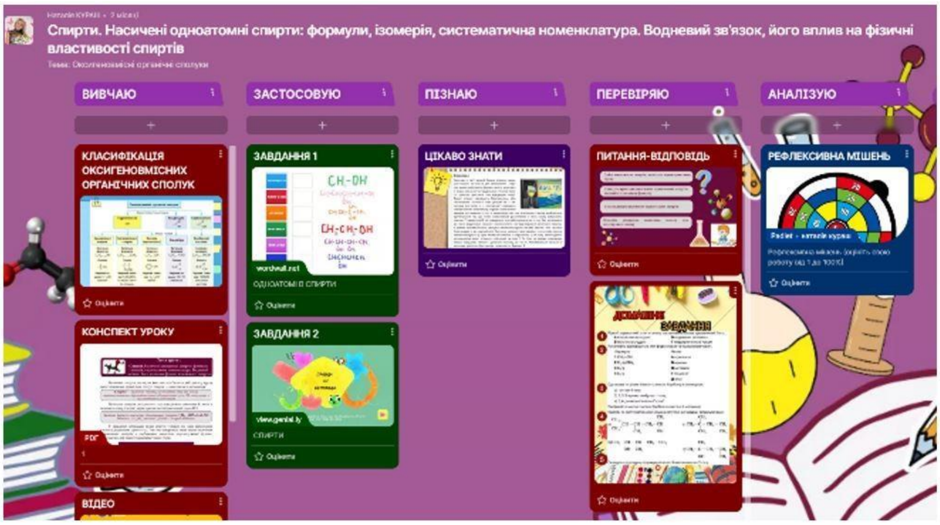

Figure 4. Screenshot of a lesson page in the online course "Chemistry"

The Padlet service offers a simplified and easy-to-understand structure for students with an intuitive interface. During lessons using this service in both distance and blended learning conditions, students can easily grasp and apply various didactic materials in the learning process.

To foster a deep understanding of the subject matter, we structured the lesson material in the online course into five distinct sections: "I Learn", where students are introduced to new concepts; "I Apply", where they practice using these concepts in problem-solving scenarios; "I Discover", where they explore supplementary information; "I Check", where they demonstrate their mastery of the material through assessments; and "I Analyze", where they critically evaluate their learning. In our view, this structure allows for the most effective organization of students' work when studying Chemistry and helps achieve the educational goals. The implementation of this lesson structure has demonstrated its effectiveness in both distance and blended learning settings. Through the utilization of digital tools like Google Classroom, each phase of the lesson can be seamlessly facilitated.

The "I Learn" section, which includes a lesson outline and a video, is designed to introduce new theoretical material and foster the development of fundamental knowledge. This section contains the lesson summary and video material on the topic. Videos hosted on YouTube add interactivity to the lessons. Students have the opportunity to watch the video lesson at their convenience. The use of videos makes the lesson more modern, original, and engaging, encouraging active student participation during synchronous classes. Videos provide a valuable educational resource, especially during distance learning. They allow students to observe laboratory experiments, which help in forming specific chemical concepts and scientific notions. Experiments concretize, clarify, and make the teacher’s explanations more convincing, thereby enhancing motivation to study the topic.

The "I Apply" section contains interactive tasks (exercises) created using services such as Quizgecko, WordWall, Genially, LearningApps, Jigsaw Planet, Kahoot!, and Quizlet. These interactive tasks help to activate cognitive activity, consolidate the lesson material, and assess students’ readiness to undertake subsequent tasks with integration into various types of lessons. The primary goal of these interactive tasks is for students to simultaneously perform tasks, compete with each other or in teams, and more effectively review the new lesson material. The final result includes a ranking of the best scores.

The WordWall service (Fig. 5) offers a wide range of interactive tasks that can be created using templates. These include familiar classic formats such as Quiz, Crossword, Random Wheel, Open the Window, Answer Sheets, Sorting by Groups, and others.

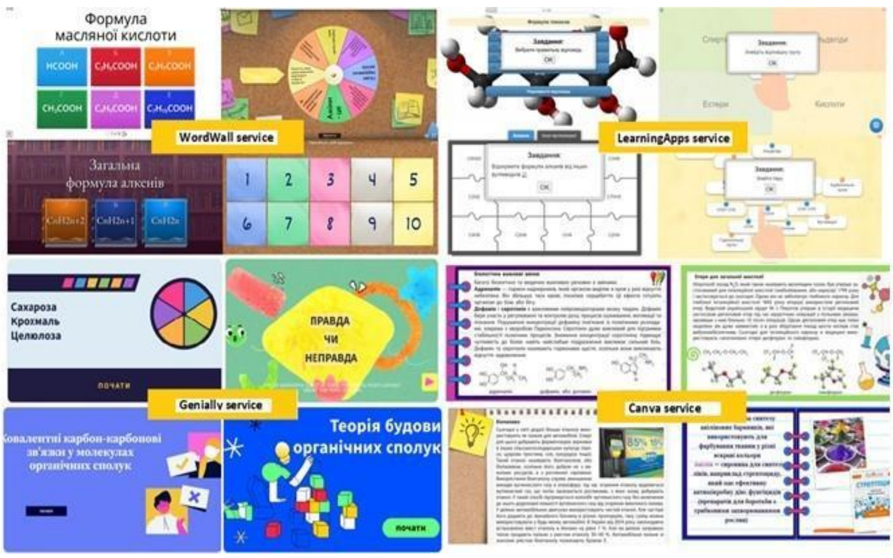

Figure 5. Interactive tasks (WordWall service, LearningApps service, Canva service, Genially service)

In the LearningApps service (Fig. 5), we created over 60 interactive tasks in a game-based format. Examples of these tasks include "Fill in the blanks", "Simple ordering", "Classification", "Find the pair", "Number line", "First million", "Free response", and so forth.

The multifunctional online service Genially (Fig. 5) enables the creation of presentations, interactive images, maps, reports, infographics, quizzes, posters, videos, timelines, games, and virtual aids. The service offers over a thousand different templates, allowing users to quickly and easily produce interactive content.

Students can access and complete interactive tasks (exercises) on any web-enabled device, such as a computer, tablet, smartphone, or interactive whiteboard. They can do this independently during both synchronous or asynchronous lessons.

It is important to note that interactive exercises actively support self-assessment of students' knowledge. However, they may not be suitable for formal knowledge assessment, as some exercises do not display scores and allow multiple attempts to complete the task.

The "I Discover" section (Canva service) contains informational material titled "Interesting to Know" (Fig. 5). This supplementary information expands and complements the fundamental educational content, enhancing and developing cognitive interest in the lesson topic.

The "I Check" section (Fig. 6) includes questions for self-review of the material and provides "Homework" assignments for written completion, which require the practical application of acquired knowledge.

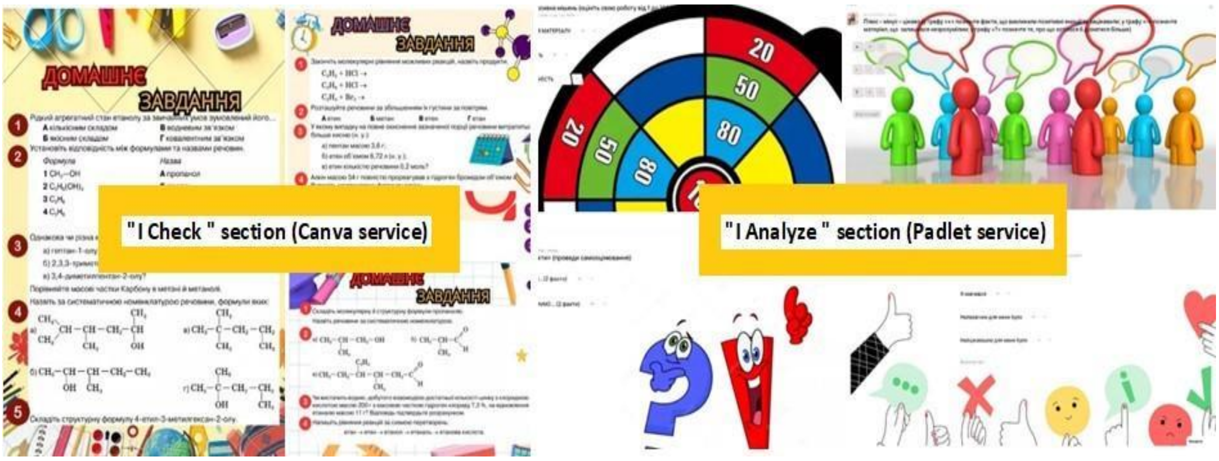

Figure 6. Interactive tasks

An important element of the lesson is reflection in terms of constructing a competency-based lesson, as it is one of the key mechanisms for personal self-development [24]. The continuous activation of student reflection during the lesson enables them to reassess their subjective experiences: personal changes, value relationships, actions, and knowledge. Summarizing is a crucial stage of the lesson. During this time, the content of the work is reviewed, a conclusion is drawn about the knowledge that needs to be assimilated, and a connection is established between what has already been learned and what might be needed in the future. A critical factor influencing the effectiveness of reflection in education is the variety of its forms and methods, as well as their alignment with the age and other characteristics of the learners.

Two types of reflection can be distinguished in the educational process: reflection on results and reflection on the process. Reflection on results involves the learners analyzing what they have learned, what experience they have gained, which skills they have improved, and where these skills can be applied. Reflection on the process involves considering the impressions gained from the lesson, which methods of action proved effective, what helped or hindered their actions, and what should be done differently.

The section "I Analyze" contains online boards (Fig. 6) for conducting reflection among students:

– the online board "Reflective target" (Padlet) invites students to assess their understanding of new material, their own activity, and independence during the lesson,

- the online board "Plus-Minus-Interesting" (Padlet) encourages students to highlight facts that elicited positive emotions and interest, identify material that remains unclear, and indicate topics they would like to explore further,
- the online board "Success ladder" (Padlet) prompts students to mark their progress on the corresponding step: step 1 – difficult, did not understand the topic; step 2 – understood almost everything, but has some questions; step 3 – understood everything,
- the online board "2 Facts" (Padlet) asks students to write down two facts they did not know before but now understand,
- the online board "Complete the Sentence" (Padlet) requests students to complete the following sentences: "I learned that…", "I learned how to…", "The most difficult part for me was…", "The most interesting part for me was…".

We utilized digital content in Chemistry lessons at various stages of the educational process, but our primary goal was to establish feedback with students during distance and blended learning. Digital lessons enabled students to explore each topic more profoundly using their devices, such as tablets, smartphones, or computers. The interactive elements of digital lessons, including videos, infographics, interactive tasks, demonstration experiments, and simulations, made the educational process more engaging and dynamic, allowing students to absorb the material better and interact with it actively. This approach not only made learning more accessible but also more captivating, aligning it with the demands of the digital age.

At the beginning of the lesson (organizational stage), digital content could be used to prepare the group for work. For example, motivational videos, QR codes for quick access to welcome messages, and interactive elements (such as puzzles) helped set a positive tone for learning and fostered a conducive atmosphere within the class. Digital resources (videos, interactive presentations, online quizzes, or tests) assist the teacher in activating students' prior knowledge before introducing new material. This enables the teacher to identify gaps in knowledge and adjust the explanation accordingly.

In the explanation of new material, digital content played a significant role. For instance, interactive simulations, scribing, 3D models of organic compounds, video materials, and demonstration lab experiments helped students visualize complex concepts. Using QR codes allowed students to explore new information independently in an interactive format.

We used interactive tests, surveys, or exercises with instant feedback to check comprehension and reinforce the material. Digital services such as Learning Apps, WordWall, Kahoot!, Jigsaw Planet, Quizlet, and Genially allowed students to answer questions via links or QR codes, while teachers received real-time results and could monitor the level of material retention.

At the end of the lesson, using digital services like Padlet or other digital tools for reflection is beneficial. Students had the opportunity to express their thoughts on an online board or participate in a survey, assessing their personal progress or offering suggestions for improving the learning process.

Overall, digital content makes lessons more flexible, engaging, and personalized for students while providing continuous feedback that enhances understanding of the material. At the same time, digital educational resources allow teachers to quickly and accurately assess how students are mastering new knowledge and make informed decisions about further adjustments to the educational process.

3.2. Results of the pedagogical experiment

The study was conducted throughout the 2023-2024 academic year. During the first semester, students were taught using traditional methods with a standard paper textbook, and knowledge assessment was carried out through oral questioning and written assignments. In the second semester, training was conducted using the online course "Chemistry".

At the beginning of the experiment, we conducted a survey of students to determine the advantages and disadvantages of traditional learning using paper textbooks. The results indicated (Fig. 7) that half of the respondents felt that working with a conventional textbook did not stimulate their interest in acquiring new information. None of the respondents believed that using the textbook increased their interest in learning. Respondents noted the most frequently cited disadvantages of using a traditional textbook: the need to carry it, its size, the lack of feedback, interactivity, and the absence of modern technologies (multimedia). The results showed that traditional approaches to studying chemistry using a textbook require updating and enhancement with modern digital technologies, which help increase students' engagement and improve their learning experience.

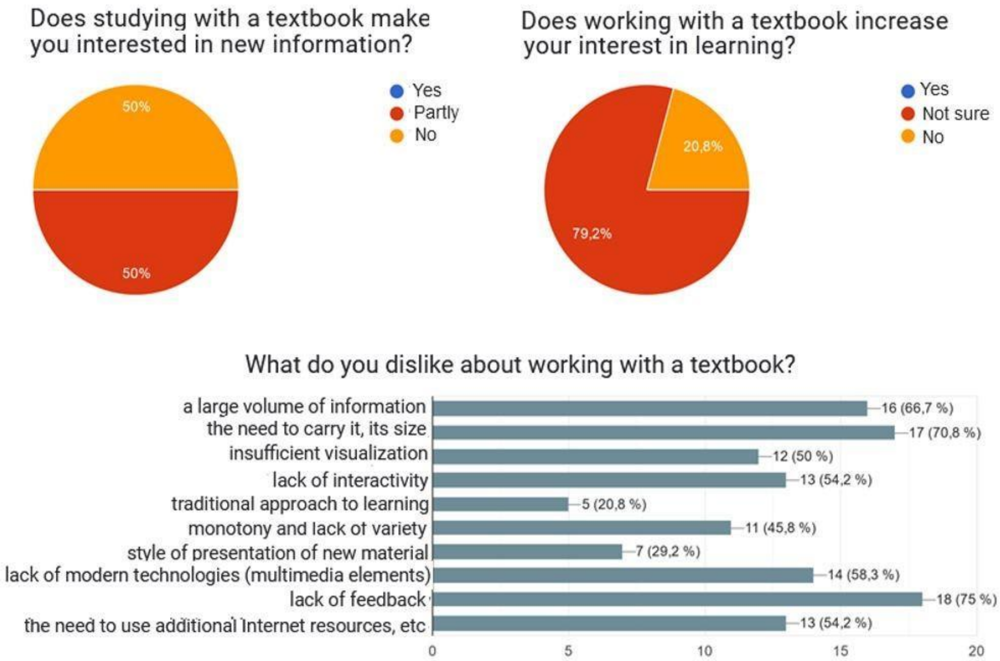

Figure 7. Survey results of students

At the end of the second semester, we conducted a final survey of the students. The purpose of this survey was to evaluate the students’ perceptions of the online course, identify its strengths and weaknesses, and understand its impact on motivation and academic performance. The survey included questions about the use of digital resources, the convenience of the course, and the perception of various elements of the course. To the question of whether the use of the online course increases interest in learning (Fig. 8), only one student responded negatively. The majority of respondents (77%) indicated that it does increase their interest.

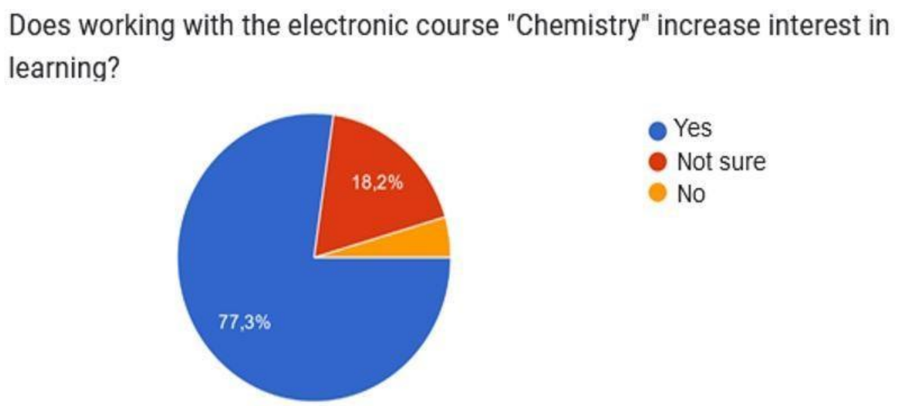

Figure 8. Survey results of students

To the question about what specifically students like about working with the online course (Fig. 9), we received the following responses. The undoubted advantages, according to students, were: the use of gamified tasks, an innovative approach to learning new information, interactivity, visualization, and the ability to study the material at a convenient time and place.

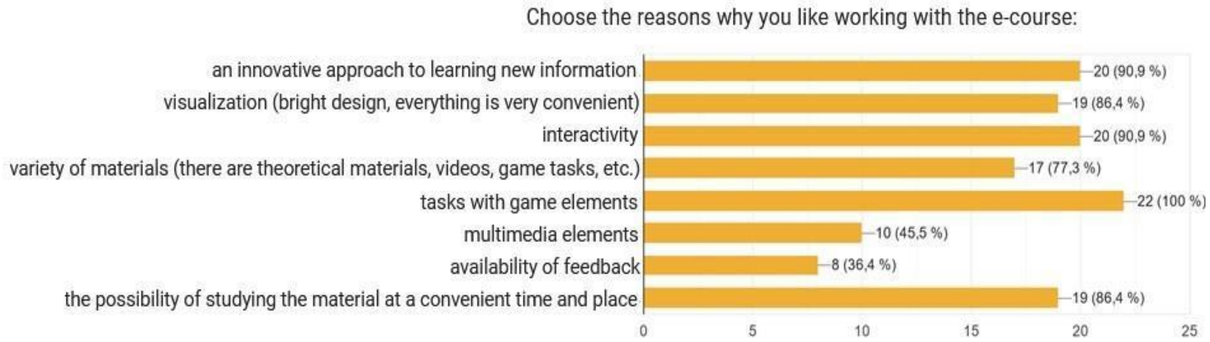

Figure 9. Students' responses showing the positive aspects of using the online course

The main difficulty (Fig. 10) encountered by course users (65%) was technical issues, including unstable internet connections. A quarter of the respondents pointed out the lack of options for adjusting the difficulty level, while 20% felt that the course contained excessive information.

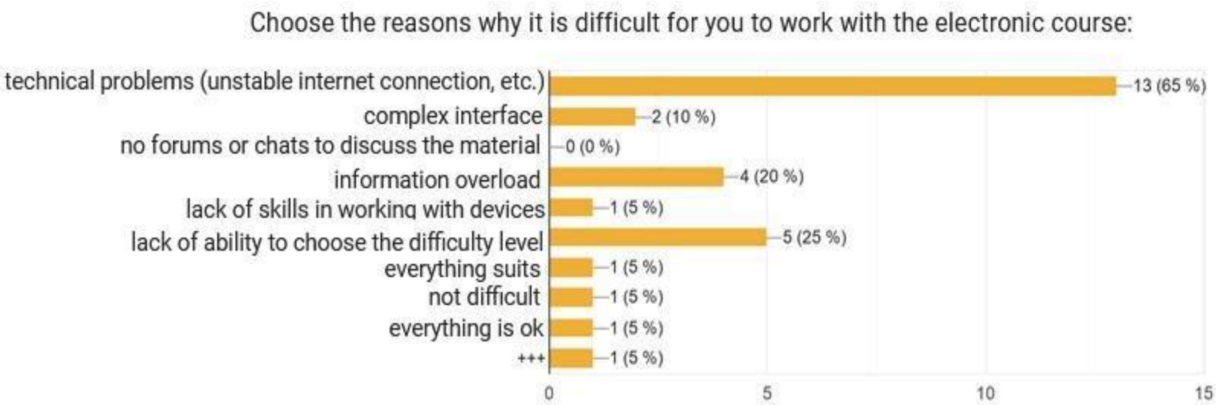

Figure 10. Students' responses showing the disadvantages of using the online course

Overall, the vast majority indicated they liked using the online course when studying Chemistry (Fig. 11).

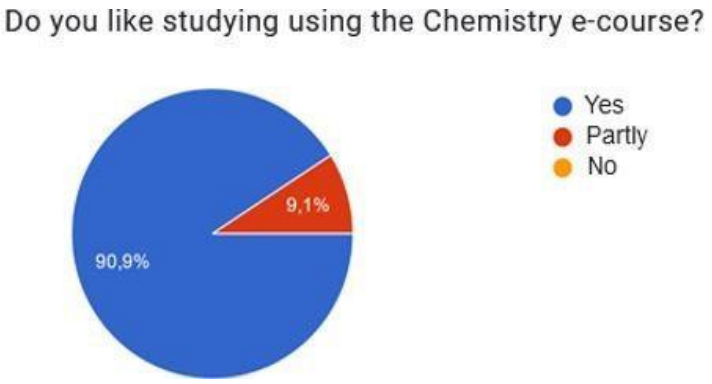

Figure 11. Survey results of students

During the formative stage of the pedagogical experiment conducted in the 2023-2024 academic year, regular monitoring was carried out to assess students' mastery of the educational material, as well as the development of their key and subject-specific competencies in Chemistry lessons. To evaluate the effectiveness of the developed methodology, we assessed the dynamics of students' knowledge over the first and second semesters of the 2023-2024 academic year. This included calculating the group's average score (X) and determining the knowledge growth coefficient (K.g.c.), which allowed us to clearly understand the student's progress in mastering the educational material. The average score (X) for the experimental group was calculated using the following formula (1):

$$X = \frac{1}{n}\sqrt{\sum_{i}^{n} = 1} \quad (1)$$

where X represents the average score, n is the number of students in the sample.

Throughout the pedagogical experiment, we analyzed the effectiveness of students' achievements. The knowledge analysis was conducted based on the results of the first semester (prior to the pedagogical experiment) and the second semester (following the pedagogical experiment) of the 2023-2024 academic year (Table 1 and Fig. 12).

As shown in the results presented in Table 1, the average grade score in the group increased by 0.82 points during the pedagogical experiment.

Table 1

The level of students' academic achievements

Semesters	**Number of students, %**				**Average score**
	Initial level of students' academic achievements	**Medium level of students' academic achievements**	**Sufficient level of students' academic achievements**	**High level of students' academic achievements**	
I semester	10,7	50,0	39,3	0	5,93
II semester	10,7	17,9	64,3	7,1	6,75

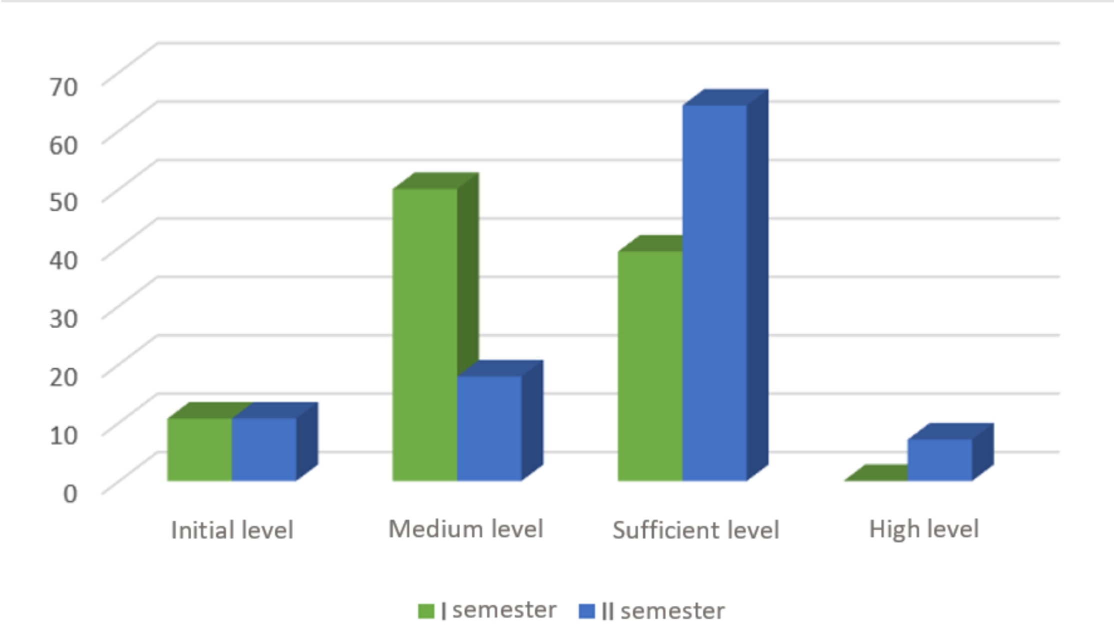

Figure 12. The level of students' academic achievements

The analysis of the obtained results indicates that the number of students with an initial level of academic achievement, characterized by low performance and very low motivation to study chemistry, remained unchanged during the experiment. The percentage of students with a medium achievement level decreased by 32.1%. At the same time, the number of students with a sufficient level of achievement increased significantly by 25.0%. At the start of the experiment, there were no students in the group with a high level of academic achievement. However, after using the online "Chemistry" course, two students (7.1%) reached a high level of achievement.

We observed changes in the percentage distribution of academic performance during the pedagogical experiment. At the beginning of the experiment, the majority of students in the group demonstrated a medium level of academic achievement (50.0%), whereas, by the end of the second semester, the sufficient level became dominant (64.3%). These results suggest that the proposed methodology, involving the use of digital lessons from the "Chemistry" electronic course, contributed to increased motivation and allowed students to comprehend the educational material better.

We also calculated the knowledge growth coefficient (K.g.c.) using formula (2):

$$K.g.c. = \frac{M}{N} \tag{2}$$

where *M* represents the current score, and *N* is the score from the preliminary knowledge assessment.

It should be noted that a K.g.c. value greater than 1 indicates an increase in knowledge level; a value approximately equal to 1 means the knowledge level remains unchanged; and a value less than 1 indicates a decline in the students' knowledge level. The calculated knowledge growth coefficient from the results of the pedagogical experiment is 1.15, which confirms a positive dynamic in students' mastery of the educational material.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The online course "Chemistry" enhances students' perception of educational material by effectively integrating new content with previously acquired knowledge, consolidating understanding through gamified activities, and assessing students' knowledge comprehensively. The course offers a range of didactic opportunities, including the dynamic updating of content, methods, tools, and teaching forms; demonstration of laboratory experiments; analysis of virtual experiments and observations; and implementation of diverse forms of knowledge assessment. The use of the online course meets the educational needs of contemporary learners.

The results we obtained during the study show a clear advantage of the online course compared to traditional education, particularly in the context of distance or blended learning.

The incorporation of gamification elements, innovative teaching methods, interactivity, and visualization makes the course more engaging and captivating for students. A significant benefit is the flexibility of the online course, enabling students to learn at their own pace and from a convenient location, thereby providing an inclusive approach to support different learners.

Google Classroom proved to be the optimal platform for developing and delivering the online "Chemistry" course. Its functionality enables the hosting of diverse digital content, management of assignments, and facilitation of assessment and monitoring. The utilization of the Padlet online service significantly simplified the organization and presentation of digital lessons. The findings of this study corroborate the effectiveness of the proposed online course structure, which is organized into sections such as "I Learn", "I Apply", "I Discover", "I Check", and "I Analyze". This structure not only proved to be user-friendly, logical, and engaging for students but, when coupled with interactive tasks and materials created using digital tools, enhanced students' motivation and interest in chemistry, positively impacting their academic achievement.

Significantly, this online course has been successfully integrated into a vocational and technical education institution, demonstrating high efficacy. Moreover, the course's structure and content exhibit the potential for adaptation in other educational institutions, offering opportunities for broader implementation and further refinement.

Developing an online course is undoubtedly a labour-intensive process for teachers, requiring significant effort in selecting appropriate services, curating educational material, planning work with the course, and periodically updating the course. However, it is important to note that a well-structured and thoughtfully designed online course allows for relatively easy updates, adapting to the needs and goals of the educational process with minimal effort once the initial setup is complete.

Additional analysis, based on observations of the course’s use, indicates that effective learning, even in an online format, depends on meaningful interaction between students and their teacher. Only under such conditions can an online environment be created that encourages students to engage thoroughly with the course, motivates them toward success, and ultimately enables them to work more effectively and achieve higher academic standards. Another significant conclusion from our research is the importance of allowing students to shape their own educational trajectories, by allowing them to select the difficulty level of assignments. Further research could explore the development of adaptive learning features that personalize course difficulty based on students' performance. This area represents a promising direction for enhancing the online course and advancing the overall effectiveness of online education.

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РОЗРОБЛЕННЯ ТА ВПРОВАДЖЕННЯ ОНЛАЙН-КУРСУ З ХІМІЇ: ПЕРЕВАГИ, ПРОБЛЕМИ ТА РЕЗУЛЬТАТИ ЕКСПЕРИМЕНТУ

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Анотація. У статті розглядаються питання використання електронних освітніх ресурсів (ЕОР) у навчальному процесі, зокрема при вивчення хімії. Проаналізовано український та міжнародний досвід використання ЕОР для організації дистанційного навчання. Отримані результати свідчать про те, що електронні освітні ресурси створюють умови навчання, за яких учні за допомогою цифрових технологій стають активними учасниками подій і процесів, повною мірою взаємодіючи з навчальним середовищем, яке імітує об’єкти та процеси реального світу. Автори досліджують особливості розробки та використання онлайн-курсу з вивчення хімії в закладах професійної (професійно-технічної) освіти. Такий курс дозволяє інтегрувати різноманітні електронні ресурси в єдину платформу, забезпечуючи візуалізацію та інтерактивність у вивченні такого предмета, як хімія, який часто є складним для здобувачів освіти. У статті описано досвід створення онлайн-курсу хімії, деталізовано алгоритм його оформлення та структуру. Наведено приклади навчальних матеріалів, завдань і сервісів, використаних для їх розробки. Цей онлайн-курс пропонує кілька дидактичних можливостей, таких як можливість динамічно оновлювати зміст, методи, інструменти та формати навчання, демонструвати лабораторні експерименти, аналізувати віртуальні експерименти та спостереження, а також впроваджувати різні типи оцінювання знань здобувачів. Використання електронного курсу відповідає освітнім потребам сучасного учня. У статті також проаналізовано результати первинного та підсумкового опитувань, проведених серед здобувачів освіти ЗП(ПТ)О, які брали участь у дослідженні та використовували онлайн-курс для вивчення хімії. Аналіз результатів вхідного опитування показав, що традиційні підручники є непривабливими та позбавленими інтерактивності, тоді як опитування після експерименту показало, що більшість здобувачів вважають онлайн-курс більш цікавим. Аналіз навчальних досягнень здобувачів показав позитивну динаміку в засвоєнні навчального матеріалу. У статті також обговорюються основні переваги та виявлені недоліки онлайн-курсу.

Ключові слова: електронні освітні ресурси; ІКТ в освіті; онлайн-курс; хімічна освіта; заклади професійної (професійно-технічної) освіти.