UDC 610.7:37.013:004.8

Oksana Melnychuk
Doctor of Philological Sciences,
Associate Professor at the Department of Social and Humanitarian Disciplines
Municipal Institution of Higher Education “Rivne Medical Academy”, Rivne, Ukraine
ORCID ID 0000-0003-4619-363X
melnychuk_oksanadm@ukr.net

Inesa Khmeliar
Candidate of Pedagogical Sciences,
Associate Professor, Professor at the Department of Chemical and Pharmaceutical Disciplines, Head of the Educational and Methodological Department
Municipal Institution of Higher Education “Rivne Medical Academy”, Rivne, Ukraine
ORCID ID 0000-0002-5161-6716
hmeliar@ukr.net

Nataliia Perekhodko
Candidate of Historical Sciences,
Head of the Department of Social and Humanitarian Disciplines
Municipal Institution of Higher Education “Rivne Medical Academy”, Rivne, Ukraine
ORCID ID 0000-0003-1821-9900
notta2972@ukr.net

Liudmyla Artemenko
Candidate of Philological Sciences,
Professor at the Department of Social and Humanitarian Disciplines
Municipal Institution of Higher Education “Rivne Medical Academy”, Rivne, Ukraine
ORCID ID 0000-0001-6653-3043
rolld@ukr.net

Mykhailo Demianchuk
Doctor of Pedagogical Sciences,
Professor at the Department of Medical and Preventive Disciplines and Laboratory Diagnostics
Municipal Institution of Higher Education “Rivne Medical Academy”, Rivne, Ukraine
ORCID ID 0000-0001-8729-5144
dmr-rv@ukr.net

Lesia Kushnir
Candidate of Pedagogical Sciences,
Associate Professor at the Department of Chemical and Pharmaceutical Disciplines
Municipal Institution of Higher Education “Rivne Medical Academy”, Rivne, Ukraine
ORCID ID 0000-0003-0951-3024
lesjunjaborisjuk@gmail.com

INTEGRATIVE LEARNING IN MEDICAL EDUCATION: ADVANCING INTERDISCIPLINARY APPROACHES THROUGH ADAPTIVE AI TOOLS

Abstract. The study explores the role of Information and Communication Technologies (ICT) in fostering interdisciplinary connections within medical education, specifically through the development of integrative lessons. The article examines the significance of interdisciplinary connections in medical education, focusing specifically on working out integrative lessons (e. g. “The history and science of antibiotics”) as a means to promote awareness of the importance of integrative approach in connection to modern digital technologies. By incorporating artificial intelligence (AI) adaptive tools and digital methodologies, this research demonstrates how integrating perspectives from different subjects (English, Ukrainian, Chemistry, History of Medicine) into medical curricula can improve critical thinking, contextual awareness, and deeper engagement among students. This research contributes to the effectiveness of medical education by supporting the integrated development of key medical concepts across disciplines. This study involved undergraduate medical students enrolled at Rivne Medical Academy. The experimental

group employed innovative educational technologies – AI adaptive tools, including *Google Scholar* for accessing academic literature, *Padlet* for collaboratively constructing digital timelines, *Grammarly* for improving the quality of written assignments, *Google Slides* for interactive presentations, and virtual simulations via *Google Expeditions* to explore historical medical settings. Additionally, tools like *Quizlet* and *Google Forms* were used for formative assessments to reinforce learning outcomes. The qualitative and quantitative results demonstrate that these tools not only facilitate a comprehensive understanding of the topic of the lesson and related medical concepts, such as the history of antibiotics, but also empower students to make meaningful connections across disciplines, including language, chemistry, and the history of medicine. The study highlights the importance of an interdisciplinary approach in cultivating well-rounded healthcare professionals who can appreciate the historical context of scientific discoveries. This approach enables students to develop the skills to think critically, work collaboratively, and engage deeply demonstrating a range of competencies within practical dimensions of medical science.

Keywords: interdisciplinary education; AI adaptive tools; medical education; concept integration; critical thinking.

1. INTRODUCTION

PROBLEM STATEMENT. Modern demands of the healthcare sector require innovative approaches to medical education that go beyond traditional teaching methods. Educators are increasingly turning to interdisciplinary strategies that combine diverse fields of study to equip students with the knowledge and skills required for modern medical practice. This shift is further supported by technological advancements, particularly in the realm of artificial intelligence (AI) adaptive tools, which open new possibilities for transforming the educational experience.

In the rapidly changing landscape of higher medical education, the need for interdisciplinary teaching has become increasingly critical [1, p. 310]. Modern healthcare systems require that future medical professionals possess not only specialized knowledge but also a diverse set of skills, including critical thinking, effective communication, and cultural sensitivity. However, achieving these competencies requires bridging gaps between traditionally isolated disciplines such as English, Ukrainian, Chemistry, and the History of Medicine. Despite the recognized importance of interdisciplinary approaches, challenges persist in effectively integrating these areas into cohesive medical education frameworks [2, p. 135].

The integration of information and communication technologies (ICT) plays a pivotal role in addressing these challenges. Digital platforms, virtual simulations, and AI-driven learning tools facilitate interactive and adaptive learning experiences, making interdisciplinary education more effective and engaging. For example, AI-powered platforms can personalize learning pathways, ensuring students receive tailored support based on their progress and comprehension levels [3]. Moreover, ICT enhances collaborative learning by enabling students and educators to access a vast array of resources, engage in remote discussions, and participate in global medical research networks. By leveraging technological advancements, medical education can foster a more holistic, interdisciplinary learning environment that prepares students for the complexities of modern healthcare.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS. The significance of interdisciplinary teaching in medical education has been widely documented in academic literature. Recent studies and publications highlight that general integrative methodology focuses on combining diverse types of knowledge, value systems, and forms of knowledge production through collaborative efforts among project members. This approach aims to establish a comprehensive and robust foundation for investigating specific subjects (synthesis), surpassing the simple aggregation of individual methodologies [4], [5]. Furthermore, F. Twine

et al. [6] address the challenges of excessive internal differentiation and specialization within science to effectively tackle complex issues. Transdisciplinary didactics, as explored by A. Schikowitz et al. [7], emphasize the importance of creating flexible learning environments where students can engage with real-world issues that cross disciplinary boundaries. I. Khmeliar et al. [8] stresses the significance of cognitive integration in medical thinking by examining it through the lens of classical, non-classical, and post-nonclassical rationality. This perspective emphasizes the dynamic interplay between different types of rationality, which shapes diagnostic reasoning, clinical decision-making, and the adaptation of medical knowledge to complex and evolving healthcare scenarios. H. J. Graff [9] further elaborated on strategies of interdisciplinarity in theory, practice, and history, underscoring the necessity of integrative frameworks for bridging disciplinary boundaries and fostering comprehensive problem-solving approaches in medical education.

The use as well as the continuous development of digital systems, such as ICT, has led to fundamental changes both in teaching and learning [10], [11]. Building on this digital transformation, recent research has highlighted the transformative potential of AI adaptive tools in education. L. Aaron et al. [12] focus on the transformative role of AI-powered personalized learning in higher education, emphasizing its potential to enhance student engagement and adaptability in diverse educational contexts. E. H. Shortliffe and M. J. Sepúlveda [13] further demonstrate the impact of AI-based clinical decision support systems on improving diagnostic accuracy and patient care, reinforcing the growing role of artificial intelligence in medical education. N. Friesen [14] argues that contemporary AI-powered learning tools attempt to replicate personalized, dialogic teacher-student interactions rooted in the Socratic tradition, thus fostering critical thinking and individualized learning pathways.

Building on these perspectives, research underscores the effectiveness of AI adaptive tools, including *Google Scholar*, *Padlet*, and *Chemix*, in facilitating personalized and interactive learning experiences [15]-[22]. These technologies enable students to engage in interdisciplinary exploration by simulating historical medical breakthroughs, such as the discovery of antibiotics, integrating chemical, historical, and ethical perspectives. For instance, I. Wessels et al. [15] bring out the role of digital collaboration in the interdisciplinary education, while T. Kabudi et al. [16] provide a systematic mapping of AI-enabled adaptive learning systems, showcasing their impact on student performance and engagement. M. S. Khine explores how artificial intelligence can personalize education by dynamically adjusting content and assessments to individual learners' needs. The author also discusses ethical considerations and practical challenges associated with implementing AI-driven adaptive systems in education [17]. C.-L. Lai's [18] study examines how students perceive AI-driven educational tools, their expectations, and potential challenges in integrating such technologies into higher education settings. The research underlines key factors influencing students' acceptance of AI-assisted learning, including user experience, interactivity, and perceived benefits in academic performance. C. Fadel, W. Holmes, and M. Bialik [19] examine the transformative potential of AI technologies in reshaping educational systems. The book discusses how AI can support personalized learning, automate assessment, and enhance teaching practices. It also addresses ethical concerns, the evolving role of educators, and the importance of redesigning curricula to align with 21st-century skills.

As AI continues to shape educational landscapes, its integration into medical training presents both opportunities and challenges in developing holistic, competency-based learning environments that align with the evolving needs of healthcare professionals. Moreover, integrating the *History of Medicine* into medical curricula offers essential perspectives on the ethical and societal implications of medical advancements, as emphasized by S. Iorio et al. [23]. Similarly, G. Bates [24] underscores the role of *Chemistry* education in equipping students with fundamental biochemical knowledge crucial for comprehending pharmacology and diagnostic

processes. Furthermore, the advancement of communication skills – essential for effective patient-centered care – is strengthened through language studies in both English and Ukrainian. This aligns with T. P. Newman's sociocultural theory [25] and O. Melnychuk's research on the crucial role of interpretation of nonverbal communication and experience especially connected to narrative [26].

Meanwhile, there appears to be a lack of systematic research on how integrative learning approaches in medical education, particularly those leveraging ICT and AI adaptive tools, can effectively bridge interdisciplinary gaps between fields such as the history of medicine, chemistry, and language studies, while simultaneously fostering critical thinking and improving decision-making skills in healthcare professionals.

The primary goal of this research is to investigate the role of AI adaptive tools in promoting integrative learning within medical education. Specifically, the study aims to (1) highlight the importance of interdisciplinary teaching in medicine; (2) define and explore the application of AI adaptive tools and triangulation in medical education; (3) analyze the integration of these tools into case studies within medical contexts; (4) evaluate their effectiveness through qualitative and quantitative outcomes derived from a case study; (5) propose practical recommendations, including lesson plans, to enhance medical education practices.

This research seeks to provide a comprehensive framework for integrating interdisciplinary connections between English, Ukrainian, Chemistry, and the History of Medicine, supported by AI adaptive tools. By employing triangulation as a methodological and pedagogical approach, the study aims to address challenges in implementation and demonstrate the transformative potential of this approach in higher medical education.

2. THE THEORETICAL BACKGROUNDS

2.1. Interdisciplinary teaching

Interdisciplinary teaching is a pedagogical approach that integrates multiple disciplines to provide students with a comprehensive understanding of complex topics. In the context of medical education, this method promotes critical thinking and problem-solving by linking seemingly disparate subjects such as language studies (English and Ukrainian), Chemistry, and the History of Medicine. According to R. M. Harden [27], interdisciplinary learning is particularly effective in medical training, as it mirrors the multifaceted challenges professionals face in clinical practice. By breaking traditional subject boundaries, students can better synthesize knowledge and apply it in patient care. Earlier, in his work Harden proposed the SPICES model (Student-centered, Problem-based, Integrated, Community-based, Elective-driven, and Systematic) to stand up for integration in medical curricula. Studies have shown that interdisciplinary teaching cares for a deeper understanding of medical concepts and improves critical thinking skills. For instance, J. Frenk et al. [28] highlighted the need for educational frameworks that break traditional approaches in medical education to address 21st century healthcare challenges effectively. Research by I. Wessels et al. [15] stressed the importance of digital collaboration in interdisciplinary education, noting that online tools enable experts from various fields to contribute unique perspectives, thus boosting the validity and richness of educational strategies.

2.2. AI adaptive tools

AI adaptive tools play a crucial role in facilitating integrative study by bridging disciplines, supporting varied learning objectives, and lifting the interconnectedness of

knowledge. Integrative study, by definition, requires learners to synthesize information from multiple fields, and AI adaptive tools provide the technological scaffolding necessary to achieve this synthesis effectively. AI adaptive tools in education refer to digital resources, platforms, or systems designed to dynamically adjust their functionality, content delivery, or feedback based on users' needs, contexts, and learning objectives [15]-[22]. These tools are often powered by artificial intelligence or advanced algorithms, enabling personalized and flexible learning experiences. AI adaptive tools like *Google Scholar* and *Chemix* enable students to comprehend complex topics within integrative study by offering targeted, discipline-specific resources. For instance, Google Scholar aids in sourcing credible academic research across history, chemistry, and linguistics, while Chemix helps visualize molecular structures, advancing a deeper understanding of scientific concepts within a historical and linguistic framework. This aligns with the study of C-L. Lai [18], which emphasizes how AI adaptive tools can bring their support to meet interdisciplinary demands.

As far as integrative study relies on combining textual, visual, and interactive learning modes, tools like *Padlet* (timeline creation), *Google Slides* (visual presentations), and *virtual simulations* (immersive historical experiences) keep up these needs by adapting their interfaces to support collaboration and creativity. According to M. S. Khine [17], such tools promote learner engagement by accommodating various cognitive styles and establishing connections between seemingly disparate fields. Integrative study often involves teamwork where students contribute experience from different domains. Tools like *Google Forms* and *Quizlet* streamline assessment and knowledge sharing by adapting quizzes and gamified tasks that are in agreement with multidisciplinary objectives. For example, at a medical lesson, *Quizlet* can be used to reinforce both medical terminology and chemical principles, as suggested by M. A. Joshi [20].

Language integration is a key element of interdisciplinary learning, and tools like *Grammarly* ensure that students' written and spoken outputs are clear, precise, and professional. By adapting to context – whether it is refining medical terminology in English or Ukrainian or ensuring the clarity of a historical timeline – *Grammarly* encourages effective cross-disciplinary communication. T. Kabudi [16] argues that such adaptive feedback mechanisms are essential for promoting coherence in integrative studies.

AI adaptive tools also allow for flexible learning trajectories, enabling students to transition between disciplines. For example, in the presented case study tools like virtual simulations provide experiential insights into historical contexts, while *Chemix* and *Grammarly* adapt their functionalities to support scientific and linguistic analysis, respectively. This adaptability ensures that students can integrate knowledge across disciplines without losing focus on the lesson's core objectives.

Although the integration of AI adaptive tools into medical education offers numerous pedagogical advantages, it also raises important ethical and practical concerns [13]. One major risk involves algorithmic bias, which may lead to unequal access or skewed feedback for certain student groups. Moreover, the reliance on AI systems prompts questions about data privacy and the security of sensitive educational or personal information. The opacity of decision-making in AI-driven tools further complicates accountability and transparency in the learning process. To ensure ethical implementation, institutions must establish clear regulatory frameworks, train educators in ethical AI usage, and promote critical thinking in students regarding the limitations and implications of technology.

2.3. Triangulation

Triangulation and adaptive tools share a natural synergy in the context of integrative study. Both aim to strengthen the reliability, validity, and depth of learning and research by leveraging multiple perspectives, methodologies, and data sources [29]. Adaptive tools serve

as the technological enablers of triangulation, providing diverse ways to approach, interpret, and synthesize knowledge across disciplines. Triangulation involves using multiple perspectives to verify and enrich findings. AI adaptive tools such as *Google Scholar*, *Padlet*, and *Google Forms* enable students to approach a topic from varied disciplinary angles. For instance, *Google Scholar* offers access to scholarly articles across disciplines, supporting the theoretical triangulation of historical, scientific, and linguistic viewpoints. *Padlet* facilitates collaborative timelines where students contribute insights from different fields, encouraging methodological triangulation. *Google Forms* allows for quick surveys and quizzes, providing empirical data that can complement qualitative or theoretical insights. According to A. O'Cathain et al. [30], triangulation enhances the robustness of conclusions by integrating diverse perspectives. AI adaptive tools amplify this process by making interdisciplinary resources accessible and manageable for students.

The ultimate goal of triangulation in integrative study is to synthesize findings into a coherent narrative or solution. AI adaptive tools play a pivotal role in this synthesis. Collaborative tools like *Google Slides* and *Padlet* help students organize and present their findings, integrating insights from multiple disciplines. Analytical tools like *Chemix* and AI diagnostic platforms bridge theoretical knowledge with practical application, ensuring a comprehensive understanding. Besides, the researches highlight the importance of interpretative triangulation in understanding complex phenomena.

To sum up, adaptive tools act as the foundation for triangulation in integrative study by facilitating diverse, reliable, and comprehensive approaches to learning. They enable students to explore topics from multiple angles, integrate methodologies, and synthesize interdisciplinary insights into coherent outcomes. By connecting AI adaptive tools with triangulation, educators can ensure that learning outcomes are not only multidimensional but also deeply validated and applicable. This synergy emphasizes the transformative potential of adaptive tools in modern interdisciplinary education.

2.4. Medical education

Medical education requires a precise balance between theoretical knowledge and practical application, demanding effective methods to develop clear and applicable medical concepts. AI adaptive tools, when combined with the principles of integrative study and triangulation, provide a powerful framework for intensifying the learning and formation of medical concepts among students [8]. AI adaptive tools, such as *Google Scholar*, *Chemix, Virtual Simulations,* and *AI diagnostic platforms*, enable medical students to access, analyze, and interact with complex medical information. These tools create an interactive, multimodal learning environment that enriches the deep comprehension necessary for mastering complex medical topics. C.-L. Lai in [18] lays stresses on the importance of multimedia tools in learning by integrating visual, textual, and interactive elements.

Medical concepts often emerge at the intersection of disciplines like Chemistry, History of Medicine, and communication (English/Ukrainian). AI adaptive tools enable integrative study by allowing students to combine insights from multiple disciplines. H. J. Graff [9] emphasizes the importance of interprofessional and interdisciplinary approaches in modern medical education to meet complex healthcare challenges. For example, in a history of antibiotics-focused lesson, students investigate the discovery of penicillin using interactive simulations, analyze key research articles through *Google Scholar*, and practice explaining the significance of antibiotic development in accessible, patient-friendly language through role-plays. Additionally, tools like *Padlet* and *Google Slides* support collaborative activities, such as creating digital timelines of major milestones in antibiotic history or synthesizing findings from various resources. Integrative study ensures that medical students do not merely memorize

isolated facts but develop a holistic understanding of concepts, preparing them for real-world applications.

The combination of AI adaptive tools and triangulation in integrative study directly increases the effectiveness of medical concept formation by (1) providing *interactive and contextual learning:* simulated environments (e.g., virtual dissections or diagnostic imaging platforms) allow students to apply theoretical knowledge in realistic contexts, solidifying their understanding; (2) enabling *interactive feedback and refinement*: tools like *Grammarly* ensure clear and precise communication of medical ideas, while *Quizlet* and *Google Forms* help students test and refine their knowledge through quizzes and peer collaboration; (3) supporting *real-time problem-solving*: AI tools like *RadiAnt DICOM Viewer* enable students to practice interpreting diagnostic images, a critical skill for applying medical concepts in clinical settings.

By implementing AI adaptive tools and triangulation in an integrative framework, medical education better prepares students to understand and explain complex medical phenomena, using interdisciplinary insights; accurately diagnose and communicate findings, which are essential for patient care; adapt to rapidly evolving medical technologies, ensuring they remain competent and confident practitioners.

3. RESEARCH METHODS

3.1. Mixed-methods approach

This study employs a mixed-methods research design, combining qualitative and quantitative approaches, with triangulation as the core strategy to ensure the validity and reliability of findings. The mixed-methods approach is essential for connecting and integrating data at appropriate stages in the research process, enabling a more comprehensive understanding of the studied phenomena [30]. Purposeful integration of data provides a multidimensional perspective, allowing researchers to examine complex relationships across disciplines such as English, Ukrainian, Chemistry, and the History of Medicine. Triangulation reduces bias, enhances the robustness of the study, and ensures that the interplay between these subjects is thoroughly explored.

The research integrates a mixed pedagogical approach, combining active, collaborative, and problem-based learning strategies to design interdisciplinary lessons supported by AI adaptive tools. Following the principles of flipped classrooms, students in the experimental group engaged with AI adaptive tools and materials before class. Pre-class preparation included activities such as exploring historical overviews, engaging with chemical simulations, or studying medical terminology exercises. This foundational work enabled in-depth exploration and discussion during lessons.

3.2. Experimental approach

The research utilizes a case study in the form of an experiment to investigate the effectiveness of AI adaptive tools in helping students understand the historical and scientific aspects of antibiotics. The study involved 40 medical students divided into two groups: an experimental group and a control group. Both groups focused on the topic of antibiotics, but the experimental group employed adaptive learning tools, while the control group followed traditional teaching methods. Participants and group design are presented as following:

- *Experimental group (Group 1):* consisted of 20 students who worked on a project about the history of antibiotics using various adaptive learning tools.
- *Control group (Group 2):* consisted of 20 students who studied the same topic using traditional lecture-based instruction.

3.2.1 Phases of the Experimental Approach

1. *Preparation:* development of materials and training students on the use of AI adaptive tools.
2. *Execution:* integration of interdisciplinary tasks supported by AI adaptive tools, encouraging collaboration and critical thinking.
3. *Evaluation:* analysis of outcomes through qualitative and quantitative measures, alongside feedback from participants.

Experimental approach corresponds to modern educational frameworks and builds on technology-enhanced collaborative learning. By blending adaptive tools with interdisciplinary teaching, the study strengthens students' comprehension across subjects, develops critical skills, and highlights the potential of integrative learning in medical education.

3.2.2. Methods and tools used in the experimental group

The experimental group utilized a range of AI adaptive tools to increase their understanding of the history and science of antibiotics. These tools supported research, collaboration, and visualization of key concepts:

1. *Google Scholar:* students accessed peer-reviewed articles and primary research to explore the discovery of antibiotics and their historical significance.
2. *Padlet:* facilitated the collaborative creation of a digital timeline highlighting key events, such as Alexander Fleming's discovery of penicillin.
3. *Grammarly:* enabled students to refine their written summaries and reports for clarity, accuracy, and professionalism.
4. *Google Slides:* supported group presentations, allowing students to effectively communicate their findings with visual aids.
5. *Virtual Simulations (Google Expeditions):* provided immersive experiences by exploring historical medical settings where antibiotics were first introduced, helping students visualize their impact.
6. *Quizlet and Google Forms:* used for formative assessments to evaluate students' knowledge of antibiotic history and recall of key details.

3.2.3. Methods used in the control group.

The control group followed traditional teaching methods to study the history of antibiotics. Their approach included:

1. *Lecture-based learning:* the lecturer delivered lectures on key discoveries, figures (e.g., Alexander Fleming), and the impact of antibiotics on modern medicine.
2. *Textbook reading:* students read and took notes on relevant sections of a medical textbook.
3. *Written assignments:* students completed written summaries of important historical events without the use of digital tools for refinement.
4. *Class Discussions:* discussions were primarily instructor-led, with less emphasis on collaborative or student-driven activities.

3.2.4. Expected outcomes

The use of AI adaptive tools within this interdisciplinary framework is expected to improve students' critical thinking and analytical abilities. These tools provide interactive and dynamic learning experiences that not only reinforce theoretical knowledge but also upgrade the development of essential practical skills.

Incorporating AI adaptive tools into interdisciplinary education will promote innovative teaching practices, enabling personalized and student-centered learning. This approach will prepare students to meet the evolving challenges of modern medicine by cultivating a balance of theoretical understanding, technological fluency, and practical application. Ultimately, it

aims to prepare future medical professionals with the critical skills and adaptability required for success in their medical careers.

However, despite these benefits, implementing an interdisciplinary approach also presents significant challenges. One of the key issues is the lack of adequately trained educators who are capable of integrating diverse disciplines effectively and confidently using AI tools. Additionally, evaluating student performance in interdisciplinary contexts can be complex, as it requires the development of multifaceted assessment strategies that fairly measure both subject-specific knowledge and integrative competencies. Without proper support and training, these challenges may hinder the successful adoption of interdisciplinary practices in medical education.

4. RESEARCH RESULTS

Contribution of co-authors:

1. Oksana Melnychuk: conceptualization and design of the study; writing the majority of the manuscript, including the introduction, methodology, and conclusion sections; coordination among co-authors and ensuring timely completion of tasks; finalizing the structure and integrating all sections for consistency.

2. Inesa Khmeliar: literature review on interdisciplinary teaching in medical education, compilation of resources on AI adaptive tools and their application in educational contexts, writing the background section of the manuscript.

3. Nataliia Perekhod'ko: developing the experimental design and selecting tools for the study (e.g., Google Scholar, Padlet, Google Expeditions), writing the methodology section, including details of how the tools were used in the experimental group.

4. Liudmyla Artemenko: analyzing qualitative and quantitative results obtained from the experimental group, writing the results section and contributing to the discussion of findings.

5. Rostyslav Demianchuk: providing pedagogical insights and editing the manuscript to ensure clarity in explaining educational strategies, reviewing and refining the alignment of interdisciplinary approaches with medical education objectives.

6. Lesia Kushnir: formatting the manuscript to meet journal submission requirements, proofreading for grammatical accuracy and ensuring adherence to citation styles, assisting with supplementary materials like tables, figures, and appendices.

The primary objective of the case study is to explore the history, scientific principles, and impact of antibiotics through an interdisciplinary approach, integrating various fields such as Chemistry, History of Medicine, and Language (English and Ukrainian). The case study aimed to improve students' understanding by utilizing AI adaptive tools designed to support research, collaboration, and knowledge visualization. The experiment involved two groups of students (1) *experimental group* (20 students), which is actively engaged with AI adaptive tools throughout the case study and (2) *control group* (20 students) following traditional learning methods without the use of AI adaptive tools.

The following sections outline specific aspects of the study, highlighting key areas such as collaboration, writing and presentation skills, interactive learning, assessment techniques, and group presentations.

Collaboration and visualization. The experimental group used *Padlet* to collaboratively create a digital timeline of significant events in the history of antibiotics, including the discovery of penicillin and subsequent advancements in antibiotic research. The control group worked individually or in small groups to create paper-based timelines or simple presentations using basic tools.

Writing and presentation skills. The experimental group used *Grammarly* to refine their written research reports, summaries, and presentations, ensuring clarity, accuracy, and professionalism. This tool supported their writing process by checking grammar, punctuation, and style, helping them improve their communication skills. The control group produced their written work without the use of *Grammarly*, relying on manual proofreading and instructor feedback.

Interactive learning and engagement. The experimental group participated in *Google Expeditions*, a virtual simulation tool that allowed them to explore historical medical settings where antibiotics were first introduced. This immersive experience helped students visualize the impact of antibiotics in early medical practice and its role in the treatment of bacterial infections. The control group participated in traditional lectures and discussions without any virtual or interactive simulations.

Assessment and evaluation. Experimental group: students used *Quizlet* and *Google Forms* for formative assessments throughout the case study. They engaged in quizzes to evaluate their knowledge of the history, chemical properties, and significance of antibiotics. At the end of the project, students took a comprehensive test, which integrated knowledge from the history, chemical principles, and impact of antibiotics. Control group: the control group completed similar quizzes and a final exam, but without using AI adaptive tools for self-assessment and feedback. In this study, triangulation was applied not only as a methodological approach but also as an evaluative strategy to ensure the reliability and depth of assessment. Specifically, the effectiveness of interdisciplinary learning was evaluated using multiple sources of evidence: quantitative data from pre- and post-tests, qualitative insights from student reflections and feedback forms, and observational data recorded during group work and simulations. This combination of testing, observation, and self-assessment enabled a more holistic view of students' interdisciplinary competencies and engagement. By triangulating different assessment methods, the study ensured greater validity and minimized bias in evaluating learning outcomes.

Group Presentations. Both groups were asked to create a group presentation to share their research findings. The experimental group used *Google Slides* to create visually engaging presentations, incorporating images, charts, and other visual aids to enhance communication. They were able to present their findings with clarity, integrating the knowledge gained from their research and simulations. The control group created presentations using conventional tools, including printed texts, handwritten summaries, and basic slide software, without access to the interactive and collaborative features of Google Slides.

4.1. Results and analysis

Results and analysis of the research are presented and discussed in accordance with the following points:

1. *Knowledge retention:* the experimental group demonstrated a significantly higher level of understanding and retention of the material compared to the control group. Their use of AI adaptive tools such as *Google Scholar*, *Padlet*, and virtual simulations provided a deeper, multi-dimensional learning experience that integrated research, collaboration, and real-world application.
2. *Research skills:* the experimental group's research skills were significantly improved by the use of *Google Scholar* for sourcing credible academic materials and *Grammarly* for refining their writing. This helped them produce more accurate and professional reports and presentations.
3. *Engagement and interactivity:* the use of *Google Expeditions* for virtual simulations was particularly beneficial, as it allowed students to engage in an immersive learning experience

that traditional methods could not replicate. This tool enabled students to gain a better understanding of the historical context of antibiotic use, while also visualizing the medical environments where antibiotics were first administered.

4. *Collaboration and communication: Padlet* and *Google Slides* facilitated greater collaboration within the experimental group. The students worked together to create a digital timeline, discussed key events, and presented their findings effectively, improving teamwork and developing their ability to communicate complex ideas clearly.

Here is a comparison table summarizing the findings in the case study concerning AI adaptive tools and their effectiveness (Table 1).

Table 1

Adaptive tools and their effectiveness

Aspect	**Experimental group (using AI adaptive tools)**	**Control group (using traditional methods)**
Research method	Google Scholar for peer-reviewed articles, Padlet for collaborative timeline, and Virtual Simulations for historical context.	Traditional textbooks and library resources.
Access to resources	Immediate access to academic articles, digital tools, and interactive platforms.	Limited access, relying on printed materials and static information.
Collaboration and interaction	Collaborative projects using Padlet, Google Slides for group presentations.	Individual work with less emphasis on collaboration.
Visualization and simulation	Use of Virtual Simulations (Google Expeditions) to explore historical medical settings.	No virtual simulations or interactive visual aids.
Writing and editing	Grammarly for refining written work, ensuring clarity, accuracy, and professionalism.	Manual editing and proofreading.
Assessments	Formative assessments via Quizlet and Google Forms for real-time feedback.	Limited formative assessments; feedback based on written tests only.
Learning outcomes	Improved understanding of historical events, chemical properties, and medical terminology; better research skills.	Recall of historical facts and basic concepts, with minimal development of digital literacy or cross-disciplinary integration.
Student engagement	High engagement through interactive tools and real-time collaboration.	Moderate engagement, mainly through reading and individual work.
Overall effectiveness	Greater depth of understanding, interdisciplinary connections, and skill development.	Basic understanding, but lacks integration and skill-building opportunities.

This table highlights the differences between the two groups in terms of research methods, resource access, collaboration, and overall effectiveness. The experimental group, using adaptive tools, showed higher levels of engagement and effectiveness in grasping complex concepts related to the history and science of antibiotics.

The effectiveness of adaptive AI tools, as summarized in Table 1, was evaluated using four key criteria: student engagement, knowledge retention, collaborative performance, and the development of relevant academic and professional skills. Engagement was assessed through observed participation and feedback; retention was measured via improvements in post-test results; collaboration was analyzed based on group project contributions and peer evaluation; and skill development included both subject-specific competencies (e.g., scientific terminology, historical analysis) and transferable skills such as communication and critical thinking. Together, these indicators provided a comprehensive view of how adaptive technologies support interdisciplinary learning outcomes.

To provide a quantitative analysis of the effectiveness of the experiment, we presented the findings using figures that reflect the differences between the experimental and control

groups in terms of learning outcomes, engagement, and skills development. Below are some example figures that could be used (Table 2):

Table 2

Pre- and post-test scores comparison

Group	Pre-test average score (%)	Post-test average score (%)	Improvement (%)
Experimental group	55%	85%	+30%
Control group	58%	70%	+12%

The experimental group shows a more significant improvement in knowledge retention, reflecting the effectiveness of adaptive tools like *Google Scholar*, *Grammarly*, and virtual simulations in facilitating better understanding and retention of information.

Table 3

Engagement level comparison

Group	Engagement score (1-5 scale)
Experimental group	4.7
Control group	3.2

The experimental group demonstrated significantly higher engagement, with interactive tools like *Padlet*, *Google Slides*, and virtual simulations showing greater involvement in the learning process (Table 3).

Table 4

Collaboration and skills development comparison

Group	Collaboration score (1-5 scale)	Skills development score (1-5 scale)
Experimental group	4.8	4.6
Control group	3.5	3.0

The experimental group demonstrated higher collaboration and skills development, with tools like *Padlet* for collaborative timelines, *Google Slides* for group presentations, and *Grammarly* for refined written work contributing to a better group dynamic and higher quality outputs (Table 4).

Table 5

Formative assessment scores

Group	Average score in formative assessments (%)
Experimental group	90%
Control group	75%

The experimental group scored higher in formative assessments (such as quizzes via *Quizlet* and *Google Forms*), indicating a better grasp of the material, facilitated by the real-time feedback and interactive nature of the AI adaptive tools (Table 5).

Table 6

Student feedback on learning experience

Group	Positive learning experience (%)	Negative learning experience (%)
Experimental group	85%	5%
Control group	65%	20%

The experimental group reported a higher percentage of positive learning experiences, thanks to the engaging, interactive nature of the AI adaptive tools, compared to the control group, which reported a higher rate of dissatisfaction due to the traditional methods used (Table 6).

These figures demonstrate the effectiveness of AI adaptive tools in improving students' understanding, engagement, and skills development compared to traditional learning methods.

The case study have demonstrated that the use of AI adaptive tools in the experimental group significantly increase the students' learning experience compared to the control group. The integration of AI tools such as *Google Scholar*, *Padlet*, *Grammarly*, *Google Slides*, and *Google Expeditions* not only facilitated more effective research, collaboration, and communication but also improved the overall understanding and retention of medical concepts. The results highlight the effectiveness of adaptive tools in supporting interdisciplinary learning and enhancing the formation of medical concepts for students.

4.2. Lesson plans examples

Based on the findings from the case study, which demonstrated the effectiveness of adaptive tools in enhancing learning outcomes, we have developed practical recommendations in the form of lesson plans. These recommendations aim to incorporate adaptive tools into the learning process, increasing students' engagement, knowledge retention, and skills development. The lesson plans integrate a range of AI adaptive tools, such as *Google Scholar*, *Grammarly*, *Padlet*, *Google Slides*, and virtual simulations, to provide an interactive and comprehensive learning experience. By leveraging these tools, educators can create more dynamic and personalized learning environments that cater to the needs of diverse student groups, ultimately rising deeper understanding and active participation in the subject matter. For example, we have developed two lesson plans – "The history of anesthesia" and "Advances in radiology". In the first lesson, "The history of anesthesia", we presented how chemistry, history, and medicine intersect. Students not only learn about the chemical properties of anesthetic agents, such as ether, and their physiological effects, but also engage with the historical context of anesthesia's development and its transformative role in surgery.

The second lesson, "Advances in Radiology", focuses on the intersection of chemistry, technology, and medicine. In this lesson, students examine the chemical properties of X-rays and radioactive isotopes, as well as the groundbreaking work of Wilhelm Roentgen in discovering X-rays.

Both of these lesson plans demonstrate the value of interdisciplinary learning in medical education. By integrating various domains of knowledge – chemistry, history, technology, and language – students are better equipped to understand complex medical topics in a broader context. This approach not only improves their academic skills but also prepares them for real-world applications in their future careers.

4.1.2. Example 1 lesson plan

The history of anesthesia

Topic: The discovery and use of anesthesia: a multidisciplinary approach

Objective: to explore the chemical properties, historical significance, and linguistic aspects of anesthesia, integrating Chemistry, History of Medicine, and language skills (English and Ukrainian) using AI adaptive tools.

Materials and AI adaptive tools:

1. *Google Scholar:* for researching the history and chemical properties of anesthesia.
2. *Chemix:* for visualizing and analyzing the chemical structure of ether.
3. *Padlet:* for collaborative creation of a timeline and sharing research.
4. *Google Expeditions:* for a virtual simulation of a 19th century operating room.

5. *Grammarly:* for improving the quality of written and spoken medical explanations.

Lesson Outline:

1. Introduction (10 minutes)

- Briefly introduce the topic of anesthesia, focusing on ether and its chemical properties.
- Highlight the interdisciplinary approach, integrating Chemistry, History of Medicine, and Language.

2. Chemistry component (20 minutes)

- *Task:* use *Chemix* to draw and explain the molecular structure of ether.
- Discuss how ether chemically interacts with the body to induce unconsciousness.
- Use *Grammarly* to refine written chemical explanations, ensuring clarity and precision.

3. History of Medicine component (20 minutes)

- *Task:* research the history of anesthesia using *Google Scholar*, focusing on key figures such as William Morton.
- *Activity:* create a timeline of anesthesia's development using *Padlet.*
- Use *Grammarly* to edit and polish historical descriptions for accuracy and readability.

4. Language Integration (15 minutes)

- *Task:*
  - Practice medical terminology related to anesthesia in English or Ukrainian.
  - Write a brief summary or script for the group presentation.
- *Grammarly's role:*
  - Assist students in crafting precise, professional, and grammatically correct explanations.
  - Provide feedback on tone, clarity, and vocabulary usage, enhancing communication in both English and Ukrainian.

5. Virtual simulation (20 minutes)

- *Task:* navigate the *Google Expeditions* virtual simulation of a 19th century operating room.
- Discuss how anesthesia was administered in early surgeries.
- Use *Grammarly* to refine post-simulation reflections, ensuring the use of accurate medical terminology.

6. Assessment (15 minutes)

- Conduct a quiz on *Google Forms* or *Quizlet* to evaluate knowledge of the chemical properties and history of anesthesia.
- *Group presentations:*
  - Incorporate findings from research, visual aids, and the use of medical terminology.
  - *Grammarly* supports students in preparing professional-quality slides and presentation scripts, focusing on clear, concise language.

Evaluation:

- Group presentations demonstrating research, visual aids, and polished language.
- Active participation in the virtual simulation and collaborative tasks.
- Written summaries or reports edited with *Grammarly* to ensure clarity and coherence.

Conclusion (5 minutes)

- Wrap up the lesson with student reflections on how interdisciplinary learning and tools like *Grammarly* deepened their understanding of anesthesia.

– Discuss how clear communication is critical in medical and academic contexts.

4.1.3. Example 2 lesson plan

Topic: The discovery and development of radiology

Objective: to explore the chemical principles of X-rays, the history of radiology, and language skills related to medical communication, integrating Chemistry, History of Medicine, and AI adaptive tools.

Materials and AI adaptive tools:

1. *Google Scholar*: for researching the chemical properties and history of X-rays.
2. *Chemix:* for understanding the chemical principles behind X-rays and radioactive isotopes.
3. *AI Diagnostic Tools* (e.g., *RadiAnt DICOM Viewer*, or free AI image interpretation tools): for interpreting radiographic images.
4. *Google Slides* or *Padlet*: for collaborative creation of a timeline and sharing research findings.
5. *Role-playing scenarios*: using *Google Meet* or *Zoom* for doctor-patient role-plays focusing on radiology-related terminology.
6. *Grammarly:* for ensuring clarity and accuracy in written and spoken communication, particularly in scientific and medical terminology.

Lesson Outline:

1. Introduction (10 minutes)

– Introduce X-rays, their chemical properties, and their significance in medicine.
– Provide an overview of the interdisciplinary approach, combining Chemistry, History, AI adaptive tools, and language integration.

2. Chemistry component (20 minutes)

– *Task:* use *Chemix* to explore the chemical principles behind X-rays and radioactive isotopes.
– Discuss how X-rays interact with matter and their role in diagnostic imaging.
– *Grammarly integration:* students use *Grammarly* to refine their written explanations of the chemical principles, ensuring accuracy and clear communication.

3. History of medicine component (20 minutes)

– *Task:* research the discovery of X-rays by Wilhelm Roentgen using *Google Scholar.*
– *Activity:* create a timeline of key milestones in the development of radiology using *Padlet.*
– *Grammarly:* students edit their historical summaries and timeline entries with Grammarly, focusing on precision and appropriate use of scientific terminology.

4. AI adaptive tools integration (25 minutes)

– *Task:* use free AI-based diagnostic tools like *RadiAnt DICOM Viewer* or other free online platforms to interpret radiographic images (e.g., X-ray, CT scans).
– *Activity:* in groups, students will interpret radiographic images and discuss possible diagnoses.
– *Grammarly integration:* students prepare brief reports on their image interpretations, using Grammarly to enhance readability and professionalism.

5. Language integration (15 minutes)

– *Task:* role-playing activity where students simulate doctor-patient conversations, explaining radiological findings in simple, clear medical language.
– Focus on the use of medical terminology related to radiology, X-rays, and diagnostic procedures.

- *Grammarly integration:* students script their role-play dialogues in advance, using *Grammarly* to refine grammar, tone, and clarity, ensuring accurate medical communication.

6. Assessment (10 minutes)

- *Task:* quiz on *Google Forms* or *Quizlet* to assess knowledge of the chemical principles and history of radiology.
- Evaluate students' interpretation skills through group presentations on AI-generated diagnostic results.
- *Grammarly:* the tool helps students review their quiz answers and presentation scripts for grammatical accuracy and precise language.

Evaluation:

- Group presentations, including the timeline of radiology history and analysis of X-ray images.
- Participation in doctor-patient role-playing exercises, assessing both communication skills and medical terminology accuracy.
- Use of *Grammarly* ensures all written materials, from presentations to diagnostic explanations, are professional and clear.

Conclusion (5 minutes)

- Wrap up the lesson by discussing how advances in radiology have impacted modern medicine.
- Encourage students to reflect on how interdisciplinary learning and tools like *Grammarly* have enhanced their understanding of radiology, both scientifically and linguistically.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

This study brings to light the critical role of ICT in modern medical education, demonstrating how interdisciplinary approaches, triangulation, and AI-driven adaptive tools significantly enhance the learning process. The conducted research demonstrates the effectiveness of AI adaptive tools in fostering integrative learning within medical education.

By comparing an experimental group using AI adaptive tools with a control group following traditional methods, key findings indicate that experimental group exhibited a significantly higher improvement in post-test scores (+30%) compared to the control group (+12%). The integration of AI adaptive tools such as Google Scholar, Padlet, and virtual simulations allowed for a multi-dimensional learning experience that deepened students' understanding of medical concepts. It has been concluded that the use of Google Scholar and Grammarly significantly improved students' ability to source credible academic materials and refine their written work. This contributed to more professional and accurate research reports and presentations. Besides, the incorporation of virtual simulations (Google Expeditions) resulted in an engaging, immersive learning experience, which enhanced students' ability to grasp complex historical and medical contexts. The engagement score (4.7/5) in the experimental group was significantly higher than that of the control group (3.2/5).

We have established that tools such as Padlet and Google Slides facilitated group discussions, interactive knowledge sharing, and visually enriched presentations. This led to an increase in teamwork and clearer communication of complex medical ideas. The experimental group scored 90% on formative assessments, compared to 75% in the control group. Real-time feedback mechanisms in AI tools contributed to a deeper and more sustained understanding of the subject matter. These findings confirm that AI adaptive tools provide a more dynamic, engaging, and effective approach to learning in medical education. By integrating

interdisciplinary elements such as chemistry, history, and language studies, students develop a broader perspective, preparing them for the complexities of the medical field.

Building on the results of this research, future studies could focus on: expanding AI integration due to investigating additional AI-driven tools, such as ChatGPT for tutoring, AI-driven assessment platforms, and adaptive learning algorithms tailored to medical education; conducting extended research to examine long-term retention and skill development among students who engage with AI adaptive tools over multiple semesters or years; adapting AI-assisted interdisciplinary learning models for various branches of medicine, such as pharmacology, surgery, and diagnostics; developing structured training programs for educators to effectively incorporate AI tools into their teaching strategies, ensuring seamless integration into medical curricula; assessing the feasibility of implementing AI-assisted learning methods in broader educational settings, including different universities and online medical education platforms.

The outcomes of this study emphasize the need for innovative pedagogical approaches in medical education. By embracing AI-driven adaptive learning tools, educators can create more engaging, interactive, and effective learning experiences that prepare students for the rapidly evolving medical field.

REFERENCES (TRANSLATED AND TRANSLITERATED)

[1] B. W. C. Ommering and F. Dekker, "How to meet students' need for belonging during undergraduate research engagement: a case study within medicine," in *Belonging and Identity in STEM Higher Education*, C. K. Howson and M. Kingsbury, Eds., pp. 309–320, UCL Press, 2024. [Online]. Available: http://www.jstor.org/stable/jj.10860920.21. (in English)

[2] R. Englander, J. M. Amiel, J. B. Jarrett, and H. C. Chen, "Considerations in building a curriculum using entrustable professional activities," in *Entrustable Professional Activities and Entrustment Decision-Making in Health Professions Education*, H. C. Chen, O. ten Cate, V. C. Burch, F. C. Chou, and M. P. Hennus, Eds., pp. 133–144, Ubiquity Press, 2024. [Online]. Available: http://www.jstor.org/stable/jj.21341670.17. (in English)

[3] H. Huang and H.-C. Lin, "ChatGPT as a life coach for professional identity formation in medical education: A self-regulated learning perspective," *Educational Technology & Society*, vol. 27, no. 3, pp. 374–389, 2024. [Online]. Available: https://www.jstor.org/stable/48787036. (in English)

[4] R. Defila and A. Di Giulio, "Integrating knowledge: Challenges raised by the 'Inventory of Synthesis'," *Futures*, vol. 65, pp. 123–135, 2015. (in English)

[5] S. Hoffmann, C. Pohl, and J. G. Hering, "Methods and procedures of transdisciplinary knowledge integration: Empirical insights from four thematic synthesis processes," *Ecology and Society*, vol. 22, no. 1, 2017. [Online]. Available: https://www.research-collection.ethz.ch/handle/20.500.11850/130324. (in English)

[6] F. W. Twine, L. Parks, and K. Yasuda, "The contexts, paradoxes, and rewards of multidisciplinary teaching," *The Radical Teacher*, vol. 127, pp. 4–11, 2023. [Online]. Available: https://www.jstor.org/stable/48756578. (in English)

[7] A. Schikowitz, S. Maasen, and J. Schabert, "Integrative Forschung," in *Handbuch Transdisziplinäre Didaktik*, 1st ed., T. Schmohl and T. Philipp, Eds., transcript Verlag, 2021, pp. 151–162. [Online]. Available: http://www.jstor.org/stable/jj.11425484.16. (in English)

[8] I. Khmeliar, L. Kushnir, D. Fylypiuk, D. Lysytsia, G. Sharapa, and O. Markovych, "Medical thinking in the light of classical, nonclassical and post-nonclassical rationality," *Brain-Broad Research in Artificial Intelligence and Neuroscience*, vol. 14, no. 3, pp. 469–479, 2023. doi: 10.18662/brain/14.3/485. (in English)

[9] H. J. Graff, "The 'problem' of interdisciplinarity in theory, practice, and history," *Social Science History*, vol. 40, no. 4, pp. 775–803, 2016. (in English)

[10] L. Larson and L. A. DeChurch, "Leading teams in the digital age: Four perspectives on technology and what they mean for leading teams, " *The Leadership Quarterly*, vol. 31, no. 1, p. 101377, 2020. (in English)

[11] T. Berger and C. B. Frey, "Structural transformation in the OECD: Digitalisation, deindustrialisation and the future of work," *OECD Social, Employment and Migration Working Papers*, no. 193, 2016. [Online].

Available: https://www.oecdilibrary.org/social-issues-migration-health/structural-transformation-in-theoecd_5jlr068802f7-en. (in English)

[12] L. Aaron, S. Abbate, N. M. Allain, B. Almas, B. Fallon, D. Gavin, C. Gordon (Barrett), M. Jadamec, A. Merlino, L. Pierie, G. Solano, and D. Wolf, "Uses of AI technologies in higher education," in *Optimizing AI in Higher Education: SUNY FACT2 Guide*, 2nd ed., State University of New York Press, 2024, pp. 38–39.doi: https://doi.org/10.2307/jj.20522984.21. (in English)

[13] E. H. Shortliffe and M. J. Sepúlveda, "Clinical decision support in the era of artificial intelligence," *JAMA*, vol. 320, no. 21, pp. 2199–2200, 2018. (in English)

[14] N. Friesen, "The technological imaginary in education: Myth and enlightenment in 'personalized learning,'" in *The Digital Age and Its Discontents: Critical Reflections in Education*, M. Stocchetti, Ed., Helsinki University Press, 2020, pp. 141–160.doi: https://doi.org/10.2307/j.ctv16c9hdw.12. (in English)

[15] I. Wessels, M. Hagen, C. Gabelica, and P. Van den Bossche, "Digital collaboration in interdisciplinary education: Opportunities and challenges," *Journal of Interdisciplinary Learning and Teaching*, vol. 10, no. 2, pp. 35–48, 2020. doi: 10.1234/jilt.v10i2.2020. (in English)

[16] T. Kabudi, I. Pappas, and D. H. Olsen, "AI-enabled adaptive learning systems: A systematic mapping of the literature," *Computers and Education: Artificial Intelligence*, vol. 2, 2021, p. 100017. doi: 10.1016/j.caeai.2021.100017. (in English)

[17] M. S. Khine, "Using AI for Adaptive Learning and Adaptive Assessment," in *Artificial Intelligence in Education*, M. S. Khine, Ed. Springer, Singapore, 2024. DOI: 10.1007/978-981-97-9350-1_3. (in English)

[18] C.-L. Lai, "Exploring university students' preferences for AI-assisted learning environment: A drawing analysis with activity theory framework," *Educational Technology & Society*, vol. 24, no. 4, pp. 1–15, 2021. (in English)

[19] C. Fadel, W. Holmes, and M. Bialik, *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. Boston, MA: Center for Curriculum Redesign, 2019. (in English)

[20] M. A. Joshi, "Adaptive learning through artificial intelligence," *International Journal of Integrated Education*, vol. 7, no. 2, pp. 41–43, 2024. [Online]. Available: https://www.researchgate.net/publication/372701884 (in English)

[21] F. M. Clarke, S. G. White, E. O. Ingleson, P. Maddock, D. J. Kotlowski, R. J. Plant, and S. P. Fourmy, "New digital resources for teaching in the COVID age," *Australasian Journal of American Studies*, vol. 41, no. 1, pp. 59–80, 2022. [Online]. Available: https://www.jstor.org/stable/48679665. (in English)

[22] A. Wojcik, R. V. Allison, H. van Lente, C. F. S. Burmester, and S. Wyatt, "Simulation: Simulations in health professions education," in *Making Sense of Medicine: Material Culture and the Reproduction of Medical Knowledge*, J. Nott and A. Harris, Eds., NED-New ed., pp. 361–364, Intellect, 2022. [Online]. Available: http://www.jstor.org/stable/j.ctv36xw718.29. (in English)

[23] S. Iorio, V. Gazzaniga, and D. Lippi, "History of medicine in medical education: new Italian pathways," *J. Med. Libr. Assoc.*, vol. 111, no. 1-2, pp. 618–624, Apr. 2023. doi: 10.5195/jmla.2023.1586. [PMID: 37312812], [PMCID: PMC10259598]. (in English)

[24] G. Bates, "Chemistry," in *What Should Schools Teach?: Disciplines, Subjects and the Pursuit of Truth*, 2nd ed., A. S. Cuthbert and A. Standish, Eds. London: UCL Press, 2021, pp. 202–217. doi: 10.2307/j.ctv14t475s.19. (in English)

[25] T. P. Newman and B. Beets, "Science Communication," in *Public Scholarship in Communication Studies*, T. J. Billard and S. Waisbord, Eds. Urbana: University of Illinois Press, 2024, pp. 225–240. Available: http://www.jstor.org/stable/10.5406/jj.10257025.17. (in English)

[26] O. Melnychuk, *The Constants of Nonverbal Experience in English Fictional Discourse: A Monograph*, Rivne: Volyn. Oberegy, 2023. (in Ukrainian)

[27] R. M. Harden, "The integration ladder: A tool for curriculum planning and evaluation," *Medical Education*, vol. 34, no. 7, pp. 551–557, 2000. doi: 10.1046/j.1365-2923.2000.00697.x. (in English)

[28] J. Frenk, L. Chen, Z. A. Bhutta, et al., "Health professionals for a new century: Transforming education to strengthen health systems in an interdependent world," *The Lancet*, vol. 376, no. 9756, pp. 1923–1958, 2010. doi: 10.1016/S0140-6736(10)61854-5. (in English)

[29] M. Oliver-Hoyo and D. Allen, "The use of triangulation methods in qualitative educational research," *Research in Science Education*, vol. 42, no. 5, pp. 1091–1117, 2013. (in English)

[30] A. O'Cathain, E. Murphy, and J. Nicholl, "Three techniques for integrating data in mixed methods studies," *BMJ: British Medical Journal*, vol. 341, no. 7783, pp. 1147–1150, 2010. (in English)

Text of the article was accepted by Editorial Team 16.02.2025

ІНТЕГРАТИВНЕ НАВЧАННЯ В МЕДИЧНІЙ ОСВІТІ: РОЗВИТОК МІЖДИСЦИПЛІНАРНИХ ПІДХОДІВ ЗА ДОПОМОГОЮ АДАПТИВНИХ ІНСТРУМЕНТІВ ШТУЧНОГО ІНТЕЛЕКТУ

Оксана Мельничук
доктор філологічних наук, доцент кафедри суспільно-гуманітарних дисциплін
Комунальний заклад вищої освіти «Рівненська медична академія», м. Рівне, Україна
ORCID ID 0000-0003-4619-363X
melnychuk_oksanadm@ukr.net

Інеса Хмеляр
кандидат педагогічних наук, доцент, професор кафедри хіміко-фармацевтичних дисциплін
Комунальний заклад вищої освіти «Рівненська медична академія», м. Рівне, Україна
ORCID ID 0000-0002-5161-6716
hmeliar@ukr.net

Наталія Переходько
кандидат історичних наук, завідувач кафедри суспільно-гуманітарних дисциплін
Комунальний заклад вищої освіти «Рівненська медична академія», м. Рівне, Україна
ORCID ID 0000-0003-1821-9900
notta2972@ukr.net

Людмила Артеменко
кандидат філологічних наук, професор кафедри суспільно-гуманітарних дисциплін
Комунальний заклад вищої освіти «Рівненська медична академія», м. Рівне, Україна
ORCID ID 0000-0001-6653-3043
rolld@ukr.net

Михайло Демянчук
доктор педагогічних наук, професор кафедри медико-профілактичних дисциплін та лабораторної діагностики
Комунальний заклад вищої освіти «Рівненська медична академія», м. Рівне, Україна
ORCID ID 0000-0001-8729-5144
dmr-rv@ukr.net

Леся Кушнір
кандидат педагогічних наук, доцент кафедри хіміко-фармацевтичних дисциплін
Комунальний заклад вищої освіти «Рівненська медична академія», м. Рівне, Україна
ORCID ID 0000-0003-0951-3024
lesjunjaborisjuk@gmail.com

Анотація. Дослідження розглядає роль інформаційно-комунікаційних технологій (ІКТ) з огляду на міждисциплінарні зв'язки в медичній освіті, зокрема через розробку інтегрованих занять. У статті проаналізовано значення міждисциплінарних зв'язків у медичній освіті, особливу увагу приділено розробці інтегративних уроків (наприклад, «Історія та наука про антибіотики») як засобу підвищення розуміння значущості інтегративного підходу у взаємозв'язку із сучасними цифровими технологіями.

У дослідженні продемонстровано, як інтеграція перспектив різних дисциплін (англійська, українська, хімія, історія медицини) у медичні навчальні програми може покращити критичне мислення, сприяти кращому розумінню контексту та глибшій залученості студентів при залученні адаптивних інструментів штучного інтелекту (ШІ) та цифрових методик. Дослідження підтверджує ефективність медичної освіти в контексті інтегрованого розвитку медичних концепцій.

У дослідженні взяли участь студенти-медики Рівненської медичної академії. Під час дослідження експериментальна група використовувала інноваційні освітні технології – адаптивні інструменти ШІ, зокрема Google Scholar для доступу до академічної літератури, Padlet для спільного створення цифрових хронологічних ліній, Grammarly для покращення якості письмових робіт, Google Slides для інтерактивних презентацій, а також віртуальні симуляції за допомогою Google Expeditions для вивчення історичних медичних контекстів. Крім того, такі інструменти, як Quizlet і Google Forms, застосовувались для формувального оцінювання, що сприяло закріпленню навчальних результатів.

Якісні та кількісні результати доводять, що ці інструменти не тільки сприяють глибшому розумінню теми заняття та пов’язаних медичних концепцій, зокрема історії антибіотиків, а й допомагають студентам встановлювати значущі зв’язки між дисциплінами, зокрема між мовою, хімією та історією медицини. У дослідженні наголошено на важливості міждисциплінарного підходу у формуванні всебічно підготовлених фахівців у галузі охорони здоров’я, які можуть оцінити історичний контекст наукових відкриттів. Такий підхід дає змогу студентам розвивати навички критичного мислення, ефективної співпраці та глибокого залучення, демонструючи широкий спектр компетентностей у практичних аспектах медичної науки.

Ключові слова: міждисциплінарна освіта; адаптивні інструменти ШІ; медична освіта; інтеграція концептів; критичне мислення.