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INTERACTIVE TECHNOLOGIES FOR CLIL-ORIENTED PHYSICS INSTRUCTION IN DISPERSED LEARNING ENVIRONMENT AT HIGHER MILITARY EDUCATIONAL INSTITUTIONS

Abstract. Higher military educational institutions operating under dispersed learning conditions require effective digital approaches that support both professional training and foreign language development. Accordingly, this study examines the effectiveness of integrating interactive technologies and the Content and Language Integrated Learning (CLIL) approach into physics instruction through the use of Moodle, Google Meet, Google Forms, multimedia presentations, bilingual instructional materials, and video-based laboratory demonstrations.

Modern military specialists require not only strong engineering knowledge but also the ability to use English-language technical resources throughout their professional careers. Consequently, physics instruction should integrate subject-specific content with foreign language development from the earliest stages of military education.

English language proficiency plays a significant role in physics instruction, since much technical documentation, device manuals, scientific articles, and materials on military technology are provided in English. Considering this, applying the CLIL approach, which enables simultaneous acquisition of physics content and professional English terminology, is well justified.

The research employed a quasi-experimental design supported by classroom observation, and comparative analysis. The study involved 69 first-year cadets, divided into an experimental and a control group. The experimental group was taught using a combination of interactive technologies, digital tools, and CLIL elements integrated into lectures, practical sessions, and laboratory work. The experimental group achieved a higher mean score (M = 73.79) than the control group (M = 57.85), indicating the positive impact of integrating interactive technologies and CLIL elements into physics instruction.

The study confirms that integrating interactive technologies and CLIL enhances the effectiveness of physics instruction in dispersed learning environments and contributes to the development of both professional and language competencies required for modern military specialists.

Keywords: physics; interactive teaching methods; laboratory work; dispersed learning environment; CLIL; integration of fundamental and professionally oriented disciplines.

1. INTRODUCTION

The problem statement. The modernization of Ukraine's higher education system requires the development of effective means to form a well-rounded individual capable not only of applying acquired knowledge in professional activities but also of continuously expanding it. Modern higher military education faces challenges in both educational and engineering domains; yet, its primary function remains the provision of fundamental academic, cultural, and practical training for specialists.

Constant updates of training programs in the military sphere reflect changes in the requirements for modern education. The necessary level of professional readiness of future military specialists – particularly their readiness to perform duties in accordance with their chosen specialty – is being redefined.

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Since the primary goal of the national education system is to create favourable conditions for personal development and self-realization, all aspects of the educational process across military educational institutions are undergoing substantial change. These changes are influenced by rapid technological progress and the ongoing war. Modern youth is shaped by information technologies; nonetheless, both general secondary and higher education must ensure that this generation is capable of lifelong learning and professional growth. This need is especially acute in the military sphere, where the shortage of young qualified personnel affects the functioning of the Armed Forces.

In higher military educational institutions that train engineering personnel, *Physics* is among the fundamental disciplines studied during the first year. Analysis of curricula, syllabi, methodological documents, and three years of experience teaching in a dispersed learning environment revealed monotony and certain limitations in physics instruction, which led to lower learning outcomes and negatively affected subsequent study of professionally oriented subjects.

The intensity of the implementation of innovative technologies in all spheres of human activity necessitates the training of highly qualified specialists who must possess extensive professional capabilities and be capable not only of continuous self-education and the acquisition of new knowledge during their studies at military higher education institutions, but also of applying the acquired professional knowledge and skills in accordance with their field of training and professional practice. Nevertheless, recent experience indicates that the level of physics knowledge among first-year cadets is considerably lower than in previous years. Yet professional expectations for modern military specialists have not decreased. Professional qualities must be developed from the first year of training.

Therefore, a modern cadet must develop the habit of systematic work to master profession-specific knowledge and skills. To ensure truly high-quality education, it is essential to employ all available approaches and methods to develop a high level of knowledge, skills, and competencies in *Physics*. All these factors must be taken into account in the contemporary educational process, particularly in the current context, where cadets of military higher education institutions study in a dispersed format across different locations and under varying living and learning conditions.

To ensure cadets are prepared for professional activity, the educational process must be organized so that fundamental disciplines – including physics – systematically involve professionally oriented and research tasks using both traditional and modern teaching tools.

Moreover, in the process of acquiring fundamental knowledge, the need for foreign language proficiency – English in particular – and its practical and professional relevance for the future military specialist is becoming increasingly significant. This is realized in the teaching of physics across all types of classes, including lectures, practical sessions, and laboratory work.

An important innovative direction for improving the effectiveness of instruction is the integration of professionally oriented disciplines with English language learning through the CLIL (Content and Language Integrated Learning) methodology. The use of CLIL makes it possible to combine the acquisition of professional and fundamental material with the development of cadets' language competencies. For example, the study of physical phenomena, laws, and modern equipment is accompanied by familiarization with the corresponding terminology and instructions in English, which forms professional language competence and prepares cadets to work with modern technical sources of information and documentation. Such an approach not only enhances cadets' knowledge of physics but also ensures their readiness to use English in professional activities, which is particularly relevant in the context of globalization and cooperation with international partners.

It is worth noting that upon entering the 21st century, the global community found itself in a situation in which the professional component of specialist training in any field –including the military – became a top priority. Military education, as an integral part of the national education system, must ensure the reproduction of the intellectual potential of the military sector and contribute to strengthening the defense capability of the state in accordance with the Constitution and the laws of Ukraine. Therefore, great importance is placed on developing in cadets – as future professionals – a clear understanding of the integration of fundamental and professional knowledge, skills, and abilities; the professional orientation of the components of fundamental disciplines within the educational process of a higher military educational institution; their role in the professional sphere; prospects for career development; and confidence in choosing their future specialty.

Even the use of modern equipment during physics classes clearly, rather than implicitly, demonstrates the importance of basic English-language skills necessary for understanding information displayed on different types of devices.

Thus, the ultimate goal of reorganizing the system of professionally oriented training is to prepare cadets, under dispersed learning conditions, for practical activity in the rapidly changing technological environment; to encourage professional self-development; to ensure a high level of competence and language readiness – all of which are supported through the implementation of CLIL in the process of teaching physics.

The study addressed the following research tasks:

• to analyze contemporary scientific literature on interactive technologies, CLIL methodology, and dispersed learning in higher education;

• to describe the methodological features of integrating interactive technologies and CLIL elements in physics instruction;

• to evaluate the effectiveness of the proposed approach through a quasi-experimental study involving cadets of a higher military educational institution.

In the context of this study, dispersed learning is understood as an educational format in which instructors and cadets participate in the learning process while being physically located in different places due to operational, security, or organizational conditions. Such a format may include elements of distance learning, blended learning, and asynchronous interaction supported by digital educational platforms.

Interactive technologies are considered a set of digital and pedagogical tools that promote active participation of learners in the educational process through the use of multimedia resources, online platforms, simulations, and collaborative learning activities.

For terminological consistency, the concepts used in this study are differentiated as follows. Interactive technologies constitute the central concept and refer to a combination of digital and pedagogical tools that facilitate active learner participation, interaction, collaboration, and feedback. Digital educational technologies are understood as digital platforms, applications, and resources used to support teaching, learning, communication, and assessment; in the present study, they include Moodle, Google Meet, Google Forms, and digital applications for processing experimental data. *Interactive teaching methods* refer to pedagogical ways of organizing learning activities through which cadets actively engage with instructional content, the instructor, and each other, including collaborative laboratory work, online activities, interactive tests, and guided discussions. The broader term *innovative teaching methods* is used only to denote newly implemented or substantially adapted pedagogical approaches and is not treated as a synonym for interactive technologies.

In the present study, interactive technologies included the Moodle learning management system, Google Meet for synchronous online interaction, Google Forms for assessment and feedback collection, video-based laboratory demonstrations, multimedia presentations with bilingual content, and digital applications for processing experimental data. These tools

supported active learner participation, independent preparation, collaborative learning, and the implementation of CLIL principles in physics instruction.

The CLIL approach involves the simultaneous acquisition of subject knowledge and foreign language competence, enabling cadets to study physics while developing their ability to use professional English terminology.

The scientific novelty of this study lies in the development and implementation of a methodological approach that combines interactive educational technologies and CLIL principles for teaching physics in higher military educational institutions operating under dispersed learning conditions.

Analysis of recent research and publications. In contemporary scholarly literature, considerable attention is devoted to the issues of educational development and the implementation of innovative teaching approaches. These aspects have been examined in the works of such scholars as V. Kremen [1], J. Mezirow [2], and J. Hattie [3]. The training of qualified military personnel has been the subject of research by V. Yahupov [4] and J. McDermott [5], who emphasize the specifics of professional preparation within the military education system.

Problems related to the implementation of modern professional education and the study of the competence of future specialists are examined in the research by O. Ovcharuk [6] and A. Mulder [7]. The introduction of innovative technologies into the educational process has been widely discussed in the studies of O. Spirin, K. Kolos, and R. Bernard, which highlight the potential of modern pedagogical tools to enhance learning effectiveness [8], [9]. Recent studies further confirm that technology-enhanced and blended learning environments contribute to increased learner engagement, motivation, and academic achievement in higher education [10], [11].

In addition, issues related to organizing and conducting laboratory practicums have been addressed in the studies of A. Hofstein, and S. Lunetta, which emphasize the role of laboratory work in the formation of professional competencies [12]. Contemporary research also demonstrates that digital laboratory environments and multimedia resources enhance students' autonomy and practical skills, particularly in technology-supported learning contexts [13].

In foreign pedagogical practice, considerable attention has been paid to the CLIL methodology. The term “CLIL” was first introduced by David Marsh [14], with further development presented in the works of C. Dalton-Puffer [15], Y. L. T Ting [16], and other scholars. These researchers demonstrated that CLIL is an effective means of integrating subject-specific and language competencies, which is particularly relevant for the training of specialists in technical and military institutions. Recent research further confirms the effectiveness of CLIL in STEM education, demonstrating its positive impact on scientific literacy, subject-specific vocabulary acquisition, and professional communication skills [17].

Furthermore, emerging technologies such as augmented reality create additional opportunities for integrating language and content learning within technology-enhanced CLIL environments [18].

Overall, existing research demonstrates that digital technologies, interactive learning environments, and CLIL-oriented instruction contribute to improving learning effectiveness, learner engagement, motivation, and academic performance across diverse educational settings [19].

Despite the significant body of research devoted to educational innovations, military professional training, laboratory practicum, and CLIL methodology, a number of important aspects remain insufficiently explored. In particular, the issue of systematic integration of interactive technologies and CLIL elements in the process of teaching physics in higher military educational institutions in a dispersed learning environment has not yet been the subject of a comprehensive scientific analysis. Existing studies predominantly consider interactive

technologies, laboratory work, or CLIL implementation in isolation, without taking into account the specific organizational, methodological, and security-related constraints associated with dispersed training of military cadets. Furthermore, the didactic potential of combining interactive technologies with CLIL in physics instruction for the purpose of developing both professional and foreign-language communicative competencies of future military specialists remains insufficiently substantiated. These research gaps determine the relevance of the present study and justify its focus on identifying effective pedagogical solutions for physics instruction in higher military educational institutions operating under dispersed learning conditions.

The aim and objectives of the study. The aim of the study is to evaluate the effectiveness of integrating interactive technologies and CLIL principles into physics instruction in higher military educational institutions under dispersed learning conditions.

2. RESEARCH METHODOLOGY

The study employed a quasi-experimental research design to evaluate the effectiveness of integrating interactive technologies and the CLIL approach into *Physics* instruction under dispersed learning conditions in a higher military educational institution. A quasi-experimental design was selected because random assignment of participants was not feasible due to organizational and educational constraints associated with the existing academic groups.

Participants. The study involved 69 first-year cadets of Korolov Zhytomyr Military Institute enrolled in the compulsory Physics course. The participants were divided into two naturally existing academic groups: an experimental group (n = 43) and a control group (n = 26). Both groups studied the same curriculum, covered identical *Physics* topics, and completed the course during the same academic semester.

Instructional Procedure. The control group received physics instruction using conventional teaching approaches routinely employed at the institution. The experimental group was taught according to a CLIL-oriented instructional model supported by interactive digital technologies.

The instructional intervention integrated:

- the Moodle learning management system for organizing course materials and independent learning;
- Google Meet for synchronous online instruction and consultations;
- Google Forms for formative and summative assessment;
- multimedia presentations containing bilingual (Ukrainian-English) educational materials;
- video demonstrations of laboratory experiments;
- digital applications supporting experimental data processing and analysis.

Throughout the course, English-language terminology was systematically incorporated into lectures, practical classes, laboratory work, instructional materials, and assessment activities in accordance with the CLIL principles.

Data Collection. Several complementary methods were employed to collect research data:

- observation of cadets' learning activities during lectures, practical classes, and laboratory work;
- analysis of academic performance throughout the semester;
- comparison of final achievement scores between the experimental and control groups;
- qualitative analysis of cadets' engagement, learning autonomy, and participation during laboratory activities.

Statistical Analysis. Descriptive statistics were calculated for both groups, including the mean (M) and standard deviation (SD). Group differences were evaluated using Welch's

independent-samples t-test, which provides reliable estimates when sample sizes differ and the assumption of equal variances is violated. The magnitude of the observed effect was estimated using Cohen's d, allowing interpretation of the practical significance of the intervention in addition to statistical significance.

Ethical Considerations. The study was conducted within the regular educational process of the institution. Participation involved the analysis of routine educational activities and academic performance. Individual participants remained anonymous during data processing and reporting, and all results are presented only in aggregated form.

3. THE RESULTS AND DISCUSSION

In all modern higher military educational institutions, significant attention is given to developing cadets' clear understanding of how fundamental knowledge can be applied in further study and professional practice. This includes understanding the professional orientation of fundamental disciplines, their role in military work, prospects for career development, as well as building confidence in choosing their future specialty. Graduates of such institutions must be ready to perform duties in primary military positions, be mobile and technologically competent, and be capable of working with modern equipment, for which technical information and operating instructions are mostly provided in English. Cadets begin acquiring this combination of competencies from the start of their studies, while learning *Physics* as part of the fundamental training cycle.

The use of interactive teaching methods during physics laboratory work under dispersed learning conditions aims to implement a competency-based approach. This helps align the fundamental and specialized components of cadets' professional training, enabling them to master essential knowledge and skills in a relatively short period–skills required both during further studies in specialized departments and in future military practice.

Therefore, for each topic, those laboratory works were selected that could be performed using interactive teaching methods. Laboratory work determines the significance not only of improving the knowledge, skills, and abilities acquired by cadets in the study of physics, but also of developing a competency-based approach to solving tasks as a whole. Therefore, a modernized system of laboratory work and a developed repository of video-based laboratory activities, combined with contemporary educational technologies, expands the possibilities for conducting classes under conditions of dispersed learning. This, in turn, increases interest in studying the discipline and brings cadets' practical knowledge closer to the future professional activities of a modern military specialist.

When laboratory work is conducted individually, the instructor's role is mainly to assist with measurements and check the finished task. However, when cadets are prepared in advance, the instructor's role becomes more guiding–helping organize the process and providing methodological support during calculations and data analysis. Cadets must complete all necessary tasks and submit (defend) their laboratory reports during the allocated class time.

Expected outcomes of performing all laboratory work using interactive methods include:

- improved quality of higher military education and competitiveness of graduates;
- increased knowledge, skills, and competencies in physics among cadets from experimental groups;
- cadets' awareness of the importance of more in-depth study of physics through laboratory work as part of professional competence development;
- refinement of didactic materials for laboratory tasks, taking into account the conditions of dispersion;
- activation of cadets' cognitive and research activity, and increased motivation;
- reduced failure rates during examination sessions;

- identification and timely correction of potential difficulties during experimental laboratory work.

Studying *Physics* in a dispersed learning environment during martial law has not decreased in scope, yet it has undergone certain transformations. Since instructors and cadets in dispersed learning environments no longer have the opportunity to meet as frequently as they did before the war, it is advisable to employ all available modern educational technologies. It is precisely under such learning conditions that the following factors become particularly evident, as they directly indicate a decline in the level of knowledge acquisition in the discipline:

- cadets struggle to record and process lecture material in full;
- during practical lessons, they lack the foundational knowledge necessary to understand and master skills needed for further study;
- laboratory works requiring prior independent preparation are often left unfinished and postponed to extra-class time;
- cadets demonstrate unwillingness or inability to develop intellectually;
- taking tests or exams becomes a challenge for many cadets who are unaccustomed to such academic procedures and can provoke some resistance to the situation.

It is worth noting that under conditions of dispersed learning in the study of *Physics*, academic staff face challenges no less significant than those encountered by cadets, particularly concerning the material resources of the laboratory.

Among the main challenges observed among first-year cadets are:

- low level of school-based physics knowledge (influenced by reduced school standards, lack of motivation, extended periods of distance learning, etc.);
- inability to work independently during class–during both practical and laboratory sessions;
- inability to read or translate information on modern devices;
- tendency of cadets to automatically copy reports from better-prepared cadets or from those who have already submitted a report form for a positive grade;
- inability to follow written instructions for laboratory work without waiting for help from the instructor (cadets are not able–or have not been trained–to follow the procedure of the laboratory work, and therefore simply wait for the instructor or engineer to assist with the necessary measurements and indicate where to record them in the tables or how to perform the calculations);
- inability to convert the obtained measurement data into the SI system;
- inability to perform calculations independently;
- inability to construct graphs correctly and determine variable relationships (cadets do not understand how to place axes (which variable depends on which) or how to construct graphs);
- inability to analyse experimental data, build graphs, and interpret results;
- lack of knowledge regarding error types and how to represent them on graphs;
- writing conclusions in a personal rather than impersonal academic style [20], [21].

Given the above, it is clear that teaching *Physics* in a dispersed learning environment cannot rely solely on previous methods. New, effective approaches must be developed to ensure high-quality training of cadets, regardless of current conditions, since the requirements for the professional level of military specialists are only increasing over time.

Special attention in this study was given to the role of digital educational technologies, including the Moodle platform, Google Forms for assessment and data collection, video-based laboratory demonstrations, and data-processing applications, which served as key tools supporting the implementation of CLIL and interactive learning methods.

To enhance the effectiveness of training and improve the level of knowledge, skills, and competencies acquired by cadets in physics, digital educational technologies must be applied–especially under dispersed learning conditions – to ensure high-quality mastery of the material. For this purpose, basic physics concepts and definitions in English were actively used during all types of classes: lectures, practical sessions, and laboratory work.

It is important to emphasize that modern approaches to teaching physics significantly benefit from the application of CLIL, which enables cadets to develop subject-specific competence in physics while simultaneously improving their English-language proficiency. When combined with interactive teaching methods, CLIL substantially increases cadet engagement, cognitive activity, and motivation.

The use of CLIL and interactive teaching methods contributes to:

- developing the ability to read and understand scientific and technical texts in English;
- mastering terminology and standard expressions used in international practice and modern military equipment;
- enhancing analytical thinking and autonomy in processing experimental data, as instructions and software for modern equipment are typically provided in English;
- integrating professional knowledge with language skills–essential for military specialists working with modern technologies and information systems.

Thus, integrating English-language materials and CLIL elements into the learning process – combined with interactive teaching methods–not only improves the effectiveness of learning *Physics* but also develops the communicative, cognitive, and practical skills required for future military service [22].

Regarding adjustments to lecture formats in a dispersed learning environment, instructors actively used the Moodle platform, providing cadets with access to course materials and lecture presentations after each session. Importantly, all key concepts, definitions, and laws were presented in two languages – Ukrainian and English (Fig. 1). This was supplemented by interactive elements, including embedded videos, test questions, and simulations. Such an approach simultaneously implemented CLIL principles and increased cadet engagement, improving comprehension of theoretical material and readiness to work with modern technical equipment.

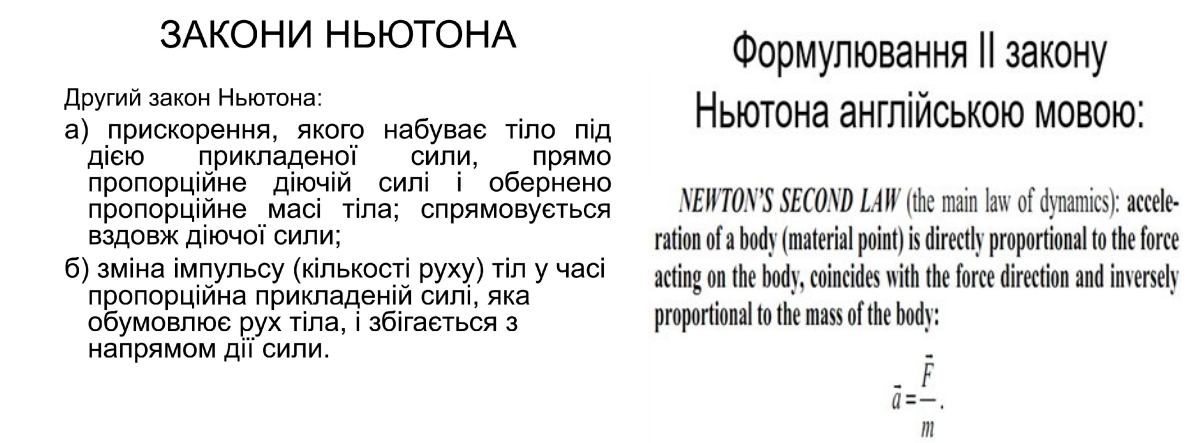

Figure 1. Examples of slides from the presentation on the topic "Dynamics," section "Mechanics."

To improve the conduct of practical classes under conditions of dispersion and to enhance the effectiveness of work with cadets, individual assignments were used in the form of tests, reports on current achievements in science and technology, calculation tasks related to the relevant topic/module, online activities via Google Meet, as well as the Moodle platform with a fully developed course.

All these activities incorporated basic English terminology, allowing the integration of CLIL principles. As a result, cadets simultaneously improved their physics knowledge and mastered the professional English vocabulary needed to operate modern equipment and work with international sources.

The greatest number of changes and variations in the organization of classes was implemented during physics laboratory sessions, since under conditions of dispersion, both cadets and instructors faced the problem that, in the event of a cadet's absence from a class, it was necessary to make up the session and submit a laboratory report as a mandatory requirement for admission to the credit test/examination. Therefore, during the initial stage of adapting laboratory work for dispersed learning, the following formats were tested:

- Individual measurements. This approach did not yield positive results due to the low level of cadets' preparedness and the instructor's inability to provide adequate support when working with groups of over 18 cadets.
- Group Measurements (groups of 2 - 4 cadets). This method worked well when instructors formed balanced groups according to cadets' knowledge levels. CLIL was effectively incorporated through joint discussion of terminology and instructions in English.
- Sessions with a Mentor for Cadets Requiring Additional Academic Support. A highly effective method, particularly when used consistently throughout the laboratory cycle. CLIL supported better comprehension of theoretical explanations and guided use of English-language materials.
- Laboratory Work with Prior Preparation. On the eve of the session, cadets watched a video demonstration of the laboratory experiment using real equipment and received a presentation with step-by-step examples of calculations for different variants (all terminology and explanations in the video and presentation were provided in English, enabling the simultaneous development of physics knowledge and English-language competence). During the in-class session, cadets independently performed measurements, completed calculations, constructed graphs, and wrote conclusions according to academic requirements. This approach proved quite effective, as it enabled even those cadets who were absent from class for valid reasons – such as duty assignments, illness, or official travel – to independently complete the entire laboratory work outside regular classroom hours [23].

It is important to emphasize that this particular method of conducting physics laboratory work – involving pre-class preparation, video demonstrations, bilingual presentations, and step-by-step explanations–produced the most positive results:

- Cadets arrived at the laboratory session already theoretically prepared, with a clear understanding of how to perform the experimental part.
- Thanks to the presentations containing photo and video materials, with English terminology and explanations, they simultaneously mastered essential professional vocabulary (see Fig. 2 for an illustrative example).

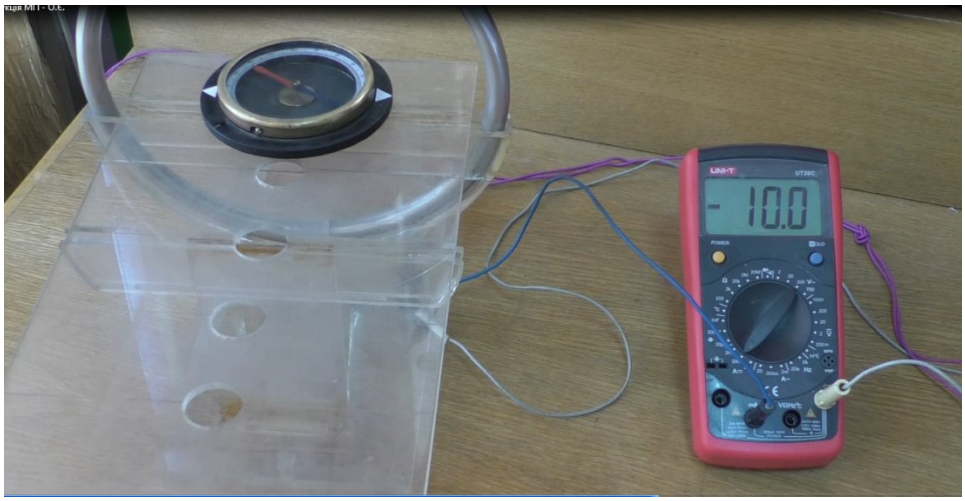

Figure 2. Video fragment of the laboratory work (recording measurements on the tangent galvanometer during reverse current flow of 10 mA).

● The process of taking measurements became much faster, which left significantly more class time for: performing calculations, filling in tables, constructing graphs, and writing well-structured conclusions.

● The level of interest in modern methods and tools of calculation using achievements in the software domain increased; cadets began to independently search for such programs to process the obtained experimental data, which enabled them to complete the task as quickly as possible. Most often, an engineering calculator and the mobile application Photomath for processing data of varying levels of complexity were used.

● The interest in studying the discipline increased due to the clear visualization of work results, the use of modern equipment, and approaches to modernizing equipment for conducting measurements (Fig. 3 presents a photo of a video fragment showing laboratory equipment and modern equipment used for its modernization).

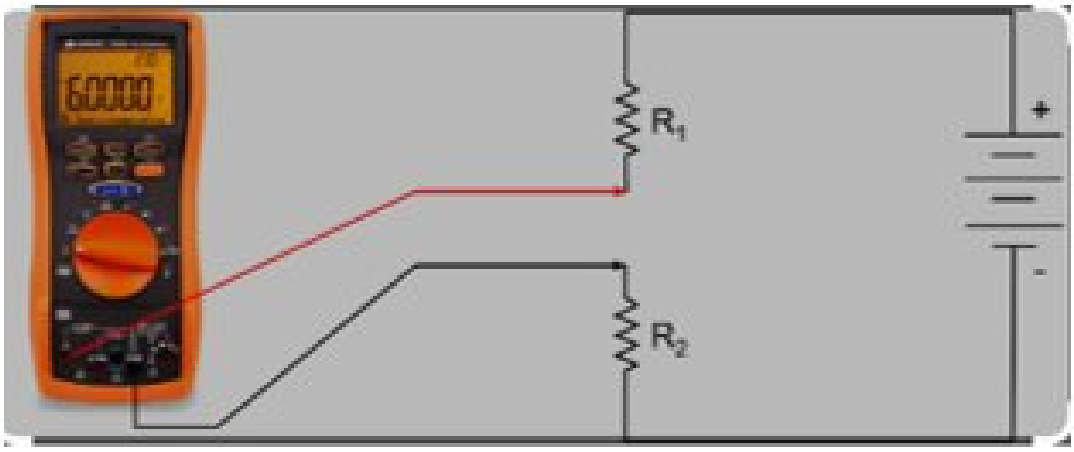

Figure 3. Diagram of measuring resistance using a multimeter.

● Cadets began submitting their work during the class itself, rather than remaining with a ‘set’ of completed laboratory assignments. This confirmed the positive impact of pre-class preparation using innovative technologies.

● When cadets were absent from laboratory sessions for valid reasons (illness, duty shifts, deployment, etc.), they could complete the assignment as follows: watch the video

demonstration; obtain their individual data set from the instructor; perform all calculations using the provided bilingual presentation; and prepare the report according to the required format (see Fig.4 and Fig. 5).

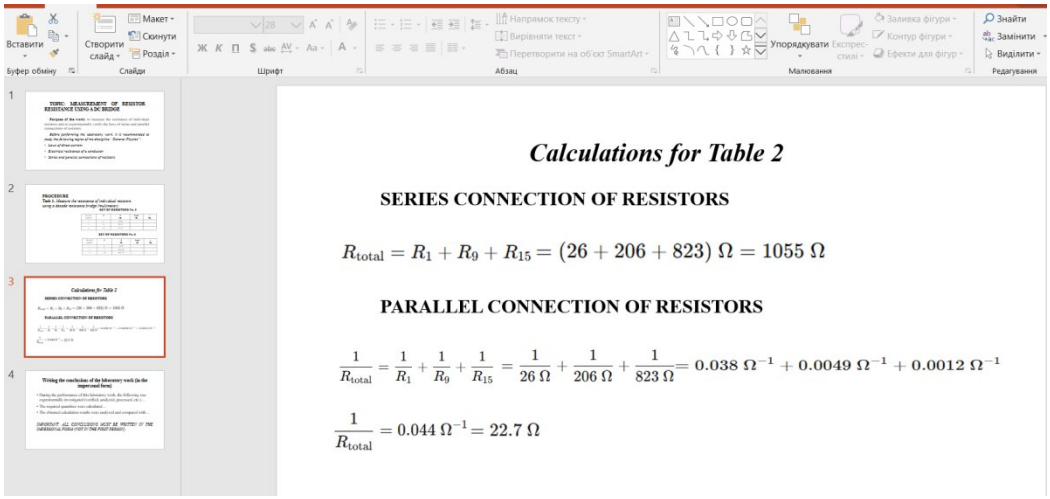

Figure 4. Presentation screenshot – instructor's explanation of the material and calculations.

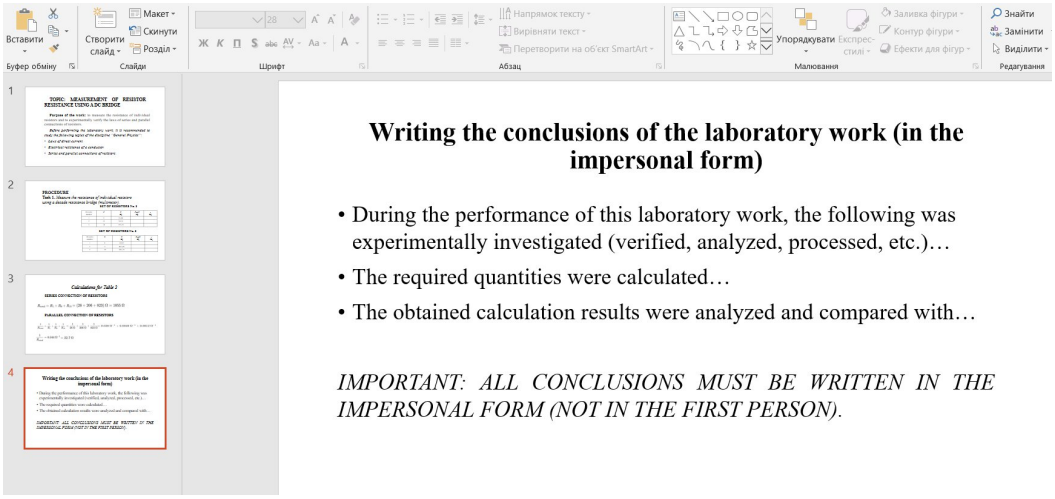

Figure 5. Google Meet session – preparation of the laboratory report conclusions.

• The general level of knowledge among cadets significantly increased in those groups where self-study was combined with innovative technologies in a dispersed learning environment. This improvement was confirmed by their successful participation in national and international student conferences.

The comparative analysis of the test results obtained from the experimental and control groups revealed a statistically significant difference in academic performance. The experimental group (n = 43), instructed using interactive technologies and CLIL elements, achieved a mean score of M = 73.79 (SD = 19.07), whereas the control group (n = 26), taught using traditional instructional methods, demonstrated a lower mean score of M = 57.85 (SD = 29.07).

Considering the unequal sample sizes and the unequal variances between the groups, as confirmed by Levene's test ($F(1,67) = 20.13$, $p < 0.001$), Welch's independent-samples t-test was applied to evaluate the statistical significance of the observed difference. The analysis

demonstrated a statistically significant difference between the groups ($t = 2.49$, $df = 38.17$, $p = 0.017$). The calculated effect size was moderate (Cohen's $d = 0.68$), indicating the practical significance of the proposed instructional approach.

The observed difference of 15.94 points indicates a substantial advantage of integrating interactive technologies and CLIL-based instruction. Furthermore, the experimental group exhibited lower variability in test scores than the control group, as reflected by the smaller standard deviation ($SD = 19.07$ vs. $SD = 29.07$), indicating more consistent academic performance.

Furthermore, the median score in the experimental group exceeds that of the control group, confirming the overall tendency toward higher achievement levels. The reduced number of low-performing students in the experimental group represents an additional indicator of improved learning effectiveness.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Considering all of the above, it becomes evident that teaching in higher military educational institutions today requires continuous methodological improvement and professional development on the part of instructors. Training future military professionals under current conditions demands maximum dedication from both teachers and cadets.

Since academic foundations are laid during the first years of study, and continuously built upon throughout the entire period of education at a higher military educational institution, the value of each course – whether fundamental or professionally oriented – becomes especially clear. Practical training, particularly the experimental component in physics, must incorporate modern technologies wherever possible and reflect today's requirements regarding English language proficiency and the skills required to use it both in the educational process and in further professional practice.

The use of innovative teaching methods in physics instruction in a dispersed learning environment enables instructors to apply a wider range of learning formats to improve results, increase interest in the discipline, and align training with real professional needs.

The study confirms the effectiveness of integrating interactive technologies and the CLIL approach in teaching physics at military educational institutions under dispersed learning conditions. The findings of the study demonstrated that the use of interactive teaching methods, digital educational technologies, and bilingual instructional materials contributes to improving cadets' engagement, motivation, and academic performance.

The integration of CLIL elements into physics instruction enables cadets to develop both subject knowledge and professional English-language competence, which is essential for working with modern technical documentation and equipment. The use of digital tools and interactive laboratory formats also facilitates more efficient organization of experimental work and enhances cadets' ability to independently process experimental data.

The comparative analysis of the experimental and control groups indicates that the combined use of interactive technologies and CLIL enhances knowledge acquisition and supports the development of analytical thinking and professional communication skills.

The results of this study confirm the relevance of applying digital educational technologies in the training of future military specialists, particularly under dispersed learning conditions caused by organizational and security challenges. The findings may be used to improve methodological support for teaching fundamental disciplines in higher military educational institutions.

Future research should focus on expanding the use of interactive technologies and digital tools in physics laboratory work, as well as on exploring additional ways to integrate CLIL methodology into STEM disciplines in military education.

The following recommendations are proposed to improve the effectiveness of laboratory work under dispersed conditions:

- developing laboratory setups using new devices and equipment;
- designing laboratory procedures that account for the complexity of tasks and cadets' levels of preparation;
- selecting assignment variants that prevent copying;
- conducting consultations before laboratory sessions;
- integrating interactive teaching methods into laboratory practice;
- further implementing CLIL for simultaneous development of subject and language competencies;
- involvement of mentors during laboratory classes from among cadets of the same group;
- advanced selection of the composition of teams;
- distributing responsibilities among group members (setup, calibration, measurements, calculations, report writing, data analysis, conclusions);
- allocating separate time for the defense of laboratory reports;
- allocating reserve time for completing outstanding laboratory assignments;
- continuously improving the quality of laboratory assignments;
- applying interactive technologies and CLIL during laboratory work;
- organizing discussions led by senior cadets about the relevance of acquired skills to future studies and military practice.

Thus, integrating interactive teaching methods and CLIL not only enhances the effectiveness of learning *Physics*, but also develops the key professional and communicative competencies required from modern military specialists.

It is also important to note that while the results indicate a clear positive trend, caution should be exercised in generalizing the findings. Factors such as sample size, group composition, and prior language proficiency may have influenced the outcomes. Therefore, further research involving larger samples and controlled experimental conditions is recommended.

Overall, the results are consistent with the existing literature, which highlights the pedagogical value of CLIL in promoting both subject-specific competence and cognitive development. In the context of military education, where integrating technical knowledge and foreign language proficiency is of strategic importance, CLIL appears to be a particularly promising instructional approach.

DECLARATION OF GENERATIVE ARTIFICIAL INTELLIGENCE AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist in checking statistical calculations. The authors reviewed the output and take full responsibility for the accuracy of the reported statistics, the interpretation of the findings, and the content of this publication.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to the preparation, submission, or publication of this article.

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ІНТЕРАКТИВНІ ТЕХНОЛОГІЇ ДЛЯ CLIL-ОРІЄНТОВАНОГО НАВЧАННЯ ФІЗИКИ В УМОВАХ РОЗОСЕРЕДЖЕНОГО НАВЧАЛЬНОГО СЕРЕДОВИЩА У ВИЩИХ ВІЙСЬКОВИХ НАВЧАЛЬНИХ ЗАКЛАДАХ

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Анотація. Вищі військові навчальні заклади, які функціонують в умовах розосередженого освітнього середовища, потребують ефективних цифрових підходів, що забезпечують як професійну підготовку, так і розвиток іншомовної компетентності. Тому у цьому дослідженні розглядається ефективність інтеграції інтерактивних технологій та підходу CLIL (Content and Language Integrated Learning) у викладання фізики з використанням Moodle, Google Meet, Google Forms, мультимедійних презентацій, двомовних навчальних матеріалів і відеодемонстрацій лабораторних робіт.

Сучасні військові фахівці потребують не лише ґрунтовних інженерних знань, а й уміння використовувати англомовні технічні ресурси протягом усієї професійної діяльності. Відтак викладання фізики має поєднувати засвоєння предметного змісту з розвитком іншомовної компетентності вже на початкових етапах військової освіти.

Вагомого значення в цьому набуває використання на всіх видах занять з фізики знання англійської мови, оскільки в інформаційному просторі значна частина технічної документації, інструкцій до приладів, наукових статей та матеріалів з військово-технічної тематики подається саме англійською. З огляду на це доцільним є застосування підходу CLIL, який передбачає одночасне опанування фізичного змісту та професійно орієнтованої англійської термінології.

У дослідженні було використано квазіекспериментальний дизайн, спостереження та порівняльний аналіз. У ньому взяли участь 69 курсантів першого курсу, яких було поділено на експериментальну та контрольну групи. Навчання в експериментальній групі здійснювалось із застосуванням поєднання інтерактивних технологій, цифрових засобів та елементів CLIL, інтегрованих у лекції, практичні заняття та лабораторні роботи. Середній показник успішності в експериментальній групі (M = 73.79) виявився вищим, ніж у контрольній групі (M = 57.85), що підтверджує позитивний вплив використання інтерактивних технологій та елементів підходу CLIL у викладанні фізики.

Дослідження підтверджує, що інтеграція інтерактивних технологій і CLIL підвищує ефективність навчання фізики в умовах розосередженого навчання та сприяє формуванню як професійних, так і мовних компетентностей, необхідних сучасному військовому фахівцеві.

Ключові слова: фізика; інтерактивні методи навчання; лабораторна робота; режим розосередженого навчання; CLIL; інтеграція фундаментальних та професійно орієнтованих дисциплін.

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