INTEGRATION OF A METHODOLOGICAL SYSTEM OF TEACHING PHYSICS AND PROFESSIONALLY ORIENTED DISCIPLINES OF THE COURT OF CONTRIBUTION

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Summary

The current state of the education system is characterized by the transition to a new qualitative level, which has positive changes in the teaching of physics and professionally-oriented disciplines based on STEM technologies. Therefore, the current stage of development of physics education aims to solve the problems of formation, development and self-realization of the students/cadets, which becomes possible by creating appropriate pedagogical conditions that promote self-knowledge, self-improvement and development of creative potential.

The article considers the methodological aspects of integration in the development of methods of teaching physics and professionally-oriented disciplines based on STEM technologies. The conceptual apparatus of «integration» and «interdisciplinarity» is outlined. The scientific and theoretical aspect of the methodology of teaching physics based on STEM-technologies in terms of integrated and interdisciplinary approaches is considered, and the effectiveness of the proposed methodological system of teaching physics and professionally-oriented disciplines on compliance with educational programs of technical aviation, which also allows to ensure the formation of the basic conceptual apparatus of physics in students and strengthen their independent cognitive and exploratory activities.

The results of the study were tested and received a positive assessment at various levels of activities.

Keywords: STEM-education, methods of teaching physics, interdisciplinarity, digitalization, applied aspect, integrated approach, institutions of higher education, technical profile.

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1. Introduction

Modern research on innovation is characterized by a tendency not only to subject but also to the methodological analysis of the nature and content of innovation in the context of digitalization *(Tsyfrova adzhenda Ukrainy, 2020)*, including physics and vocational education in the XXI century.

The need to use scientific methodology in the study of innovation processes is explained by the fact that any innovation, scientific discovery causes a critical analysis of the accepted content of fundamental end-to-end generating concepts in physics, changing approaches and methods to interpret existing and construct new theoretical concepts and reassess professionally oriented disciplines in the conditions of integration approach and interdisciplinary connections. S. Honcharenko emphasizes the importance of the methodological foundation in the research and organization of innovation processes in educational institutions, as there is a large-scale phenomenon of «pedagogical shamanism and adventurism» *(Honcharenko, 2004: 2–6)*.

It should be noted that the problem of realization of interdisciplinary connections and integration of fundamental disciplines, in particular physics, and disciplines of professionally oriented direction acquires great importance.

Integration is one of the features of modern science, which combines theoretical knowledge into a holistic system, reflects the objective world in its unity and development. The integration of modern knowledge of physics, as an important basic science, should be reflected in the disciplines of professional orientation studied by students/cadets in technical institutions of higher education (hereinafter – HEI).

The chosen area of research is related to the research topic «Creating an innovative educational and scientific STEM-learning environment of physics and mathematics disciplines based on ontological approach in terms of digital agent» (state registration № 0121U100279) STEM-Center of the Flight Academy of the National Aviation University (hereinafter – FA NAU) and with research and experimental work of the all-Ukrainian level on «Scientific and methodological principles of creation and operation of the all-Ukrainian scientific and methodological virtual STEM-center» order of the Ministry of Education and Science of Ukraine № 708 from 17.05.2017.

The purpose of the research is to outline the methodological aspects of integration in the development of a methodological system for teaching physics and professionally-oriented disciplines based on STEM technologies.

According to the purpose of the study, the *following tasks* are formulated:

1. Perform an analysis of scientific research, scientific and methodological literature on innovative trends in education and integration approach to develop a methodological system for teaching physics and professionally oriented disciplines.
2. Investigate the problem of the development of integration of physics and disciplines of professionally oriented profile in the educational process of technical HEI, taking into account the concept of STEM education.
3. To develop a methodical system of physics experiments based on STEM technologies, namely with modern teaching kits in physics for cadets/students of HEI, taking into account fundamental physics concepts.
4. Experimentally test the effectiveness of methodological support for teaching physics based on STEM technologies in technical HEI.

The object of research is the educational process in physics and professionally-oriented disciplines in technical HEI.

The subject of research is the methodological aspects of integration in the development of a methodological system for teaching physics and professionally-oriented disciplines based on STEM technologies.

The research was based on the *hypothesis* according to which to theoretically develop and substantiate methodological aspects of integration for the development of the methodological system of teaching physics and professionally-oriented disciplines based on STEM technologies in HEI technical profile, and its introduction will provide a scientifically sound selection of physics content and learning outcomes. If the educational process is based on integrated and interdisciplinary approaches, as well as accompanied by STEM technologies and optimally combined with the methodological support developed by the authors. (*Kuzmenko, 2021; Kuz`menko & Sadovyi, 2017; Borota, Kuzmenko, & Ostapchuk, 2021*).

The following methods were expediently used during the *research*:

− *theoretical*: analysis of textbooks, research, manuals and publications, educational programs that reflect the problem of research on methods of teaching physics and professionally-oriented disciplines, STEM-education, in order to identify modern physical scientific positions and achievements, trends in physics as a basic science in technical HEI;

− *empirical*: diagnostic and sociometric methods to determine the level of interest and activity of cadets/students in teaching physics and professionally-oriented disciplines using STEM technologies;

− *experimental methods*: pedagogical experiment and experimental verification of the methodical system of teaching physics and professionally-oriented disciplines with the use of STEM technologies in HEI technical profile.

The results of the research were implemented in the educational process of educational institutions of Ukraine: National Center «Junior Academy of Sciences of Ukraine»; Flight Academy of the National Aviation University.

However, the analysis of the content of research *(Chapaev, 1998; Dokuchaieva, 2007; Danylenko, 2004; Dychkivska, 2004)* shows that quite often the problems of educational innovation are considered rather narrowly, limited to attempts to find solutions only from the standpoint of one. disciplinary theory of innovation process, thus the introduction of elements of integration and their interdisciplinarity reflects qualitative changes in teaching methods of physics and professionally-oriented disciplines (introduction of STEM-technologies, elements of augmented reality, robotics, digital technologies, etc.). We believe that the complexity and multifactorial nature of innovative educational processes necessitates their comprehensive analysis using a number of general scientific approaches.

The process of teaching physics in HEI technical profile should be professionally oriented, taking into account current trends in digitalization, which aims to train highly qualified specialists in the speciality 272 «Aviation Transport». At the moment, it is difficult to predict what difficulties a technical freelance graduate will face in practice and what section of physics he will deal with. To do this, it is necessary to provide an appropriate level of training in physics for cadets/students of the technical field of study using STEM technologies. This training in physics will create a basis for the development of professionally oriented disciplines with an integrated approach and will meet the objectives of the current stage of reforming HEI (development of the Digital Agent of Ukraine).

2. Integration and interdisciplinarity in education

The traditional pedagogical system is developing and acquiring signs of innovation due to interaction with systems of the high level of development (social, economic, political, pedagogical) and integration in its structure and functions of their progressive goals, content, forms of activity. «Integration is a system of systems, the result of systematization of a higher order» (*Selevko,2006: 451*).

The definition of «integration» according to the explanatory dictionary of the Ukrainian language is defined as the union of something into a single whole *(Novyi tlumachnyi, 2006: 793)*.

If we consider this concept in the dictionary of foreign words, the «integration» is interpreted as the union of disparate parts into a single common whole, relating to different spheres of life and used in different sciences *(Slovnyk, 2022)*.

The processes of integration in the pedagogical system are associated with qualitative and quantitative transformations of its elements, changes in the relationships between them. The functions of nonlinearity and linearity of the integrative system are manifested in the fact that when one of its elements changes, the others change not proportionally, but according to a more complex law. For example, when integrating the content of education, it is necessary to anticipate several possible consequences of the introduction of certain innovation structures (STEM-laboratories, STEM-centers, innovation hubs, etc.). Therefore, the construction of integrative content can not give the appropriate result without adherence to the principle of continuity. Linearity implies the existence of direct and indirect connections between the elements of the created integrative system, which allows compensating for the shortcomings due to its nonlinear characteristics *(Chapaev, 1998: 62)*.

The generalization of the results of the analysis of scientific research and educational practice makes it possible to identify the most important areas of integration of innovative educational processes in teaching physics and professionally-oriented disciplines based on STEM-technologies, based on three main levels:

− *methodological level* – solving problems of integration of innovation processes in modern education (STEM, mixed learning, e-learning); use of cognitive means of the integrative approach as tools for analysis of innovative pedagogical phenomena; optimization of traditions and innovations in the conditions of modernization of education; building an integrative educational paradigm; synthesis of methodological, theoretical, methodological and technological knowledge;

− *theoretical level* – providing integration links between the main components of pedagogical innovation: neology, axiology and praxeology; creation of invariant integrative models of innovative educational processes; synthesis of principles and conditions of efficiency of all stages of the life cycle of innovation; integration of innovative systems related to different types of pedagogical process (for example, a combination of problem-based and modular learning);

− *practical level* – ensuring continuity between scientific and experimental research and implementation of their results; coordination of the cluster of various innovations that are simultaneously implemented in the HEI of the technical profile; coordination of management of innovative educational processes at different levels: state, regional, in a separate educational institution; designing the integrated content of education and appropriate forms and methods of its development; organization of integrated forms of innovation: innovation centres, laboratories, schools of innovation, etc.

According to G. Shatkovskaya, the process of integration in the educational process is a much broader concept than interdisciplinary connections, which in the content of disciplines reflect the dialectical relationships that objectively operate in nature and are known by modern sciences. Integration not only strengthens the connection but also ensures the interpenetration of the content of professionally oriented disciplines *(Shatkovska, 2007: 3)*. Scientist I. Kovalenko considers interdisciplinary connections as a means of in-depth study of physics by students, to overcome in the subject system of teaching the contradiction between the disparate assimilation of knowledge and the need for their synthesis, for integrated application in practice *(Kovalenko, 2011)*.

The foundation of the interdisciplinary direction of the study of the phenomena of innovation was laid at the beginning of the XXth century by the theorists G. Tard, I. Schumpeter and M. Kondratiev. Their main ideas became the basis of modern innovation theories, in which the engine of social progress is not one, but a set of social, technological, economic and other factors of society.

Significant developments in the implementation of the principles of interdisciplinarity in the study of innovation processes are presented in the works of R. Akoff, V. Andrushchenko, V. Vasilkova, V. Dudchenko, E. Durkheim, S. Krymskyi, N. Kropotova, S. Kurdyumov, T. Levovitskyi, O. Markov and others.

Thus, the above-mentioned scientists in the process of substantiating the strategy and content of modernization of education according to modern trends go beyond traditional pedagogical theories, searching for and integrating innovative ideas from almost all scientific fields.

The methodological arsenal of modern pedagogy, namely the didactics of physics and professionally-oriented disciplines based on STEM technologies requires methods of both theoretical understanding and practical analysis of problems that can not be solved only using the pedagogical methodology. It is integrated and interdisciplinary approaches that position changes in the education system with the process of the interpenetration of new in all scientific and practical areas, which brings research to the metatheoretical level of construction and conceptualization of models of innovative educational processes, including STEM education *(Chernetskyi, Polikhun, & Slipukhina, 2017; Kuzmenko, Dembitska, 2017; Kuzmenko, 2017)*.

Leading scholar V. Vasilkova identifies the need to go beyond the internal disciplinary paradigm as the main principle of interdisciplinary discourse, in order to weaken its inherent limitations, expand ways of describing reality, which have some researchers, and shift perception in meta position to individual participants in relation to individual participants, interdisciplinary discourse *(Vasilkova, 2004: 72)*.

The interdisciplinary approach directs the research of innovative educational processes at the methodological, theoretical and technological-practical levels. The importance of the methodological level lies in the integration of laws and principles, the complementarity of different approaches and methods of scientific knowledge of the essence and sources of origin, formation and establishment of new in education.

At the theoretical level of interdisciplinary research, the issues of diffusion into pedagogical innovation of concepts, concepts, models, principles, methods, ontological ideas from other scientific fields, as well as the expediency and legitimacy of their application are addressed.

The interdisciplinary perspective of research of praxeological problems of pedagogical innovation allows synthesizing theoretical constructs from various scientific spheres for the development of technologies of designing, examination, realization and monitoring of innovations in HEI. In an interdisciplinary perspective, praxeological tasks are directly related to applied needs and cover all substructures of innovation: goals, principles, content, methods, tools and forms, etc.

The problem of expediency of interdisciplinary approach in the educational process, O. Afanasyeva notes that interdisciplinary integration reflects the processes of unification of academic disciplines to address epistemological, methodological, technological and practical needs. Integration is interpreted by the researcher as ensuring the integrity of the educational process *(Afanaseva, 2006)*.

The principle of interdisciplinary relations as a separate didactic principle, suggests that the content of academic disciplines should reflect those dialectical relationships that exist in nature and are known by modern science. Interdisciplinary links are the equivalent of interdisciplinary ones, and their methodological basis is the processes of integration and differentiation of scientific knowledge. The psychological basis of interdisciplinary relationships is the formation of intersystem associations that allow reflecting the various objects and phenomena of the real world of unity and opposition, in their multifaceted and contradictory *(Metody sistemnogo issledovaniya, 1980: 42)*.

Levels of integration of scientific knowledge, V. Sydorenko considers through the directions of scientific research to solve complex interdisciplinary problems *(Sydorenko, Bilevych, 2004)*: intradisciplinary (within individual sciences); interdisciplinary (within two or three branches of science); supra disciplinary (high degree of integration); transdisciplinary (integration of scientific concepts, theories of methods and techniques in philosophical concepts).

The solution to the problem of overcoming the contradiction between the need to ensure a high level of integration of scientific knowledge in physics and the accelerating process of differentiation of disciplines of the cycle of professionally oriented training is seen at the intra- and interdisciplinary (interdisciplinary) levels to study disciplines of professionally oriented direction in the HEI of technical profile.

Peculiarities of interdisciplinary interaction in his research outline L. Shestakova *(Podopryhora, 2015)*, namely through:

− *structure of modern scientific knowledge*, which is formed in the process of influence of natural science knowledge; techno-knowledge (artificial intelligence, virtual and augmented reality, ICT technologies); socio-knowledge; humanitarian knowledge;

− *the structure of modern scientific knowledge* is a constant and dynamic interaction between all four branches of modern knowledge;

− *humanitarian knowledge* penetrates all branches of scientific knowledge at the present stage of education development. This is manifested, in particular, in the presence of features of different scientific schools and scientists, in the style and methods of thinking of different researchers, in the presence of heuristic and intuitive methods of work in different fields of scientific knowledge, in the use of associations and others.

The integrative approach is aimed at establishing the unity of basic research, applied research and practical experience in innovations in school management, reforming the content of education, ensuring the continuity of all levels of education, etc. (M. Berulava, S. Honcharenko, V. Ilchenko, V. Lednev, V. Serikov, M. Chapayev and others).

The set of theoretical propositions explaining the essence of the phenomenon of integration in modern pedagogy are united by the general concept of «integrative approach»: as a result of integration previously independent elements are combined and synthesized into a single system based on functional relationships, mutual transition and complementarity, management, the convergence of theories of teaching and education, unification in the systems of education and its content. The main methods of integration include: unification, universalization, categorical synthesis, extrapolation, generalization, modelling, systematization *(Vozniuk, Dubaseniuk, 2009 : 95–96)*.

The strategic concept of integration of the theory and practice of innovative education is determined by a triad of components: basic research, applied research, practical implementation of innovations. However, often the gap between methodological, theoretical and methodological knowledge reaches alarming proportions *(Chapaev, 1998: 96)*. Therefore, modern innovation is characterized by a tendency to integrate the goals, content, functions of neology, axiology and praxeology, which determines the integrity of the processes of creation, perception, evaluation, development, implementation and analysis of the effectiveness of new in pedagogical practice. The methodology of innovation emphasizes the unity of the three components of the innovation process: the creation, development and implementation of innovations. This three-component process is the object of study in pedagogical innovation *(Hutorskoj, 2005)*.

3. Methodical system of teaching physics and STEM

Methodological provisions of pedagogical integration are a function and method of knowledge of the theory and practice of innovation processes. As methodological knowledge, pedagogical integration can ensure the continuity of traditional and new, theoretical knowledge and practical experience in teaching physics and professionally-oriented disciplines using STEM-technologies. As a tool for transforming practice, pedagogical integration can eliminate duplication, i.e. optimize the pedagogical process, lead to the creation of new theoretical and practical objects: concepts, theories, pedagogical systems, training courses, activities, models, technologies, teaching aids *(Vozniuk, Dubaseniuk, 2009)*.

Methods of teaching physics is a pedagogical science that solves the problem of ensuring a highly effective educational process in physics. It determines the place of physics in the educational process of free technical education; the content of teaching physics; the structure of the educational process; the ways, methods and means of ensuring high efficiency of the educational process in physics as a fundamental science for professionally oriented disciplines.

The transition to STEM training requires improving the methods of teaching physics and professionally-oriented disciplines based on STEM technologies in an integrated and interdisciplinary approach, which includes: the use of new methods, techniques, teaching aids that would help solve several methodological problems; application and introduction of interesting and important scientific achievements in the educational process in physics, as well as strengthening those aspects that stimulate and activate the independent cognitive activity of cadets/students during the study of physics-based on STEM-technologies in HEI technical profile.

Applied integrative research is aimed at finding ways to apply theoretical concepts in the development of technologies for innovation in the activities of HEI. Practical aspects of integration cover all substructures of innovation: goals, principles, content, methods, tools and forms. «Integrative-pedagogical concepts, condensing a rich set of integrative means, are used as technological-methodological and technological tools for the implementation of integrative-pedagogical activities. They can on their basis give birth to integrative pedagogical technologies» *(Chapaev, 1998: 48)*.

Researchers of innovation processes emphasize that in the conditions of high competition and rapid development, typical for the XXI century, it is possible to achieve atypical for a certain industry growth rate only by being able to manage these three different aspects of innovation for development. Each of them is very important, but to pay attention to only one is not enough to make full use of all opportunities for the development of the organization *(Taker Robert, 2006: 17)*. Given the complexity of innovative educational processes, their nonlinear nature, the simultaneous implementation of the cluster of innovations, to achieve success it is necessary to strengthen the integration of actions of all subjects of innovation in all aspects of innovation.

One of the effective ways to improve the methodology of teaching optics, which allows solving the problem of active independent learning work of students/cadets, is the widespread introduction into the educational process of innovative learning technologies, including the latest information technologies and modern tools.

The methodological system of physics and professionally-oriented disciplines is outlined by us in our research *(Fizika. Posobie, 2013; Sadoviy, Kuzmenko & Gavrylenko, 2021)*.

Along with this, the methodology of teaching physics and professionally-oriented disciplines on the basis of STEM-technologies of technical HEI should:

− not exclude the possibility of using those tools and educational equipment in physics, which have justified themselves and passed the test of educational practice;

− new teaching aids should complement existing ones and provide opportunities to expand their functions following the digitalization of education, in which the student is considered as an active subject, on the conscious learning activities which largely depend on the result of the educational process;

− at different stages of formation of physical knowledge of physics-based on STEM-technologies, to provide growth of the level of independent cognitive-search activity of cadets/students for which provision of created sets of equipment can act, where all elements and get the best results and achieve the appropriate level of physical education, awareness of the role of human personality in it;

− to provide an opportunity to develop the ability of students/cadets to use modern ICT tools and computer technology, focusing them on the further use of digital tools in educational activities and the future professional field.

4. Experimental efficiency of methods of teaching physics

One of the tasks of our study was to verify the results of the introduction of methods of teaching physics and professionally-oriented disciplines based on STEM technologies.

During the research and experimental work, diagnostic research methods (surveys, testing, interviews, questionnaires) were used, which allowed obtaining statistical data. Diagnostic methods were used in experimental and control groups.

The study, adjustment and generalization of the results of approbation of the proposed methodology of practical and experimental tasks by cadets/students of physics and professionally-oriented disciplines were conducted through selective attendance, discussion with teachers of opportunities to improve the learning process development of STEM education.

The analysis of the results obtained during this pedagogical experiment was aimed at testing the quality and effectiveness of the proposed method of teaching physics using modern teaching aids, taking into account STEM education and comparing the achievements of students of experimental and control groups. In each group that participated in the experiment, tests were conducted, as a result of which the level of knowledge, skills and abilities during the proposed method of teaching physics was tested, and comparisons were made with students who studied the traditional method. When selecting questions for tests, preference was given to the optimal amount of multilevel tasks, questions, answers to which required knowledge and understanding of the observed phenomena in the study of physics and the basic laws of their course: the ability to explain experimental facts and justify the necessary conditions under which of a physical phenomenon; explain the methods and ways of managing its basic laws of phenomena and processes, the possibility of their practical use.

Statistical methods allow to establish the probability of certain events in the pedagogical process, to predict learning outcomes, to establish in the pedagogical process, to predict learning outcomes, to establish average, critical and optimal norms and deviations from the norms to be followed by the pedagogical process.

For statistical processing of results of forming pedagogical experiment methods of check of statistical hypotheses based on comparison of measurements of some property in two independent samples (Kolmohorov-Smirnov criterion) were applied.

To conduct a pedagogical experiment, we selected 341 students in the control group (CG) and 353 students in the experimental group (EG), a total of 694 students took part in the pedagogical experiment with free technical education in Kyiv, Kropyvnytskyi.

The Kolmohorov-Smirnov test is determined to be sensitive in the application to find any difference in the distribution function of this property in some of the considered populations.

The Kolmohorov-Smirnov criterion was also used to conduct the pedagogical experiment. Laboratory work on optics «Determination of light wavelength using a Jung interferometer» was performed in EG and KG according to various methods. During this work, the experimental groups used modern learning technologies and developed this set of manuals *(Kuzmenko, Sadovyi & Vovkotrub, 2015; Fizika. Posobie, 2013)* and guidelines *(Borota, Kuzmenko & Ostapchuk, 2021)*, which greatly facilitate performing laboratory work in physics in the context of the development of STEM education, and the control groups used traditional methods.

Students from Kropyvnytskyi and Kyiv took part in the experiment. The experiment meets all the requirements necessary to meet the Kolmohorov-Smirnov test as a mathematical statistic of the nonparametric method in pedagogical research *(Grabar, Krasnyanskaya, 1977)* to determine the effectiveness of experimental methods. The results of student's laboratory work were evaluated on 6 levels, aimed at performing experimental and computational skills.

In order to determine the performance of laboratory work, we divided the scope and results of its implementation into 6 levels, which corresponded to its main objectives:

1. Recording and clear formulation of the topic, the purpose of work and equipment.
2. Carrying out and availability of records necessary for measurements and calculations, the correct filling of the made table.
3. Execution of calculations, measurement errors with the indication of deviations of individual values of one quantity.
4. Execution of a drawing or graph that accurately illustrates from a physics point of view the progress of work and the accuracy of the measured values, the results of calculations.
5. Formulation of the conclusion at which it is necessary to specify regularities of the investigated size.
6. Performing an additional task or answering test questions.

Accordingly, during the pedagogical experiment, the hypothesis $H_0 : F(x) = G(x)$ or assumption about the uniformity of the functions of distribution of scores on the performance of laboratory work in physics among students of experimental and control groups according to traditional and experimental methods was tested.

For this purpose, 341 students from the number of students who performed laboratory work in physics and studied according to different variants of the methodology were taken into the CG and 353 students into the EG. As a result of random selection, two samples were formed (f_1 – students who studied by experimental methods, f_2 – by traditional methods), respectively, $n_1 = 353$ and $n_2 = 341$ the student.

The data for finding the Kolmogorov-Smirnov characteristic are shown in Table 1.

Table 1

Table of data for finding statistics of the Kolmohorov-Smirnov test based on the results of laboratory work "Determination of light wavelength using a Jung interferometer" in experimental and control groups

№	Number of correctly completed tasks	Absolute frequency in sample № 1 (EG), f_1	Absolute fre-quenc y in sample № 2 (CG), f_2	Accumulated frequency in the sample № 1 (EG), $\sum f_1$	Accumulated frequency in the sample № 2 (CG), $\sum f_2$	The difference of the accu-mulated fre-quencies in the samples № 1 and № 2 $\left\|\sum f_1 - \sum f_2\right\|$
1	6	118	115	353	341	12
2	5	88	86	235	226	9
3	4	67	64	147	140	7
4	3	44	42	80	76	4
5	2	30	30	36	34	2
6	1	6	4	6	4	2

An alternative hypothesis $H_1 : F(x) \neq G(x)$ assumes that the functions of distribution of scores are not the same in the two considered sets of students.

The maximum value of the expression for the difference of accumulated frequencies in samples №1 and № 2 $\left|\sum f_1 - \sum f_2\right|$ is 12.

That is: $$T_1 = (\frac{1}{n_1}) \cdot \max\left|\sum f_1 - \sum f_2\right| = (\frac{1}{353}) \cdot 12 = 0{,}034;$$

$$T_2 = (\frac{1}{n_2}) \cdot \max\left|\sum f_1 - \sum f_2\right| = (\frac{1}{341}) \cdot 12 = 0{,}035.$$

The critical value of the criterion is found by the formula for relatively large samples ($n > 40$). Accordingly, for our case, the experimental values $n_1 = 353$ and $n_2 = 341$.

$$W_{1-\alpha} = \lambda_\alpha \frac{\sqrt{(n_1 + n_2)}}{n_1 \cdot n_2}$$ *(Grabar, Krasnyanskaya, 1977).*

For the value $\alpha = 0{,}05$ we matter $\lambda_\alpha = 1{,}36$

$$W_{1-\alpha} = 1{,}36 \cdot \frac{\sqrt{694}}{120373} \approx 0{,}0003$$

Thus, the inequality holds:

$T_{obs.} > W_{1-\alpha}$, that is (0,035 > 0,0003).

Отже, робимо висновок, що у відповідності до правила прийняття рішення про нульову гіпотезу відхиляється і приймається альтернативна гіпотеза H_1, що вказує на різницю у розподілі оцінок у балах за виконання лабораторної роботи у процесі навчання фізики в контексті розвитку STEM-освіти, що навчались за експериментальною і традиційною методиками у ЗВО технічного профілю навчання.

Therefore, we conclude that following the rule of deciding on the null hypothesis, the alternative hypothesis is rejected and accepted, which indicates the difference in the distribution of scores for laboratory work in the process of teaching physics in the context of STEM education and traditional methods in HEI technical profile of training.

5. Conclusions

Thus, the current reform of physics education in the context of STEM education in Ukraine is closely interrelated with the requirements of preparing graduates HEI for active self-realization in various spheres of human activity, taking into account individual personality, abilities and capabilities, interests and plans for the future.

Accordingly, the modernization of the educational process is based on its humanization and requires the strengthening of the subject-object approach in his organization, which should raise the level of cognitive activity, which in this process should manifest itself both as to its object and as the subject. These aspects require the development of new methods of teaching physics based on STEM technologies, the introduction of modern technologies and the latest advances in psychological, pedagogical, methodological and logistical support of the educational process during the study of physics in technical HEI.

Experimental verification confirmed the correctness of the previous positions contained in our assumptions, the reliability of the results of the comparative experiment was proved by various methods of mathematical statistics recommended for pedagogical research, namely the statistical criterion Kolmohorov-Smirnov.

Research should be continued in the following areas: further study of the problem of content development, as well as methods of improving the digital aspects of the study of optics to develop the activity and independence of subjects; development of methods of teaching physics and professionally-oriented disciplines with the use of virtual technologies.

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