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Research paper

STEM-Based Training in Future Specialists in Higher Education

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Abstract

The article emphasizes the importance of STEM education today. It reveals the strategy for developing STEM areas in the professional training of specialists; it describes the essence, structure, and benefits of STEM competence within the higher education system. The most popular fields for developing STEM competence are highlighted. Methods for applying modern approaches and STEM technologies in training future specialists are demonstrated. The study's goal was to develop STEM competencies in the professional training of future specialists. By investigating the research problem, we identified ways to build STEM competence as a foundation for successful professional adaptation and as part of the professionalization process. The results from the initial phase of the study showed a low level of STEM competency among future specialists, highlighting several issues and leading to the development of pedagogical conditions for effective training using STEM technologies in higher education to strengthen their STEM skills. The outcomes of the experimental phase confirmed the effectiveness and validity of these pedagogical conditions for training future specialists in higher education through STEM technologies to develop their competencies.

Keywords: *STEM Technologies; Robotics Classes; Technological Equipment; Creativity; Computer Learning.*

1. Introduction

STEM education is a change in the reality of the educational space in all areas, a way of expanding the consciousness of the individual, transferring knowledge from teachers to students, because education today, to solve complex situations in professional activities, requires skills in the field of science, technology and mathematics (STEM), and these capabilities need to be developed from elementary school [1]. The appropriate experience of the teacher and the child's early interest will positively influence the development of the individual's interest in STEM. Integrated approaches to teaching and teacher training are key aspects that should be focused on to create a responsible generation. Therefore, society needs specialists who are qualified and interested in STEM [2].

Students in the process of STEM education can solve problems and gain new knowledge, which is presented by STEM teachers through critical thinking skills, project-based approaches to research, collaboration, etc. At the same time, the education of each person should correspond to their everyday life. The activities of students in the educational space include cultural factors, social elements, and physical interaction in the educational process between them. Therefore, with the help of STEM education, it is possible to train qualified and competitive specialists in the era of globalization [3].

In the process of training future specialists, the use of STEM technologies is a key approach to the successful development of higher education in society, because it is precisely such technologies in education in the modern world that are characterized by high variability, the use of innovative and flexible, pioneering methods and are one of the main conditions for improving the quality of education in modern higher education.

2. Literature Review

Researching the problem of the formation of STEM education, scientists note the importance of the integration of technological, scientific, mathematical, and engineering STEM programs in the present, which is an educational trend. High-quality preparation for the requirements of the 21st-century of higher education applicants requires continuous professional development of teachers, which is based on competencies, combined with practice, and focuses, in the context of the real world, on the development of STEM logical thinking abilities.

Mayes & Rittschof [4] proved that for high-quality preparation of higher education students for the requirements of the 21st century, it is necessary to introduce STEM technologies in education to meet the future needs of society, and that the introduction of STEM technologies in education is focused on the development of interdisciplinary experience.

The results of the introduction of STEM technologies have taught students to make informed decisions that affect their future, solve grandiose real problems in the pedagogical system, and professional activities. It is proven that the introduction of STEM technologies is aimed at meeting the future needs of the labor market by increasing the number of students knowledgeable in STEM technologies and developing their STEM literacy.

Guo [5], in his scientific research, analyzed Chinese education, noting that a positive, official introduction of STEM education into the primary school curriculum was made by the Chinese Ministry of Education. A series of STEM textbooks and teaching materials has been developed and implemented for future teachers.

When preparing future teachers for the implementation of STEM approaches, García-Carrillo et al. [6] identified shortcomings such as insufficient scientific knowledge of teachers and their didactic training – these are the positions that may be lacking in the professional activities of teachers. Studies have shown that during the educational reform, negative attitudes of teachers were identified, which are due to their fragmented and superficial knowledge in the professional field. The lack of sufficient knowledge of scientific content, as well as the deficit of professional, personal experience, and practical knowledge of how best to apply this content in the educational process, were emphasized.

The problems faced by teachers and students, such as unstable internet connections and psychological stress, are investigated, new methods and approaches to conducting classes are considered, including the use of online platforms and digital resources, and the experience of implementing flexible study schedules to consider the individual needs of students is described [7].

In the field of STEM education, the results of the research of Ortiz-Revilla et al. [8] were systematized and analyzed. The scientists determined the scientific novelty, relevance of the research, formulated the practical significance; determined the features of introducing robotics into the educational process to develop critical thinking in students; gave examples of the use of robots in the educational process, considered the integration of design into the educational process and programming; conducted studies that demonstrate the increase (thanks to robotics) of students' interest in STEM disciplines.

So, having analyzed scientific research, we argue that the introduction of STEM technologies is a promising, necessary direction of education development, because it is this direction that contributes to the development of key competencies of students, improving the quality of their education, and preparing them for successful adaptation and successful implementation of innovative approaches, taking into account the needs of the modern labor market.

Despite the significant interest of a large number of scientists and scholars in the professional training of future teachers in general, the problem of training future specialists using STEM technologies in higher education institutions remains insufficiently researched, both in theoretical and practical aspects, which is reflected in the lack of a single definition of the essence and structure of this process, a theoretically grounded and methodologically defined model, a developed and experimentally tested methodology for applying STEM technologies in the process of training specialists.

The relevance of solving the outlined problem, as well as the analysis of the theoretical and practical principles of training specialists using STEM technologies, indicates the presence of several contradictions in this process:

– There is a contradiction between traditional approaches to training specialists and the need to introduce STEM technologies into the educational process.
– A discrepancy between the needs of the modern educational space for technologically knowledgeable, STEM-competent teachers and the limited capabilities of higher education institutions in introducing STEM technologies into the educational process.
– There is a significant theoretical foundation, which is enshrined in the scientific literature; however, in practical terms, there is a lack of developed methodologies for the application of STEM technologies in the training of students.
– There is a contradiction between the high requirements for the qualification of pedagogical personnel in the field of STEM and the insufficient level of training of specialists in STEM technologies.

Research purpose: high-quality training of future specialists in higher education institutions using STEM technologies.

3. Methodology

To realize the outlined research goal, a set of methods was used: theoretical: systematic study of literature and research approaches for the purpose of comparative analysis of different points of view on the problematic under study, study of practical training regarding the organization of the educational process of training future specialists in higher education institutions using STEM technologies; empirical: observations, surveys, interviews, questionnaires in order to study the features of the use of STEM education tools; showing a pedagogical experiment to gather data on the effectiveness of the proposed pedagogical conditions for training future specialists; statistical: using statistical methods to summarize the data obtained and analyze them in order to determine the degree of effectiveness of introducing STEM technologies; statistical analysis using methods (Pearson's non-parametric $\chi 2$ criterion) of statistical processing; processing the results of the experimental study.

The creation of STEM competencies was the task of our study. Investigating the outlined research problem, we identified the formation of STEM competence as the basis of successful professional adaptation, as a process of professionalization. In the study, we identified the components of STEM competence, its criteria, indicators, and levels of formation.

At the start of the experiment, we identified the standards, components, and points of STEM ability of future specialists that create conditions by modernizing the humanitarian and natural science and mathematics training profiles for the implementation of balanced education of future specialists.

The experimental study was directed towards a specially organized experiment. The success of the enactment of the developed pedagogical circumstances for the formation of STEM competencies in future specialists during the educational process of higher education was tested, which involved making fundamentally important changes to the teaching in accordance with the tasks and goals of the experimental work.

The study and experimental work covered three steps of scientific and pedagogical search and was carried out during 2021–2025. The stages of the experiment were as follows: constant, formative, and control. 164 people were involved in the experiment; these were students, from whom the control (CG) and experimental (EG) groups were formed.
Having compared the analysis of the obtained values of the Pearson criterion ($\chi2emp$) for all criteria with the critical value of the criterion ($\chi2cr < 0.05$), we concluded that in the control and experimental groups at the learning stage of the study, the initial level of formation of specialists in STEM competencies does not differ significantly.
The results of the ascertaining stage of the experimental study showed an insufficient level of formation of future specialists in STEM competencies, which allowed us to outline a range of problems and develop and substantiate the pedagogical conditions for the effective training of future specialists to form their STEM competencies.
The course of the formative experiment was determined by the results of the discovery experiment. The quantitative composition of students remained unchanged. The formative experiment involved testing the pedagogical conditions for the effective training of future specialists to form the STEM competencies of future specialists.
The outcomes of the formative step of the experiment established the effectiveness and validity of the proposed pedagogical circumstances for the effective training of future specialists to form their STEM competencies.

4. Results and Discussion

4.1 The importance of STEM education for today. Strategy for the development of STEM areas in the professional training of specialists. The essence and structure, and advantages of STEM competence in the higher education system. The most popular areas for the development of STEM competence are.

In the setting of our study, the introduction of methodological lines to STEM education into the higher education process will ensure better socialization of the personality, the formation of key characteristics in higher education applicants that determine the formation of researcher competence and competent thinking [9].
Not all specialists are ready to implement new teaching methods, for example, project activities. Only a part of the educational space of universities and schools uses project-based learning and develops methodological support. Therefore, considering the research of scientists, we argue that one of the key points in the training of specialists and their professional development has been the introduction of new standards of STEM education using STEM technologies. The experience of Australia, whose education is known for its flexible requirements for the education system as a whole and for teachers, deserves attention. The ideas identified in this country are reflected in the educational strategy of Australia. The Australian government, in the interests of the state, since 2013, has adopted a strategy for the development of STEM areas [10].
Let us name the key tasks of the plan for the progress of STEM areas that correspond to the context of our study:

– Increasing the awareness of teachers and their interaction with STEM technologies.
– Qualitative improvement of disciplines that are the basis of STEM production.
– Promotion of technology, engineering, mathematics, science [11].

Having studied and analyzed the experience of educational development strategies, we will highlight the most popular options for STEM education:

– STEM (Technology, Science, Mathematics, Engineering) – humanities and natural sciences, design, innovative technologies.
– STEAM (Technology, Science, Arts, Engineering, Mathematics) – humanities and natural sciences, engineering, innovative technologies, mathematics, and art.
– STREAM (Technology, Science, Engineering, Mathematics, Reading, Arts) – innovative technologies, natural sciences, reading, art, engineering, mathematics [12].

In ensuring quality education, a key factor is the creation of STEM ability in specialists that meets the needs of modern society. Thus, it is necessary in higher education to ensure the training of students who can contribute to the development of society, technology, science, and, in general, adapt successfully to a rapidly changing world [13].
As a result of clarifying the structure and essence of STEM competence in the higher education system, a deep consideration of the options and essence of STEM technologies has been laid in the higher education structure, which, in turn, serves as the basis for improving and further developing pedagogical approaches and educational programs in each professional field of society.
It should be noted in the context of our study that the advantages of STEM competence in the process of training future specialists are:

– Future specialists learn to find innovative ways to solve the task through errors and attempts in real time, and not in theory, because, according to the STEM methodology, the focus of the educational development is a practical problem or task.
– STEM competence is considered an opportunity to expand the worldview of the future specialist, his creative space, where he prepares for real life in society, and not only realizes his own needs, but also makes a conscious choice of future educational professional activity.
– In the process of forming STEM competence, the use of STEM technologies by future specialists contributes to the development of cognitive interests of higher education applicants; encourages creativity and imagination; and develops the ability to quickly analyze the situation in future specialists.

The most popular and brightest direction in the development of STEM competence is robotics, which today is one of the promising educational directions, where the key place is occupied by the problems of developing STEM technologies.
Due to the possibility of using special equipment, such innovative classes have gained great popularity, and methodological materials for conducting innovative STEM classes are a significant contribution to the educational process. Yes, robotics classes allow students to not only study science, but also work in a team, manipulate electronics, technological equipment, and sensors, following creative approaches and standard plans. The ability to create finished projects over the course of several classes or a single class is one of the key advantages of robotics [14].
Teachers often turn to makerspaces in cases where there is a lack of special equipment for robotics or there is a need for other types of activities.
Makerspaces often include creative activities of future specialists, during which students create things themselves, for example, electronic devices made of wood or parts printed on a 3D printer. This form of the educational process allows you to work with a variety of equipment and materials, as well as implement your own or group projects.

Considerable freedom of creativity is a feature of makerspaces for both students and teachers. Creative teachers try to provide the most accessible knowledge through integrated classes and STEM approaches and often do not limit themselves to their own subject, working in collaboration with other teachers [15].

4.2 The use of modern approaches to the application of STEM technologies in the training of future specialists

The use of STEM technologies, in this context, in the training of future specialists, acts as a key factor in the training of qualified, technologically competent specialists, to teach students to effectively implement innovative teaching methods.
Today, higher education institutions ensure the successful formation of skills and professional knowledge in students, and conduct research in various scientific fields. However, to meet the needs of modern society and remain competitive, they must improve their teaching methods, programs, and scientific approaches [16].
Active use of STEM technologies is one of such technologies in the professional training of future specialists, which orients modern specialists to obtain knowledge through active search activities, to create conditions for the cognitive activity of students themselves, to provide not a ready-made system of information, but a creative [17].
In the procedure of training future specialists, modern approaches to the application of STEM technologies are interactive learning technologies, which include both dialogic (non-situational) and game (situational) methods, including non-imitative and imitative interactive methods, such as modeling and analysis of professional situations [18].
The central aspects of such a modern approach to the use of STEM technologies are the joint efforts of students to achieve learning outcomes, their active interaction, and taking responsibility for their own learning. [19].
Group (cooperative) learning activities in the training of future specialists are the next innovative approach to the use of STEM technologies – this is a model (form) of organizing the training of future specialists in small groups that are united by a common educational goal. With such an organization of the educational process, the teacher directs the group's activities through tasks. The developed innovative tasks that the teacher provides to students allow for indirect management of the work of each participant in the educational process. Cooperative learning provides students with the opportunity to cooperate with their colleagues in learning, which meets their natural needs in communication and contributes to the formation of skills and mastery of knowledge to achieve higher results [20].
To summarize, we note that cooperative and interactive learning contribute to improving the process of applying STEM technologies, are effective methods in training future specialists, because they activate the educational process, increase students' motivation for learning, and contribute to the development of key skills.
Project-based education and problem-based education are important approaches to the application of STEM technologies. There is a possibility of an approach when the educational process is structured and appropriate forms are selected for the methods, or when, depending on the content and needs, teaching methods are selected. These can be educational process technologies as the use of information technologies, game technologies, problem-based learning, the use of supporting notes and diagrams, the use of audiovisual books or tools, classical lecture teaching, computer-based learning, and distance learning. Each of these educational process technologies can be used to achieve specific educational goals, and has unique features depending on the tasks and context of the educational process [21].
Project-based learning in the process is a modern approach to the application of STEM technologies. Implementation of projects should be based on real information, considering the principles of STEM education. We observe an increase in the level of professional competence of future specialists [22].
The case method, which is an analysis, study, and decision-making in accordance with a problem (situation) that may arise under certain circumstances or because of events. There are fictional (armchair) situations, cases, and field situations based on actual material. Students must understand the essence of the problems, analyze the situation, propose a solution, and choose the best possible solution. One of the most effective methods for developing STEM competencies in future specialists is the case study method, particularly for those in this field. Students, within the framework of using the case study method, need to solve a real problem in the field of professional activity, develop their own project that meets the requirements of the received task. Students must solve tasks that are close to real professional practice.
The considered approaches are important elements in improving the quality of students' training; the application of STEM technologies is key, contributing to the development of their competencies through STEM technologies. All of them allow for to effective combination of practical skills with theoretical knowledge and stimulate the development of an innovative approach, creativity, and critical thinking to solving problems [23].

4.3 Organization of an experimental study

The development of STEM competencies was the task of our study. Investigating the outlined research problem, we defined the formation of STEM competencies as: the basis of successful professional adaptation, as a process of professionalization. In the study, we identified the components of STEM competencies, their criteria, indicators, and levels of formation.
At the start of the experiment, we identified the criteria, components, and levels of STEM competencies of future specialists, which create conditions by modernizing the humanitarian and natural science and mathematics training profiles for the implementation of balanced education of future specialists.
To assess the level of formation of future STEM-competence specialists, we have identified criteria (cognitive, activity, reflective, motivational) and components: cognitive criterion (cognitive component), reflective criterion (analytical component), activity criterion (operational component), and motivational criterion (value component).
The levels of formation of STEM competencies have been established: low, medium, and high, to analyze the dynamics of the levels of creation of future STEM-competence experts.
The experimental study was conducted according to a specially organized experiment. The effectiveness of the application of the settled pedagogical conditions for the formation of future STEM-competence specialists during the educational process of higher education was tested, which involved making fundamentally important changes to the teaching in accordance with the tasks and goals of the experimental work.
The research and experimental work covered three phases of methodical and pedagogical search and was carried out during 2021–2025. The stages of the experiment were as follows: ascertaining, formative, and control. The experiment involved 164 people, who were students, from whom the control (CG) and experimental (EG) groups were formed.

At the ascertaining stage of the experiment, an analysis of the problem was carried out based on the study of professional literature, and the experience of practical work was taken into account. The relevance of the problem was determined, and pedagogical conditions were developed for the formation of STEM competencies in future specialists; components, criteria, and levels of student development were substantiated. The features of the formation of STEM competencies in future specialists were studied; a program of experimental work was developed, using a complex of empirical methods, and the current state of formation of STEM competencies in students was checked: observations, conversations, surveys, questionnaires, etc.

At the formative stage of the experiment, the developed pedagogical circumstances for the formation of STEM competencies in the professional training of students were implemented and experimentally tested.

Let us reveal the content of the pedagogical conditions for the effective training of future specialists using STEM technologies to form their STEM competencies. To progress the procedure of training future specialists using STEM technologies, we have distinct and substantiated the following pedagogical conditions:

1. To actively master the future profession, it is essential to certify stable motivation for the chosen direction of activity.
2. An innovative approach to organizing the request of STEM skills in the process of specialists' professional training.
3. Progress of didactic and organizational innovative care for the development of professional training of students using STEM technologies.
4. Use of interactive teaching methods based on the application of STEM technologies.

Let us reveal the substantiated content of the pedagogical conditions.

1. **To actively master the future profession, it is necessary to ensure sustainable motivation for the chosen field of activity. The implementation of the outlined condition contributes to the development of critical thinking, creative, and problem-solving potential in students, which are key competencies of future specialists in the modern educational environment, and increases interest in students' educational activities.**

The enactment of the first educational condition is possible under the following circumstances:

– Creation of a favorable professional and pedagogical environment.
– Formation of awareness in the field of STEM technologies, familiarization with the system of introducing modern pedagogical STEM technologies, which increases motivation to master the profession and promotes the change of innovative thinking.
– Active involvement of students in practical activities.
– Personally oriented approaches to professional training, which contribute to the personal growth of students and their self-realization, consider the interests of future specialists and their individual needs.
– Development of information and communication needs of students, information, and application of technologies that increase interest in education.
– Formation of a constructive attitude towards the future profession using discussions of professional aspects.

2. **Innovative approach to the organization of the application of STEM technologies.**

Implementation of the second pedagogical condition provides for:

– Application of STEM-technologies during the whole period of students' education. Varying the volume of educational STEM-technologies during the period of study in higher education, it is necessary to develop a coordinated plan for the application and implementation of STEM-technologies in different educational modules, planning and organizing the educational activities of students.
– In the procedure of training of students, the content of the organization of the process of application of STEM-technologies should be built according to an interval system in the procedure of education, cyclic repetition of the request of STEM-technologies, with gradual complication during the transition of students from one course to the second course.
– When applying STEM technologies, it is needed to provide for the wide use of the acquired knowledge in real life and in pedagogical practice.
– The organization of the educational process using STEM technologies should be based on solving specific professional tasks related to the challenges of modernity. Higher education applicants should analyze the needs of the modern educational environment in parallel with the educational process, determine the current requirements and problems that arise in the modern process of higher education, which requires the use of STEM technologies. Students should learn to acquire knowledge using STEM technologies, which includes a sequence of methods and steps necessary to achieve the set goals, related to real life, which is the basis of STEM education.
– Future specialists must be competent in the STEM field, in the means of modern technologies, and not only in their main professional field; therefore, the development of the content of professional training of future specialists using STEM technologies is key to the formation of qualified specialists in modern fields.
– It is necessary to improve the quality of education for students to study the special course "Main advantages of STEM technologies in the professional training of specialists" for the effective training of future specialists.

3. **Progress of didactic and methodological innovative funding for the procedure of professional training of students using STEM technologies.**

The third pedagogical condition provides high-quality training using STEM technologies by analyzing the needs of students to form STEM competence. This is facilitated by the following forms of training: technologies (training, case studies, project activities); group training, seminars, lectures, laboratory work, practical classes; methods (experimental projects, creative tasks, problem-based learning, online resources, multimedia, interactive methods).

4. **Use of interactive teaching methods based on the request of STEM skills.**

The fourth pedagogical condition provides for the active involvement of students in learning using interactive methods, which contribute to in-depth and active mastery of the material in the process of qualified training. Interactive learning takes place through teamwork, cooperation, interaction, and communication, in which both students and the educator are subjects of the educational process, which promotes the contact of all members in the educational process.

We believe that the pedagogical conditions developed by us for the effective training of future specialists are sufficiently detailed and complete to be useful for innovative aspects of professional activity, for the implementation of STEM technology methods in the process of training future specialists.

At the control stage of the experiment, the results of the formative stage of the experiment were checked, statistical processing and systematization of empirical data were carried out, a comprehensive analysis of the research results was carried out, the effectiveness of the implementation of pedagogical conditions for the effective training of future specialists was determined to form STEM competencies of future specialists, and general conclusions were formulated.

4.4 Results of the ascertaining stage of the study

According to the results of the pedagogical experiment at the ascertaining stage, it was found that (Fig. 1):
– 15% of the CG respondents had a high level of STEM competence formation.
– 32% of the CG students had an average level of STEM competence formation.
– 53% of the CG respondents had a low level of STEM competence formation.

Similar results were obtained in the EG:
– 14% of the EG respondents had a high level of STEM competence formation.
– 32% of the EG students had an average level of STEM competence formation.
– 54% of the EG respondents had a low level of STEM competence formation.

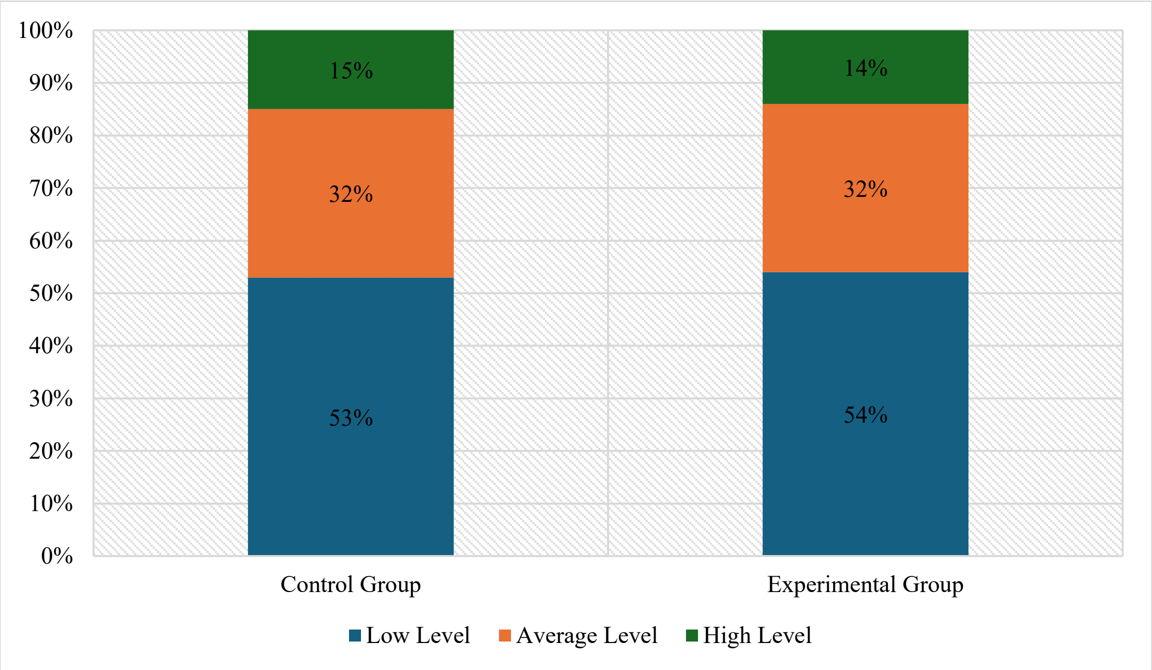

Fig. 1: Levels of STEM competence formation in EG and CG at the ascertaining stage of the experiment.

Diagnostics of the levels of creation of future STEM competences in future specialists at the ascertaining stage showed insufficient effectiveness of the process of introducing STEM technologies into the process of training future specialists.

Having compared the analysis of the obtained values of the Pearson criterion ($\chi2emp$) for all criteria with the critical value of the criterion ($\chi2cr < 0.05$), we concluded that in the control and experimental groups at the ascertaining stage of the study, the initial level of formation of future STEM-competence specialists does not differ significantly.

At the significance level of 0.01 and 0.05 between the groups (CG and EG) that participated in the experiment, according to the results of the ascertaining experiment, there are no statistically significant differences in the level of formation of future STEM-competence specialists. Therefore, we conclude that the contingent of students in the experimental group and the control group is equivalent, making it impossible to influence the validity and reliability of the results of the formative stage of the experimental study.

The reliability of experimental data at the ascertaining stage was determined by us using the nonparametric Pearson $\chi2$ criterion, as well as the dependability of the consequences of the experiment, which permitted us to measure the dependability and find variances between the two distributions, and obtain a 95% reliability of the probability results.

Using the nonparametric Pearson $\chi2$ criterion, the reliability of the results obtained was checked, to test the hypothesis H0, which indicates the absence of differences between the two empirical (experimental) distributions. Thus, during the comparative analysis of the obtained values of the Pearson criterion ($\chi2emp$) for all criteria with a critical value of the criterion ($\chi2cr < 0.05$), it was proven that the initial level of formation of future STEM competencies in the experimental group and the control group does not differ significantly. This serves as a basis for the conclusion that the contingent of students in the experimental group and the control group is equivalent, which makes it impossible to influence the validity of the results and their reliability in the formative stage of the experiment.

The results of the ascertaining stage of the experimental study showed an insufficient level of formation of future specialists in STEM competencies, which allowed us to outline a range of problems and develop, substantiate pedagogical conditions for the effective training of future specialists to form their STEM competencies.

4.5 Analysis of the results of the formative experiment on the implementation of pedagogical conditions for the effective training of future specialists to form their STEM competencies.

The course of the formative experiment was determined by the consequences of the ascertaining experiment. The quantitative composition of the students remained unchanged.

The formative experiment involved testing the pedagogical conditions for the effective training of specialists using STEM technologies to form STEM competencies of future specialists.

Let us describe the obtained generalized data of the formative stage and the ascertaining stage of the study regarding the levels of formation of STEM competencies of future specialists in the control group and the experimental group after the experiment and at the start of the experiment:

Cognitive criterion (Fig. 2), CG:

- The high level of formation of STEM competencies of future specialists, CG increased by 4%.
- The average level – CG increased by 9%.
- The low level – CG decreased by 12%.

Cognitive criterion, EG:

- The high level of formation of STEM competencies of future specialists of the EG increased by 19%.
- The average level – EG increased by 14%.
- The low level – EG decreased by 33%.

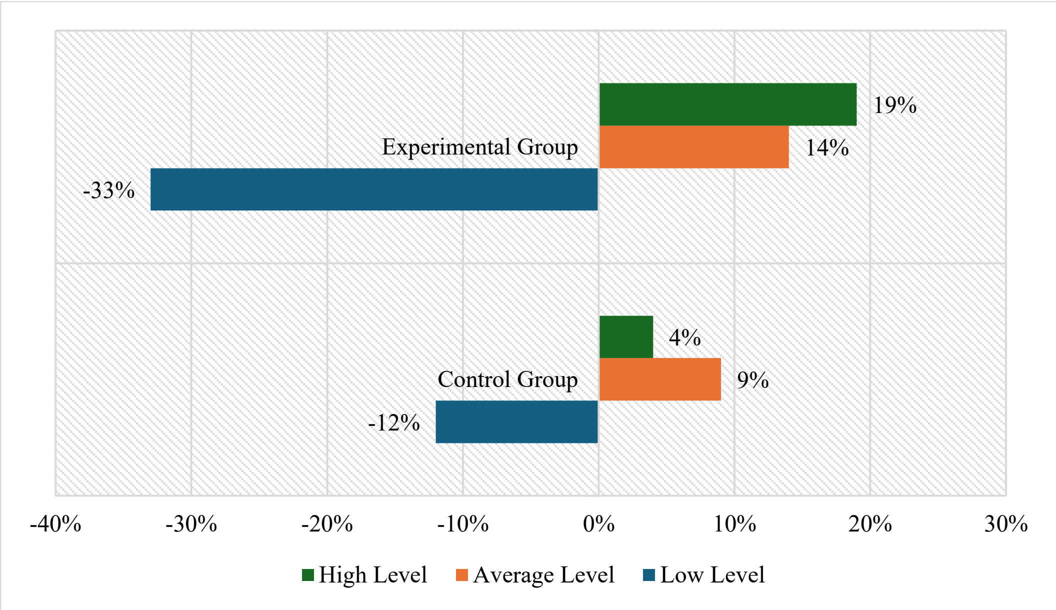

Fig. 2: Dynamics of STEM competence formation according to the cognitive criterion in CG and EG.

Reflective criterion (Fig. 3), CG:

- The high level of formation of STEM competencies of future specialists of the CG increased by 3%.
- The average – CG increased by 7%.
- The low level – CG decreased by 11%.

Reflective criterion, EG:

- The high level of formation of STEM competencies of future specialists of the EG increased by 17%.
- The average level – EG increased by 14%.
- The low level – EG decreased by 32%.

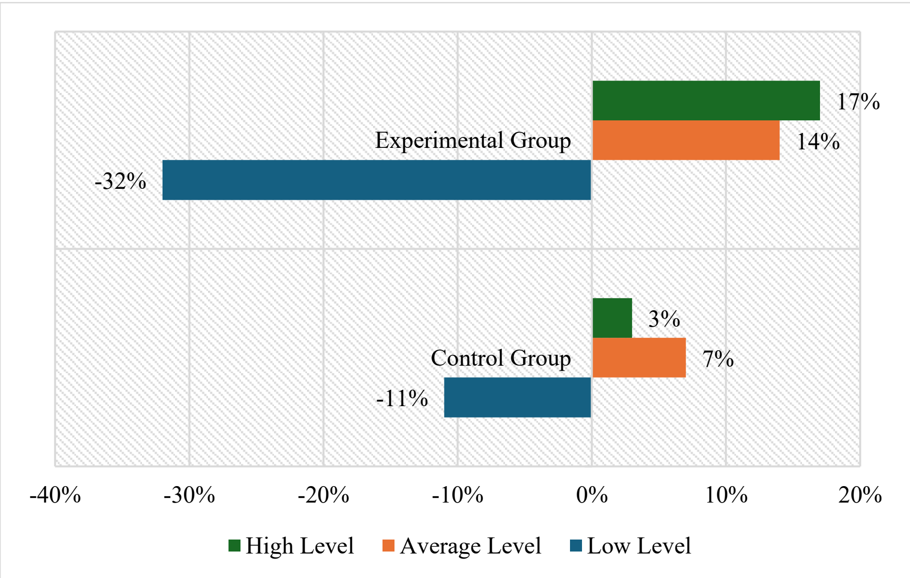

Fig. 3: Dynamics of STEM competence formation according to the reflective criterion in CG and EG.

Activity criterion (Fig. 4), CG:

– The high level of formation of STEM competencies of future specialists of the CG increased by 2%.
– The average – CG increased by 9%.
– The low level – CG decreased by 10%.

Activity criterion, EG:

– The high level of formation of STEM competencies of future specialists of the EG increased by 18%.
– The average level – EG increased by 11%.
– The low level – EG decreased by 29%.

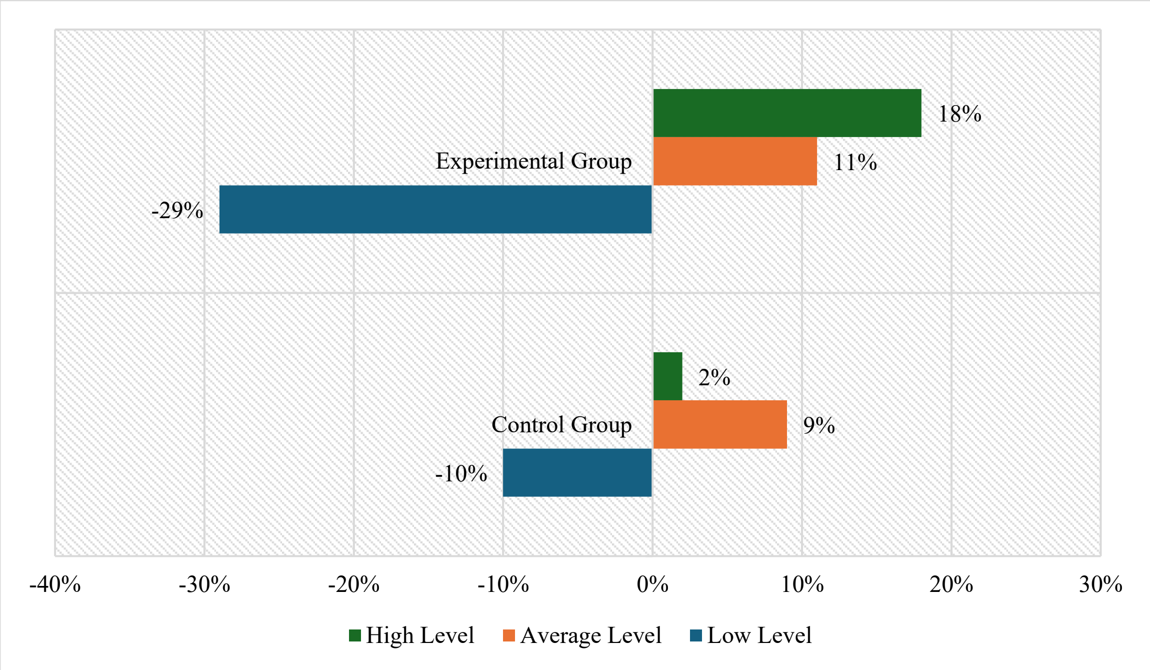

Fig. 4: Dynamics of STEM competence formation according to the activity criterion in CG and EG.

Motivational criterion (Fig. 5), CG:

– The high level of training of STEM competencies of future specialists of the CG increased by 3%.
– The average level – CG increased by 8%.
– The low level – CG decreased by 11%.

Motivational criterion, EG:

– The high level of formation of STEM competencies of future specialists of the EG increased by 18%.
– The average level – EG increased by 13%.
– The low level – EG decreased by 31%.

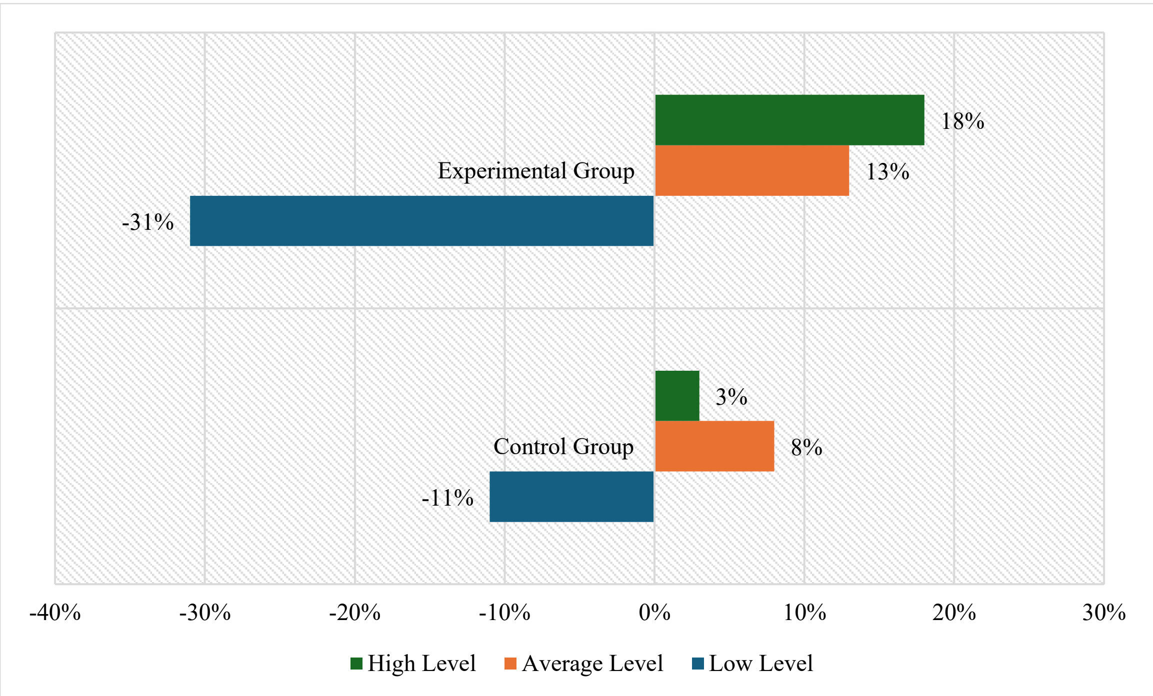

Fig. 5: Dynamics of STEM competence formation according to the motivational criterion in CG and EG.

Thus, at the formative stage of the study, the results of the research and experimental work showed that the number of respondents in the EG who reached a high level increased by 17% in accordance with the established levels of formation of STEM competencies, and in the CG, it increased only by 2-3%.
The quantity of respondents with an average level of formation of STEM competencies in the EG increased by 14%, in the CG by 9%.
The indicators of the low level changed most significantly: in the EG, the number of respondents decreased by 31%, and in the CG, the number of respondents decreased by only 11%.
The results of the formative stage of the experiment confirmed the effectiveness and validity of the proposed pedagogical conditions for the effective training of future specialists using STEM technologies in order to form their STEM competencies.
A statistical analysis was conducted using statistical processing methods to confirm the dependability of the study hypothesis and the conclusions obtained throughout the formative stage of the experiment (Pearson's non-parametric $\chi 2$ criterion); to clarify the fact that the difference in indicators is significant in the CG and EG, that is, the result of the implementation of pedagogically justified conditions for the effective training of future specialists using STEM technologies to form their STEM competencies, and not the influence of random factors.
Therefore, the null hypothesis H0: the experimental sample and the control sample are homogeneous in terms of the level of formation of STEM competencies of respondents according to the studied criterion $\chi 2$.
Alternative hypothesis H1: the experimental sample and the control sample are different in terms of the level of formation of STEM competencies of respondents according to the studied criterion $\chi 2$.
We receive the alternative hypothesis as true and reject the null hypothesis – in the EG, according to the specified criteria, the dynamics of the indicators make it possible to assert that the proposed pedagogical conditions contribute to an increase in the level of formation of STEM competencies of respondents.
Therefore, we conclude that the pedagogical conditions proposed by us for the effective training of future specialists to form their STEM competencies are effective, which is confirmed by the statistical processing of experimental data.
The qualitative and quantitative analysis of the results presented in the study showed a positive dynamic of the levels of formation of STEM competencies of students in relation to the specified criteria.
The results of the formative stage of the experiment confirmed the validity and effectiveness of the proposed pedagogical conditions for the effective training of future specialists to form their STEM competencies and gave grounds to assert that the goal of the study has been achieved.

4.6 Research limitations.

The implementation of the pedagogical experiment was carried out in three stages during 2023-2025: preparatory, main, and final.
At the preparatory stage (2023), the goal and objectives of the study were determined, the experimental plan was developed, the methods of measuring and processing the results were determined, the control and experimental groups were selected, and their homogeneity was checked.
At the main stage (2024), the experiment was conducted.
At the final stage (2025), the results of the experiment were analyzed, their reliability was confirmed, and conclusions were drawn about the pedagogical effect of the experiment.
Research relies largely on the accuracy and reliability of data. The following digital data collection tools were useful in the study: MS Excel and SPSS (Statistical Package for Social Science).
The total sample size in the article is 164 respondents. The sample of respondents was formed by random selection using the technical procedure for calculating the selection step.
During the experimental study, diagnostic data on the levels of social competence of higher education applicants were determined through informational influence and were divided into a control group and an experimental group.
The study was implemented by using methods and various forms: multimedia technologies (projector, multimedia board, video and audio equipment), software that combines animation, graphic, text, video and sound data and information, their simultaneous use in the information space; mobile devices, personal computers, web-oriented resources that are freely available and free of charge (YouTube, specialized sites, social networks, cloud technologies, social network technologies), etc.
The limitations of this study allowed to have the following impact on the results: improving the qualitative characteristics of the material, optimally specified goals and objectives, and increasing the effectiveness of the results.

5. Conclusion

The article shows the importance of STEM education for today. The strategy for the development of STEM areas in the professional training of specialists is revealed; the essence, structure, and advantages of STEM competence in the higher education system are described. The most popular areas of STEM competence development are highlighted. Ways of using modern approaches to the application of STEM technologies in the training of future specialists are shown.
The task of our study was the formation of STEM competencies in the professional training of future specialists. Investigating the outlined research problem, we identified ways of forming STEM competence in future specialists as: the basis of successful professional adaptation, as a process of professionalization. In the study, we identified the components of STEM competence, its criteria, indicators, and levels of formation.
The research and experimental work covered three stages of scientific and pedagogical search and was carried out during 2021–2025. The stages of the experiment were as follows: constant, formative, and control. 164 people were involved in the experiment; these were students, from whom the control (CG) and experimental (EG) groups were formed.
Having compared the analysis of the obtained values of the Pearson criterion ($\chi 2emp$) for all criteria with the critical value of the criterion ($\chi 2cr < 0.05$), we concluded that in the control and experimental groups at the ascertaining stage of the study, the initial level of formation of future specialists in STEM competencies does not differ significantly.
The results of the ascertaining stage of the experimental study showed an insufficient level of formation of future specialists in STEM competencies, which allowed us to outline a range of problems and develop and substantiate the pedagogical conditions for the effective training of future specialists to form their STEM competencies.

The course of the formative experiment was determined by the consequences of the determining experiment. The quantitative composition of students remained unchanged. The formative experiment involved testing the pedagogical conditions for the effective training of future specialists to form the STEM competencies of future specialists.
The results of the formative stage of the experiment confirmed the effectiveness and validity of the proposed pedagogical conditions for the effective training of future specialists to form their STEM competencies.

Future Research Directions.

The issue of organizing the international activities of a modern university requires further study, primarily specifying priority areas and current tasks of innovative activities in the context of the internationalization of higher education.
Future research directions can be used to study the effectiveness of combined learning methods that combine traditional and innovative approaches, as well as the impact of individual learning trajectories on student success. It is worth investigating the use of artificial intelligence to personalize learning, analyzing the long-term consequences of using virtual simulations in disciplines, and developing approaches to improve learning paths in combination with innovative learning tools.

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