Теорія та методика професійної освіти

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STEM, STEAM OR STREAM-EDUCATION: IT IS YOUR CHOICE!

The article deals with an actual problem of the improvement of pedagogical education system, namely a new direction – STEM-STEAM-STREAM-education. The objective of the study is to outline the origins of the problem genesis, to analyze the essence and content of STEM-education, to identify the main problems and contradictions, to identify the main means of its implementation. Synergistic, systemic, competence-oriented and activity-oriented approaches have become theoretical and methodological foundation of the study. The conclusion about the expediency of STEM-STEAM-STREAM-education combining has been made on the basis of theoretical analysis of the problem and the students of higher pedagogical institutions questionnaires. It will allow to develop left and right hemispheres of a brain simultaneously, which will contribute to its holistic functioning.

With the aim of formation of future natural sciences teachers' key and subject competences the means of STEM-STEAM-STREAM-education have been determined. That is the implementation of environmental projects in the process of education. The essence and methodology of the following projects implementation have been characterized: «Plastic bottle – a valuable thing from the past or a useless thing of nowadays? », «Let's save the Christmas tree together», «Destruction of nature», «Eco-feeder for our feathered friends», «Clean gullies – clear conscience». Enumeration of competences based on the reflection of students' own activities, the formation of which is mostly facilitated by the mentioned project activity has been determined.

Fulfilment of eco-projects has a positive effect on the development of components of innovative competence of the students of higher pedagogical institutions (the ability to apply scientific methods of cognition in the educational process, the ability to use innovations in professional activities, the ability to apply various approaches to solving problems in pedagogical activities).

The prospects for further study consist in the research of the following problem: preparation of future natural sciences teachers for modeling of educational activity using STEAM-technologies and their significance in the

methodology of forming a model of bioethical behaviour of school students on the basis of the concept of sustainable development.

Keywords: *newest educational technologies, natural sciences, project activity, environmental projects.*

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STEM, STEAM ЧИ STREAM-ОСВІТА: ВИБІР ЗА ВАМИ!

У статті розглядається актуальна проблема вдосконалення системи педагогічної освіти, а саме новий напрям – STEM-STEAM-STREAM-освіта. Мета дослідження полягає в окресленні витоків проблемогенезу, проведенні аналізу сутності та змісту STEM-освіти, виявленні основних проблем та суперечностей, визначенні основних засобів їх реалізації. Теоретико-методологічною основою дослідження склали синергетичний, системний, компетентнісно-орієнтований та діяльнісний підходи. На основі теоретичного аналізу проблеми та анкетування студентів закладів вищої педагогічної освіти зроблено висновок про доцільність поєднання STEM-STEAM-STREAM-освіти. Це дозволить одночасно розвивати ліву і праву півкулі головного мозку, що сприятиме його цілісному функціонуванню.

З метою формування у майбутніх учителів природничих дисциплін ключових і предметних компетентностей визначено засоби STEM-STEAM-STREAM-освіти. Тобто реалізація екологічних проектів у процесі навчання. Охарактеризовано сутність та методологію реалізації наступних проектів: «Пластикова пляшка – цінність минулого чи марна річ сьогодення?», «Збережемо ялинку разом», «Знищення природи», «Екогодівниця для наших пернатих», «Чисті яри – чиста совість». На основі аналізу результатів рефлексії власної діяльності студентів, визначено перелік компетентностей, формуванню яких найбільше сприяє досліджувана проектна діяльність.

Встановлено, що виконання екологічних проектів позитивно впливає на розвиток складових інноваційної компетентності студентів вищих педагогічних закладів освіти (уміння застосовувати наукові методи пізнання в навчальному процесі, вміння використовувати інновації у професійній діяльності, здатність до застосовування різних підходів до вирішення проблем у педагогічній діяльності).

Перспективи подальшого вивчення полягають у дослідженні проблеми підготовки майбутніх учителів природничих дисциплін до моделювання навчальної діяльності з використанням STEAM-технологій та їх значення в методиці формування моделі біоетичної поведінки школярів на основі концепція сталого розвитку.

Ключові слова: *новітні освітні технології, природничі науки, проектна діяльність, екологічні проекти*.

Statement of the problem in general. We all are witnesses of the world's changes and its moving towards the information-holistic world space. The rapid increase of scientific knowledge (every 2 years the total content of information increases by 6-8 times), the emergence of computer facilities, the importance of which is obvious to each of us, especially in the period of quarantine (online learning), make actual the need for evolutionary changes in the society, in general, and the education system in particular. The world we live in has already changed. And what is being done in our general secondary education institutions?

It was substantiated in the theory and practice of teaching long ago that the studying of school natural sciences subjects, in which energy-information and material components of the world are separated from each other in order to study only simplified physical, chemical or biological forms of matter motion, hinder progressive changes in education. However, they do happen, because every day the future in the form of our children comes to school with the eyes in which one can clearly see the question: «Why should I know that? ».

An analysis of recent research and publications. The problem of STEM-education was the object of scientific research of Babiichuk S. (2018), Balyk N. (2017), Besedin B. (2018), Hloba O. (2021), Kuzmenko O. (2020), Polikhun N. (2017), Slipukhina I. (2017), Smoliakov O. (2018), Chernetskyi I. (2017), Shmyher H. (2017) and others. Their researches describe the educational technology of STEM as a means of reforming the educational system of Ukraine, the essence, directions, approaches and use of STEM-STEAM-STREAM-education. However, the problem of integrating the content and activity during the carrying out of environmental projects in the process of future natural sciences teachers training has not yet been the subject of scientific research.

The purpose of the article. The objective of this paper is to outline the origins of the problem genesis, to analyze the essence and content of STEM-STEAM-STREAM-education. To characterize the essence and methodology of the environmental projects as a means of STEM-STEAM-STREAM-education implementation.

To achieve the abovementioned objective and tasks, a number of methods have been used, namely: theoretical – comparative analysis to find out different views on the problem, identify areas of study; modeling to develop a methodology for using information devices in the process of future natural sciences teachers training; systematization and generalization to formulate conclusions and recommendations for improving the educational process in biology; empirical – generalization of pedagogical experience, scientific observation, interviews, questionnaires in order to determine the state of implementation of the problem in practice; pedagogical experiment, which provided verification of the effectiveness of the proposed methodology; statistical methods for analyzing and establishing the reliability of the study results.

Experimental research has been carried out on the basis of Ternopil V. Hnatiuk National Pedagogical University, Sumy A. Makarenko State Pedagogical University among the students of educational programs 014 Secondary Education (Biology and Human Health), (Chemistry), (Geography), (Natural Sciences) during 2022-2023 and 2023-2024 academic years. A total of 553 students participated in the experimental research (333 students out of them studied in experimental groups and 220 students studied in control groups) and 25 respondents from the teaching. The criteria of efficiency of the offered methodology of realization of STEM-STEAM-STREAM-education have been defined: the level of development of innovative competences.

Presentation of the main research material. Recollect the well-known saying: «Everything new is actually well-forgotten old». The scientists trace back the origins of STEM-education to the methodological developments of the following founders of project activities as J. Dewey, W. Kilpatrick and others. However, in our opinion, the technology of complex education, which was widely implemented in Ukraine in the 20-30s of the XX century during the period of maximum activity of pedagogical public opinion, received insufficient analysis and evaluation. And namely this technology is the basis of STEM-education.

An attempt of the holistic reflection of nature in the content of education was made in 1923,

when comprehensive programs were implemented in school practice. According to scientific sources [12], the authors of the programs followed the way of synthetic generalization of educational material around 3 topics: «Nature», «Labour», «Society». Labour activity of people, which had to be considered in connection with nature as the object of this activity was in the center. Herewith, subject structures as such were mostly liquidated. F. Krasinov, a scientist of that time, defines the complex as: «The complex is a group of objects which are subjected to scientific and pedagogical research, a group united by a certain internal connection and adjacent to a certain central idea, which is like an idea, a core or a kind of ridge, around which all the studied material is organically and harmoniously placed» [12, p. 75]. A typical example of the complex of that time is the project named «Well» (F. Krasinov), developed on the basis of integration of physical, technical and partly hygienic knowledge. The scientist divided the material into 8 parts: On the importance of the well; Well measurement; About where the water in the well comes from and how it gets there; Where from and how water penetrates into the well; On the property of water to dissolve some solids; About the water temperature in the well; Hygiene and sanitary importance of wells; Investigation of the phenomena that have to be dealt with when collecting water from a well by buckets or pumps.

It is worth paying attention to M. Zaretskyi's remarks concerning the suggested material. Thus, the researcher believes that cultural and historical, economic, artistic, and mathematical elements could be built around the relevant core. At the same time, it was recommended not to be delighted with the idea of complex teaching, but to use it sporadically, to diversify school work [12]. That is, as we consider, the idea to combine STEM-STEAM-STREAM-education was uttered.

Hereby, in general didactic term, we can recognize that complex teaching was developed in line with the approach, which in modern pedagogy is called STEM-education, but the basis of its integrity from the very beginning was separated from the systematic character of subject knowledge. Therefore, obviously, complex education could not become the basis of school education in general, and, unfortunately, the mentioned ideas were not widely developed, as the entire experimental search of the 20-30s was eliminated.

Let us focus on the interpretation of the notions, which are increasingly being introduced into our present: STEM-education; STEAM-education; STREAM-education. STEM (S - science, T – technology, E-engineering, M-mathematics). The acronym STEM is used to denote the current trend in education, which includes science, technology, engineering and mathematics. This is an area of education in which the curriculum enhances the science component and innovative technologies.

In STEAM-education, art is added to the above-mentioned characteristics, and in STREAM-education - reading and writing. As we can see, science and mathematical education (STEM) when enriched by art is already STEAM, and with the inclusion of key components of reading and writing it becomes STREAM. Definitely, studying of the theme in complex is the guarantee not only of the development of key competences, but also the consolidation of school students' natural interest in exploring the world, and for future teachers – communication skills.

Taking into account our extensive experience of pedagogical activity, especially the training of current future natural sciences teachers, the content of the Professional Standard for Teachers of General Secondary Education, we consider it appropriate to combine STEM-STEAM-STREAM-education. It helps to develop left and right hemispheres of a brain simultaneously, which contributes to its holistic functioning.

Studying the practice of modern introducing of STEM-education, for example, shows that, summarizing the experience of Kropyvnytskyi secondary school № 79, teachers conclude about its ten advantages:

1. Efficiency of integrated teaching according to the «themes», but not by the subjects.

2. Application of scientific and technical knowledge in the real life. STEM-education through practical classes demonstrates to children the application of scientific and technical knowledge in the real life. Children study specific project and then create a prototype of a real product with their own hands. For example, when getting acquainted with a rocket, young engineers learn what the

engineering design process is, launching angle, pressure, tension force, friction force, trajectory and coordinate axes.

3. Development of critical thinking and problem solving. STEM programs develop critical thinking and problem-solving skills needed to overcome the difficulties that children may face in life. For example, they construct cars at classes, then they are tested. After the first test the children analyze why their car did not reach the finish line, eliminate errors and test the model again. And so it continues up to achieving the goal.

4. Increase of self-confidence. Creating your own products, models, testing and improving them help children not only succeed in a specific project, but also to learn to solve problems on their own and to become confident.

5. Active communication and team work. There is a congenial atmosphere for discussions and expression of opinions, presentations and development at classes. Actively participating in the process, children remember the lesson better.

6. Development of interest in technical subjects. Tasks of STEM-education create conditions for the development of school students' interest in natural sciences and technical disciplines, because they are very entertaining and dynamic, and children never get bored.

7. Creative and innovative approaches to the projects. STEM-education consists of six stages: questions / tasks, discussion, design, structure, testing and development. These stages constitute the basis for the project approach. Simultaneous study and application of science and technology can create many new innovative projects.

8. The bridge between education and career. According to various ratings, 9 out of 10 popular specialties will require STEM knowledge. In particular, the growth of the demand for specialties such as chemical engineers, software developers, petroleum engineers, computer systems analysts, mechanical engineers, civil engineers, robotics engineers, nuclear medicine engineers, underwater buildings architects and aerospace engineers is anticipated.

9. Preparation of children for technological innovations of life. STEM programs also prepare children for the technologically advanced world. Over the past 60 years technologies have evolved greatly from the discovery of the Internet (1960), GPS technology (1978) to DNA scanning (1984), and of course to the iPod (2001). Today nearly everyone uses an IPhone and other smartphones. It is simply impossible to imagine our world today without technologies. Technological development will continue, and STEM skills are the foundation of this development.

10. STEM as a supplement to the school curriculum. STEM programs for school students aged 7-14 are also designed to increase their interest in their regular classes. For example, at physics lessons, school students get acquainted with gravity, which is explained by formulas on the board, and during STEM-education they launch parachutes, rockets or airplanes.

The results of monitoring the educational process and questionnaires of 25 natural sciences teachers of higher education institutions showed that 92% of respondents do not sufficiently implement an integrated approach in forming the content of education both at the level of educational material (projective content) and at the level of pedagogical process (content implementation). Respectively they do not implement STEM-education, the basis of which is an integrated approach to the study of natural phenomena. Teachers experience significant difficulties in establishing interdisciplinary and intradisciplinary links for a holistic view of natural phenomena and processes, interpretation of general laws of nature, and others.

During the fundamental disciplines studying the teachers pursue the goal to acquaint students with the facts, concepts, laws and theories of the corresponding foundations of sciences. Herewith, the fact that the content of the foundations of sciences is a source of only the cognitive component of future natural sciences teachers' professional competence formation is not taken into account. Figurative thinking development was not the goal in none of the analyzed educational programs. Only those teachers who teach methods of school subjects teaching are aware of the feasibility of combining figurative and logical thinking (12%). But even they do not take into account its specifics

in the process of constructing the content of educational material at the level of pedagogical activities. 4% out of them consider it to be superfluous in teachers professional training, answering that its combination only complicates the teaching process. However, in the past century it was substantiated in didactics that it is advisable to take into account in forming the content of education of students the model of the academic subject, including to the objects of study such knowledge as historical, logical, methodological, evaluative, and others. Exactly the components of procedural (auxiliary block) of school subjects that are included in the curriculum in order to study the basics of sciences, is a means of overcoming the main methodological contradiction of cognition: between the integrity of nature and the fragmentary character of its cognition.

With the aim to check the efficiency of environmental projects using, the students were asked to carry out the following environmental projects: «Plastic bottle – a valuable thing from the past or a useless thing of nowadays? », «Let's save the Christmas tree together», «Destruction of nature», «Eco-feeder for our feathered friends», «Clean gullies – clear conscience». Their choice is determined by the specifics of the subject.

All the projects were carried out by students during independent work individually, in pairs or in groups as individual research tasks. There was certain time to defend the projects, where each student could present the results of his work. The fulfilment of each project required knowledge not only of physics, chemistry, biology or ecology, but also creative, research, interdisciplinary approaches, creativity, use of computer technologies, mathematical literacy and the ability to communicate actively and work in a team.

Let us characterize the peculiarities of the mentioned environmental projects in the process of future natural sciences teachers training, taking into account the concept of STEM-education [15] and the Concept of pedagogical education development [16]:

1. Integrated teaching. STEM-education combines in itself interdisciplinary and project approaches, based on the integration of natural sciences into technologies, engineering and mathematics. During the carrying out of the project «Plastic bottle – a valuable thing from the past or a useless thing of nowadays? », at first students studied the chemical composition of plastic, its properties (critical reading skills were developed), and then, taking into account aesthetic preferences, made things from plastic bottles for their reuse (development of figurative thinking). They made bird-feeders, pencil cases for stationary and even adornments. To make earrings, it was necessary to take an engineering decision regarding the fastening of the plastic component on the hook. To make a pencil case, it was necessary to calculate mathematically the total length of the manufactured object and the length of the clasp, to think about how to fasten them together. The carrying out of the project «Destruction of nature» combines knowledge of Ukrainian folk traditions, creative embroidery, sewing, fabric selection, decoration and understanding of the harmful effects of modern disposable plastic bags on the environment.

2. Application of scientific and technical knowledge in the real life. During the carrying out of all environmental projects, students studied a specific phenomenon or process, and then created a prototype of a real product with their own hands.

In the course of the environmental project «Eco-feeder for our feathered friends» fulfilment all the final developments were hung on the territory of universities. Eco bags, which were made by the students, were able to replace disposable plastic bags, which contributed to the formation of entrepreneurial competence of future natural sciences teachers. The handmade New Year's compositions (which did not have branches of coniferous trees) were used during winter celebrations. Thus, the products made during the project fulfilment were used in everyday life.

3. Development of critical thinking and problem solving. STEM programs develop critical thinking and problem-solving skills needed to overcome the difficulties that a person may face in life.

The problem of environmental pollution is not new today. Everyone wants to have a cozy place for outdoor recreation and comfortable conditions for this. During the carrying out of the environmental project «Clean gullies – clear conscience» the students were able to clean the the

Sumka River floodplain, which flows through Sumy region. To carry out this project it was necessary to show team spirit and organizational abilities. Some students gathered rubbish following safety standards and using personal hygiene items, while others arranged the organized removal of collected waste.

4. Increase of self-confidence. Creating one's own products, models, testing and improving them helps every person to become more confident and increases the level of self-esteem. During the final questionnaire, some students noted that they had worked with the similar materials for the first time in their lives and they liked it. During the environmental projects defence, students conducted workshops for all interested people in order to promote skills and abilities that they have acquired independently.

5. Active communication and team work. There was a congenial atmosphere for discussions and expression of opinions, presentations and development during the fulfilment of the project. STEM anticipates teamwork. Working together students expressed their ideas and suggestions, discussed, and justified their position.

Before fulfilment the project «Clean gullies – clear conscience» a curatorial hour was held with students on the topic: «Clean environment – everyone's desire». The problem of soils, water and air pollution was discussed at this class. The students were asked to draw (artistic competence) a «friendly caricature» for nature during the class. The work was carried out in groups, and after its completion the leader of each group offered to start the practical implementation of solving the problem of environmental pollution.

6. Development of interest in technical subjects. One of the key tasks of STEM is to demonstrate the advantages of technical and natural sciences specialties. The student who understands the structure of living organisms and the processes that take place in them, finds learning entertaining and interesting. Today it is interesting to study living objects with the help of 3D (4D) (5D)-models, which help the researcher to create augmented reality. The use of Google Play Market applications allows to develop computer, mathematical and entrepreneurial competences.

7. Creative and innovative approaches to the projects. STEM-education consists of six stages: questions / tasks, discussion, design, structure, testing and development. Environmental STEM projects involve realization of any of students' creative ideas. Embroidery to decorate eco bags, the use of orange peel to make a feeder, work with a plastic bottle to make adornments or the use of a plastic bottle to make a Christmas tree – all these things contribute to the implementation of innovative and creative approaches.

Let us consider how we can trace the components of STEM-STEAM-STREAM-education while working on the project «Plastic bottle – a valuable thing from the past or a useless thing of nowadays? »

Science

- working up of scientific literature about plastics, pollution of the environment by plastic (formation of reading and writing skills);
- carrying out observations and experiments with a plastic bottle;
- establishing of causative relationships (why does a plastic bottle not decompose for a long time, etc.);
- identification of interconnections between soil contamination, water pollution by plastic and human health;
- explanation of the phenomena connected with water pollution by plastic waste;
- description of the properties of plastics (art);
- awareness of the value of nature and the need to take responsibility for environmental pollution, follow the rules of environmental behaviour.

Technology

- prognostication, selection of optimal methods of activity;
- goal setting and action planning;

- teaching how to search, select, convert necessary information;
- monitoring and correction of the results of actions;
- working with simple information objects: a text, a picture, audio and video fragments;
- using of general rules of creation manmade objects (conformity of the product to needs, convenience, durability, aesthetic value);
- product analysis: selection of details, their shape, determining the relative position, kinds of connection of details.

Engineering

- ❖ changing of the kind and way of connection of details (completion, granting of new properties to a design);
- ❖ creating of the construction based on a simple drawing;
- ❖ realization of project activities (creation of the plan and ways of its implementation, its embodiment in the model);
- ❖ searching for optimal technological sequence of the plan implementation;
- ❖ prognostication of the final practical result according to the tasks;
- ❖ creating of the imaginary form of the construction, embodiment of this form in the model.

Mathematics

- ✓ comparison and generalization of information;
- ✓ planning, writing down, execution and updating of the sequence of work;
- ✓ research planning, collecting and presentation of the received information;
- ✓ interpretation of the information (explanation, comparison, generalization of data, conclusions and forecasts);
- ✓ conducting calculations during the designing of reducing the consumption of plastic materials by one person.

8. Connection between education and career. According to various ratings, 9 out of 10 popular specialties will require STEM knowledge in the nearest future. During the fulfilment of environmental projects, each participant tried himself as an ecologist, engineer, builder, craftsman, artist, fashion designer or mathematician.

9. Preparation for technological innovations of life. Every student, taking into account the necessity for distance learning, has a computer or mobile learning tool. The use of interactive models and dynamic flash-presentations allows to imitate biological processes and phenomena, to conduct virtual observations of natural objects, to consider in details their structure, functioning of individual organs and systems, to study the processes in organisms at the cellular and molecular levels.

Interactive models open up new opportunities by transforming students from passive observers to active participants of virtual experiments.

10. STEM as a supplement to the syllabuses. STEM environmental projects are designed to increase students' interest in their ordinary classes. For example, the fulfilment of such projects promotes more attentive work of students at classes in genetics, molecular biology, soil science, ecology.

The efficiency of the proposed methodology of fulfilment eco-projects as a means of implementing STEM-STEAM-STREAM-education was tested during the formative experiment. Students from experimental groups studied according to our proposed methodology, and those from control groups – according to the traditional one. After the completing of experimental training, a survey of its participants was conducted to determine the effectiveness of the proposed methodology of using eco-projects based on self-analysis of the level of formation of students' innovative competence components. The results of the survey are presented in Table 1. We chose this criterion on the basis of our own conclusion from the theoretical analysis of the content of educational and professional programs for training students of pedagogical specialties, concerning the insufficient level of reflection of this competence and the needs of practice to implement the principle of «lifelong learning».

Analyzing the data of Table 1, we can see that the results of self-analysis of the level of formation of the first component of innovative competence (the ability to apply scientific methods of cognition in the educational process) are higher by 29. 2% for the students from E groups in comparison with those for the students from C groups. At the same time the sufficient level of this component formation was assessed by 3.7% more students from C groups than from E groups. Regarding the level of formation of the second component (the ability to use innovations in professional activities), so and here the respondents from E groups rated their level of competence formation at high level compared to those from the C groups by 54.1% higher. 7.3% more students of C than E groups assessed their academic achievements at a sufficient level of this competence formation.

Table 1.

Level of formation of students' innovative competence components

(based on the results of students' reflection)

Innovative competence components	Level of competence formation	Number of students whose answers correspond to the selected groups			
		Control (C) groups		Experimental (E) groups	
		Number of students	%	Number of students	%
1. The ability to apply scientific methods of cognition in the educational process	I	136	61,8	303	91,0
	II	72	32,7	24	7,2
	III	12	5,5	6	1,8
	IV	0	0	0	0
2. The ability to use innovations in professional activities	I	74	33,6	292	87,7
	II	124	56,4	32	9,6
	III	22	10,0	9	2,7
	IV	0	0	0	0
3. The ability to apply various approaches to solving problems in pedagogical activities	I	60	27,3	182	54,7
	II	60	27,3	74	22,2
	III	66	30,0	55	16,5
	IV	34	15,4	22	6,6

(I – high level; II – medium level; III – sufficient level; IV – low level)

Similar results were obtained in the process of reflecting of the level of the third component formation (the ability to apply various approaches to solving problems in pedagogical activities): respondents of E groups rate their level of its formation as high by 27.4% higher and sufficient by 27.4% lower than respondents of C groups.

Interesting results were obtained as a result of reflection of the level of formation of the IVth low level of all the above-mentioned components of innovative competence formation. Respondents from both the E and C groups did not identify it as the one which is not inherent for them regarding the first two components. Regarding the third component both respondents of E and C groups indicate a low level of its formation (6.6% and 15.4%, respectively). So, from this we can come to the conclusion that its formation is more significantly influenced by other content of educational and professional programs 014 Secondary Education (Natural Sciences), (Biology and Human Health), (Chemistry).

The analysis of the formative experiment results provides grounds to come to a conclusion about the effectiveness of the proposed methodology of using eco-projects as a means of implementing STEM-STEAM-STREAM-education in future natural sciences teachers training. For greater reliability of the obtained conclusions, a statistical analysis of the results of the experimental study using criterion $\boldsymbol{X^2}$ was carried out. It confirmed that teaching according to the experimental

methodology helps to improve the quality of innovative competence of future natural sciences teachers' formation, which is reflected in changes of the levels of their development for the students, and these changes are not accidental.

Conclusions and prospects for further research. The use of modern technologies and means of STEM-STEAM-STREAM-education in a complex creates a single information educational environment, which is based on real nature objects, integrated computer networks and communication systems. This allows to accompany and coordinate the educational process of studying wildlife objects based on a combination of logical and figurative thinking with maximum consideration of the emotional and value component of the content of education. When implementing eco-projects as a means of STEM-STEAM-STREAM-education in the educational process of future natural sciences teachers training, it is necessary to adhere to the principles of reasonable conservatism, continuity, student-centered teaching. The use of eco-projects should not be the only means of STEM-STEAM-STREAM-education.

The educational process with the use of eco-projects encourages independent work of each student, creates a favourable communicative situation and conditions for the development of creative abilities of the individual, which are especially important for every future natural sciences teacher; increases the motivation and cognitive activity of students, improves individualization, differentiation and intensification of the learning process, expands and deepens interdisciplinary links, systematizes and integrates knowledge of individual academic disciplines, organizes systematic and reliable control, helps to overcome subjectivity in assessing the level of learning outcomes.

Fulfilment of eco-projects, besides other competences which have already been studied by scientists, has a positive effect on the development of components of innovative competence of the students of higher pedagogical institutions (the ability to apply scientific methods of cognition in the educational process, the ability to use innovations in professional activities, the ability to apply various approaches to solving problems in pedagogical activities). However, like in any educational innovation, the teacher must always play a key role. But he turns from the main source of knowledge into a coach, mentor, a person who shows how many ways exist to gain knowledge and solve problems. This substantiates the expediency of transition to the creation of a multi-subject educational environment (nature, teacher, student, information devices).

The prospects for further study consist in the research of the following problems: the impact of the use of eco-projects as a means of STEM-STEAM-STREAM-education on the formation of key competences of future natural sciences teachers and school students; determining the place of STEM-STEAM-STREAM-technologies in modern natural sciences education; preparation of future natural sciences teachers for modeling of educational activity using STEM-STEAM-STREAM-technologies and their significance in the methodology of forming a model of bioethical behaviour of school students on the basis of the concept of sustainable development.

REFERENCES

1. Babiichuk, S. (2018). STEM-education in the USA: problems and prospects. Pedagogical journal Volyn, no, 1 (8), pp. 12-17.

2. Balyk, N & Shmyher, H. (2017) Approaches and peculiarities of modern STEM-education. Physical and Mathematical Education, no, 2 (12), pp. 26-30.

3. Besedin, B. & Smoliakov, O. (2018). Learning technologies of 21st century: STEM-education. Humanization of the educational process, no, 1 (87), pp. 76-84.

4. Hloba, O. (2021). Introducing the newest technologies into the educational process in the teaching of chemistry and biology in educational institutions. Scientific Bulletin of the Izmail State University of Humanities. Section Pedagogical Sciences, no, 56, pp. 73–81.

5. Karbovanets, O., Kuruts, N., Holub, N. & Maiorosh, A. (2008) Project method as a modern pedagogical teaching technology in educational establishments of various levels. http://archive.nbuv.gov.ua/portal/natural/Nvuu/Ped/2008_15/karbovanets42.pdf.

6. Kosohova, O. The method of projects in the practice of modern school. Kh.: Ranok Publishing House.

(2011).

7. Krasinov, F. Well. Complex research experience. To help the teacher of the 1st stage school. M.: State. ed. (1922).

8. Kuzmenko, O. (2017). STEM education concept and areas of focus. Naukovi zapysky, vyp. 9, Ser. «Problemy metodyky fiz.- mat. i tekhnol. osvity. Chas. KDPU. pp. 188–190.

9. Kyian, T. (2011). Project and research activities in extracurricular activities in biology. Biology, no, 2, pp. 17-20

10. Moroz, I., Stepanyuk, A., Honchar, O. et al. (2006). General methodology of Biology teaching: manual. K.: Lybid, pp. 25–38.

11. Polikhun, N., Slipukhina, I., & Chernetskyi, I. Pedagogical technology STEM as a means of reforming the educational system of Ukraine. Education and development of gifted personality, no. 3, pp. 5-9 (2017).

12. Stepanyuk, A. (2012). Formation of holistic knowledge of schoolchildren about wildlife. 2nd ed. Ternopil: Vektor.

13. Stryzhak, O., Slipukhina I., Polikhun N., & Chernetckiy I. (2017). STEM-education: main definitions. Information technologies and learning tools, no 62 (6), pp. 16-32

14. Ten advantages of STEM-education. Retrieved from: https://sites.google.com/site/karacunino79/stem-osvita-proekt-majbutnogo/10-perevag-stem-osviti.

15. The concept of development of science and mathematical education (STEM-education) Government portal. Retrieved from: https://www.kmu.gov.ua/npas/pro-shvalennya-koncepciyi-rozvitku-a960r.

16. The concept of development of pedagogical education. Retrieved from: https://mon.gov.ua/storage/app/uploads/public/5b7/bb2/dcc/5b7bb2dcc424a809787929.pdf. Accessed 29 December 2021.

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