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Использование метода проектов в математической подготовке студентов – будущих экологов

Проблема и цель. В современных условиях действительности важность решения экологических проблем глобального и регионального характера делает актуальным поиск путей совершенствования процесса обучения математике будущих экологов, одним из направлений которого выступает проектная деятельность. Цель настоящей статьи – определение и теоретическое обоснование методических требований к эффективной реализации метода проектов в математической подготовке студентов – будущих экологов.

Материалы и методы. Использованы теоретические методы исследования (анализ отечественных и зарубежных литературных источников, изучение и обобщение педагогического опыта), обсервационные методы (наблюдение за учебной и научно-исследовательской деятельностью по математике студентов экологических направлений подготовки Вятского государственного университета и самонаблюдение).

Результаты. Представлена совокупность методических требований, обеспечивающих эффективное использование проектного подхода к процессу обучения математике будущих экологов. К числу важнейших из них относятся прикладная, проблемная и практическая направленность проектов, их исследовательский, комплексный и систематический характер, превалирование математической составляющей в проектной деятельности, междисциплинарная интеграция в процессе ее реализации.

Заключение. Выполнение прикладных исследовательских проектов студентами – будущими экологами способствует овладению ими умениями по применению изученного теоретического материала к решению современных задач экологии. Подобная форма работы по освоению содержания математического образования наглядно демонстрирует возможность его использования в последующей профессиональной деятельности, обеспечивает формирование у студентов исследовательских навыков, создает мотивацию к самообразованию с целью изучения прикладных математических методов и построения новых математических моделей применительно к экологической проблематике.

Ключевые слова: проектная деятельность, метод проектов, прикладной исследовательский проект, студенты – будущие экологи

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Using the project method in the mathematical education of students – future ecologists

Problem and purpose. In modern conditions the importance of solving environmental problems of a global and regional nature makes us search for ways to improve the process of teaching mathematics to future ecologists. The project activity is one of directions here. The purpose of this article is to define and theoretically justify methodological requirements for the effective implementation of the project method in the mathematical education of students – future ecologists.

Materials and methods. The authors use theoretical research methods (analysis of Russian and foreign literature, the study and generalization of pedagogical experience), observational methods (observation for educational and research activities in mathematics of students of environmental direction at Vyatka State University, self-observation).

Results. The authors present a set of methodological requirements that ensure the effective use of the project approach to the process of teaching mathematics to future ecologists. An applied, problematic and practical orientation of projects, their research, integrated and systematic nature, the prevalence of the mathematical component in project activities, interdisciplinary integration in the process of its implementation are of great importance.

Conclusion. Implementation of applied research projects by students – future ecologists contributes to their mastery of the skills to apply the studied theoretical material to the solution of modern environmental problems. This form of work demonstrates the possibility of using mathematics in subsequent professional activities, provides students with the formation of research skills, creates a motivation for self-education in order to study applied mathematical methods and build new mathematical models in relation to environmental issues.

Key words: project activity, project method, applied research project, students – future ecologists

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Problem and purpose

Global environmental crisis makes seriously rethink the goals of environmental education. One of the key tasks of training future ecologists is to develop skills of analyzing the relationship between environmental impact and the effect they produce, assessing harm to human health and negative consequences for ecosystems, calculating the complex effect of multiple types of pollution, choosing and measuring indicator environmental indicators. The success of solving these problems largely depends on the level of mathematical education of students - future ecologists.

According to T. Irish, A. Berkowitz, C. Harris [29], national and international scientific and educational communities recognize the need to educate scientifically competent environmental experts who can apply scientific methods in analyzing important environmental issues in order to make right decisions on ecosystem protection. Consequently, students should become critical consumers of professional information. However, the arguments they often hear, for example, in the mass media, often have poor scientific justification or insufficient evidence base. In the context of the identified problem, future ecologists need to develop critical thinking skills, as well as apply mathematical statistics methods.

The authors of this article identify groups of statistical knowledge and skills: to interpret the main trends in the field of data presentation; determine data variability (DV), describe potential sources of DV, describe its importance and consequences; assess requirements based on available data. There is no doubt that the successful formation of these competencies is carried out, in particular, through the mathematical education of students-ecologists.

The present research is relevant due to the need to find possible ways to increase the effectiveness of teaching mathematics to future ecologists in the conditions of overcoming the environmental crisis and meeting the requirements of society. In our opinion, one of the ways to achieve it is to use the potential of the project method in the professional mathematical training of students - future ecologists.

Using project activities in environmental education is proved by scientific and methodological studies. So, [11] underlines that the technology of project training meets the requirements of the logic of studying environmental situations and solving environmental problems, and also reflects the active nature of their content. E. Karahan, G. Roehrig [31] emphasize the role of the project method in studying local environmental problems, in attracting students to participate in various environmental activities. An empirical study [1] is devoted to the formation of the ecological culture of university students and states that the participation of students in the implementation of international and regional projects is of paramount importance.

YT. Pan, KK. Yang, ZR. Hong, HS. Lin [32] prove that effective environmental protection is provided to a greater extent by active involvement in scientific activity, in particular, through the project method, rather than by interest, formed, for example, by passive watching TV shows on environmental topics. N. M. Ardoin, A. W. Bowers, N. W. Roth, N. Holthuis [18] have carried out a systematic review of international publications in the field of environmental education over the past twenty years. They have identified the main trends, one of which is an increase in interdisciplinary project research.

An analysis of the world practice of applying the project method in [8] states that the project approach to higher environmental education was most widespread in China, where a high degree of environmental friendliness is provided at all levels of university activity.

In this regard, students mastering the basic educational programs solve urgent problems of their region and the country [8, p. 47].

Many scientific studies point out the importance of organizing project activities in the field of environmental education while studying various subjects at university, in particular, mathematics.

The purpose of this study is to determine and theoretically substantiate methodological requirements for the effective implementation of the project method in the mathematical preparation of students - future ecologists.

Materials and methods

Materials for the study were Russian and foreign researches in the following areas:

- evolution of educational project technology, its possible modifications, advantages and disadvantages, assessment of implementation experience; these provisions were tested by us while teaching "Mathematics";
- a description of applying the project approach to environmental and mathematical education; conditions for the implementation of project activities presented in the articles can be used in project training for students - future ecologists, in particular, providing intersubject communications of mathematics, ecology, biology and other related disciplines;
- integration of mathematical and environmental activities in the implementation of the project method; studying these research made it possible to obtain reliable information about project teaching activities in various countries and caused a number of requirements for the mathematical training of future ecologists in the context of project training.

Based on the systematization of the studies and the generalization of the relevant pedagogical experience, we have proved the expediency of applying the project approach to the mathematical education of students - future ecologists. Observation of the educational and research activities of students - future ecologists was taking place at Vyatka State University. The use of the project method in the process of teaching mathematics was based on the fulfillment of the proposed set of methodological requirements.

Results

The analysis of the practice of project training described in a number of Russian and foreign articles [2]–[8], [10]–[39] (the list of published scientific papers related to the topic of the article is not complete and presents the most important and latest studies), has revealed the following advantages (Table 1).

A great number of works have been devoted to the problem of the effective use of the project method in the process of mathematical education. In particular, the importance and relevance of project activities in teaching methods of mathematical statistics is justified in research [5; 34; 36]. K. W. Remijan [33] notes that project-based learning gives students the opportunity to apply the mathematical apparatus to solving real-life problems.

The authors [3] state the following fact: if everything is well organized, there is constant monitoring and objective assessment, then there is a significant increase in motivation to master mathematical disciplines and an interest to the specialty. Researchers [5; 12; 15] emphasize that in the course of project tasks students have updated knowledge about the relationship of mathematics with professional disciplines. Russian and foreign authors [20; 36; 39] consider the project activity to be the potential for the development of creative mathematical thinking. The stated provisions prove that the project training has a significant resource and perspective while studying mathematics.

Scientific studies which describe the experience of involving students in project activities in ecology using mathematical models and methods are of particular interest.

Table 1**Advantages of project technology training**

Project technology provides...	Researchers
formation of professional competencies among students	Kazun A. P., Pastuhova L. S. [8], Du X., Ebead U., Sabah S., Ma J., Naji K. K. [23], Virtue E. E., Hinnant-Crawford B. N. [37] et al.
orientation of the learning process to the chosen profession	Esaulova I. V. [5], Semenova B.G., Tomina I. P. [12], Trishenko D. A. [14] et al.
better learning outcomes than with the traditional approach	Trishenko D. A. [14], Siswono T. Y. E., Hartono S., Kohar A. W. [34], Zancul E. S., Sousa-Zomer T. T., Cauchick-Miguel P. A. [38] et al.
involvement of student in activity	Edmunds J., Arshavsky N., Glennie E., Charles K., Rice O. [24], Freitas A. M. M., Rossi B. C., Pereira S. G., Dos Santos M. R., Dos Santos C. A. M., Pereira M. A. C. [25], Karahan E., Roehrig G. [31], Shin MH. [35] et al.
development of critical thinking skills	Alawi N. H., Soh T. M. T. [17], Hebe H. [26], Zapata-Grajales F. N., Cano-Velásquez N. A., Villa-Ochoa J. A. [39] et al.
attracting students to research activities	Dos Santos E. F., Gonçalves B. C. M., de Oliveira K. B., Silva M. B. [22], Hernawati D., Amin M., Irawati M., Indriwati S., Aziz M. [27] et al.
interdisciplinary integration	Esaulova I. V. [5], Kazun A. P., Pastuhova L. S. [8], Hsu YC., Shiue YM. [28], Remijan K. W. [33] et al.
combination of theoretical knowledge with practical experience when applying	Ivanova S. V., Pastuhova L. S. [7], Fedoseev V. M. [15], Remijan K. W. [33], Shin MH. [35], Virtue E. E., Hinnant-Crawford B. N. [37] et al.
demonstration of the applied nature of the discipline	Esaulova I. V. [5], Zapata-Grajales F. N., Cano-Velásquez N. A., Villa-Ochoa J. A. [39] et al.
real problem research	Voronin D. M., Egorova G. V., Hotuleva O. V. [3], Du X., Ebead U., Sabah S., Ma J., Naji K. K. [23], Remijan K. W. [32] et al.
choosing topics for students' projects	Dos Santos E. F., Gonçalves B. C. M., de Oliveira K. B., Silva M. B. [22], Karahan E., Roehrig G. [31] et al.
gaining skills in working with various sources of information	Ivanova S. V., Pastuhova L. S. [7], Trishenko D. A. [14] et al.
the opportunity to work on their own	Esaulova I. V. [5], Trishenko D. A. [14], Telegina N. V., Drovosekov S. E., Vashbieva D. G., Zakharova V. L. [36] et al.
forming ability to make decisions	Ivanova S. V., Pastuhova L. S. [7], Karahan E., Roehrig G. [31] et al.
presenting results to fellow students	Culclasure B. T., Longest K. C., Terry T. M. [20], Siswono T. Y. E., Hartono S., Kohar A. W. [34], Virtue E. E., Hinnant-Crawford B. N. [37] et al.
introduction of modern information technologies	Semenova N. G., Tomina I. P. [12], Hsu YC., Shiue YM. [28] et al.
stimulation of educational motivation	Voronin D. M., Egorova G. V., Hotuleva O. V. [3], Hsu YC., Shiue YM. [28], Remijan K. W. [33], Shin MH. [35] et al.
recognition of the value of collaboration at work	Anishenko E. A., Baisultanova L. B., Karasheva A. G., Nasipov A.J. [2], Kazun A. P., Pastuhova L. S. C. [8], Virtue E. E., Hinnant-Crawford B. N. [37] et al.

H. Hebe [26] describes the integration of environmental and mathematical education in schools in the Republic of South Africa. Based on the analysis of numerous curricula, the author discovered a number of topics in mathematics that provide environmental education. They include, for example, the determination of the value of natural resources through mathematical calculations, spatial forms in the environment, etc. The authors also point out that in connection with the spread of the environmental crisis, the world community is concerned about the orientation of educational programs in environmental education. However, as the researcher states, in South Africa, environmental education is carried out mainly while teaching certain subjects, in particular, geography, and it is the prerogative of a narrow circle of teachers. At the same time, many subjects represent the potential for the formation of knowledge and skills in the field of ecology, including mathematics. The described problem is also relevant for the system of Russian environmental education.

Authors [22; 25] describe environmental projects implemented at universities in São Paulo (Brazil). Using mathematical methods, the authors studied the reuse of water and its saving [22], as well as the harmful effects of noise pollution for the environment [25].

N. H. Alawi and T.M.T. Soh [17] study the development of an environmentally friendly product on the basis of dynamic modeling of ecosystems. [31] describes a study of the problems of the river basin Minnesota from a triune perspective: social, environmental, and economic-mathematical.

M. Ćurčić, D. Milinković, D. Radivojević [21] evaluate integrated teaching of mathematics and ecology as a desirable learning model that provides an introduction and application of mathematical concepts, transforms the role of all participants in the educational process. The study presents experimental teaching based on a project to study the habitat (garden, field, orchard, vineyard, park, flower garden) and living communities in it by mathematical methods. The authors come to the conclusion: the experimental group, where the teaching was based on the project method, has shown a higher quality of education (in the categories of “knowledge”, “understanding” and “application”) both in the knowledge of nature and mathematics.

F. N. Zapata-Grajales, N. A. Cano-Velásquez, J. A. Villa-Ochoa [39] offer a research project to study the shape and geometric quantities of plants based on mathematical modeling. This method is considered as a tool for the mathematization of natural objects. Using linear regression equations, the authors analyze conditions of the growth zone and plant size in order to determine the optimal conditions for their growth. In addition, they build leaf models that establish the relationship between its area and dimensions - length and width. In conclusion, linear models are specified by nonlinear ones.

The value of mathematical modeling in higher environmental education is also emphasized by M. Bloom and S. Q. Fuentes [19]. The authors point out that one of the most important components of modern environmental literacy is energy production and related environmental consequences. According to scientists, this provision should be adequately reflected in the education of future ecologists. A mathematical modeling method is proposed to be a means of evaluating any energy source in the “cost – impact” system.

In all these studies the authors highlight the advantages and disadvantages of project education and point out a number of conditions that provide a significant increase in its effectiveness in the mathematical education of future specialists.

We believe that the implementation of the project method in the process of mathematical preparation of students - future ecologists will be effective when fulfilling the following methodological requirements. Let us consider these requirements in details.

The first requirement is the *applied, problematic and regional focus* of projects. Applied orientation involves the application of the mathematical apparatus, primarily mathematical modeling as a general scientific method of cognition, to solving problems of professional environmental activity. Problem orientation involves focusing on the study of a socially significant problem. Regional orientation implies taking into account the specifics of the place of residence or training of participants in the educational process, involving students in solving problems of a particular territory.

The conceptual approach has been used to projects implemented by future ecologists at Vyatka State University. In fact, the process of implementing work is done on a real-life environmental problem in the Kirov region. The work is based on information available for students' research activities, using mastered and recommended mathematical methods. Moreover, it is possible to test the results of project activities in the form of scientifically based forecasts of the primary incidence of the region's population based on the constructed mathematical models.

The second requirement is the *research nature* of the projects. According to Yu. V. Krasavina and O. F. Shikhova, "research projects are close to the structure of scientific research" [10, p. 166]. Working at them means identifying the problem, arguing its relevance, setting goals and objectives of the study, formulating hypotheses, choosing research methods, analyzing the literature and collecting the necessary information, substantiating the solution, discussing the results, their design, determining future prospects. We emphasize that the organization of project activities in this context ensures the development of future sustainable environmental research skills for future ecologists which they can not obtain in traditional forms of learning - lectures and seminars.

Also, according to their research, "if data collection requires the analysis of a large amount of heterogeneous information, including sources that are not in the library of the educational institution," then such projects "are recommended to perform using software, including specialized one, for statistical data analysis". The stated position is in demand while training environmental specialists, since they have to work with large volumes of information provided in various forms, competently process and analyze it using appropriate software. Therefore, we additionally form the modern computational culture of students and create conditions similar to their future professional activity.

The third requirement is the *need to ensure the unity of project activities and the system of teaching mathematics*, i.e., the mathematical part of the project should prevail.

The fourth requirement is the *practical orientation* of the project, implying its focus on the result of activities and development of the project product [10, p. 166]. In our case, an intellectual product is statistically significant mathematical models with scientific novelty. Environmental students who independently construct these models are like discoverers, since the construction of characterized regression models hasn't been studied before [9].

The fifth requirement is *interdisciplinary integration*: we form relatively independent knowledge through the implementation of interdisciplinary connections between mathematics, ecology and biology, as well as other related disciplines, mainly focused on getting professional skills by future ecologists [13]. The interdisciplinary character of projects is necessary for several reasons.

Firstly, environmental knowledge is *interdisciplinary*, since ecology as a science was formed on the basis of a number of scientific fields dealing with environmental problems, primarily biology, chemistry, geography, physics, medicine, and economics. Secondly, global environmental issues are multidisciplinary. It is known that a direct threat to the existence of the natural environment and living organisms is manifested not only in the environmental

crisis, but also in crises of the economy, politics, culture and other areas of public life. This means that all branches of scientific knowledge should participate when studying global problems. Thirdly, the solution of environmental problems is possible through the synthesis of modern achievements, methods and techniques of various sciences. Consequently, environmental training at universities should also take into account the establishment of interdisciplinary ties.

The sixth requirement is the *integrated and systematic nature* of project activities. According to Russian and foreign scientists, in particular, S. V. Ivanova, L. S. Pastukhova [7], A. P. Kazun, L. S. Pastukhova [8], Y.C. Hsu, Y. M. Shiue [28], L.A. Jacques [30], non-systemic and fragmented project activities can seriously slow down the effective implementation of the project method. We plan and organize the project activities of environmental students in such a way that the object is studied comprehensively as a result of not just one, but a whole sequence of projects where each subsequent result has scientific novelty and deepens the knowledge gained in the previous step.

The seventh requirement is a *group form* of work that allows to create conditions for joint learning of students, awareness of the value of cooperation in joint work and their own role in it [7; 14]. It is also advisable that future ecologists develop skills in presenting the results of project activities to fellow students. This form of work models the presentation of the results to potential customers, the target audience, etc. It is very important that future environmental bachelors, who are involved to implement projects, bring the results of their research to the public in the form of student scientific papers.

Discussions

Recognizing the advantages of the technology of project training, we should pay attention to the following fact. The implementation of the project method has certain difficulties, according to teaching experience, obtained while teaching mathematics on the basis of the project method, and the study of scientific works.

Firstly, in the process of implementing an environmental project, students often miss its mathematical component, focusing on the medical and environmental aspects of the research problem. Some scientists, in particular, M.V. Yegupov [4, p. 227], D. A. Trishenko [14, p. 148], V. M. Fedoseev [15, p. 131], J. Edmunds, N. Arshavsky, E. Glennie, K. Charles, O. Rice [24], E. E. Virtue, B. N. Hinnant-Crawford [37] underline this fact. J. Edmunds et al. in [24] contrast two projects, according to the level of severity of the mathematical apparatus used in them. The first one was carried out in an environmental class and aimed to study the effects of natural disasters. The authors note that it was unsuccessful because it was not based on a high level of presenting the educational material. The second project was dedicated to solving the problems of maximizing profits, taking into account a certain set of restrictions, including environmental ones. The implementation of this project was more effective due to integrating the knowledge that students have about linear equations systems and methods for solving them with new information about linear programming. Researchers emphasize the role of a teacher in the organization of the described project activity, who ensured the rigor of measurements and calculations, the active inclusion of each student and stimulated the development of their mental operations.

We organized the mathematical education of future bachelors-ecologists of Vyatka State University, including the use of the project method, so that the presentation of

environmental material was subordinate to the logic of the main discipline - mathematics. It was mentioned above as a methodological requirement.

Secondly, D. A. Trishenko [14, p. 148], S. G. Shulezhkova, A. M. Maksimova [16, p. 117], N. V. Telegina et al. [36], note that this method is not universal for universities. According to V. M. Fedoseev [15, p. 128], it is effective for solving such problems that require significant time costs and in terms of complexity it cannot be offered in classes of mathematics. E. Karahan, G. Roehrig [31] point out the advisability of organizing project activities to analyze issues which are the subject of various disciplines, since the curriculum of one particular discipline, as a rule, is not able to cover all interdisciplinary aspects. In our practice of preparing future bachelors-ecologists, the project method is used selectively to solve applied mathematics problems of an interdisciplinary environmental nature. We emphasize that the main means of teaching mathematics to such students remains the solution of educational mathematical problems and problems of a professional environmental orientation [13].

Thirdly, the most difficult part is to attract poorly motivated students to project activities who do not have the ability to plan their time, creatively and responsibly solve research problems. Project-based learning to a greater extent ensures the development of competencies of more trained students.

Conclusion

According to our research, the methodological requirements that ensure the effective use of the project method in the mathematical preparation of students - future ecologists are the following: an applied, problematic and regional orientation, research, integrated and systematic nature, the unity of project activities and the system of teaching mathematics at the university, practical-orientation of projects, interdisciplinary integration, group work.

The mathematical education of students of the environmental areas at Vyatka State University is built on the implementation of these requirements. A generalization of the experience of a mathematics course allows to conclude the following.

Independent original scientific research of practical importance for the region of the Russian Federation ensures the formation of the methodological component of the content of the mathematical education of future ecologists, including getting scientific research experience and mastering probabilistic, statistical and other general scientific methods of cognition. Students, carrying out their own scientific research, work under the guidance of a teacher, a scientist with reliable, independently collected environmental information, take part in solving urgent problems of their native region "here and now".

We also emphasize the psychological and pedagogical effect of the systematic project activities of future ecologists. While doing research, students learn to formulate their own hypotheses, take responsibility for the choice of mathematical methods and suitable applied software, develop the ability to reasonably express their ideas and thoughts, and look for the causes of difficulties. Consequently, it provides a certain degree of research freedom and an atmosphere of creativity with scientific results obtained. The applied orientation of projects and immersion of students in the field of professional activity maintains a high degree of educational motivation, stimulates students to self-education in studying applied mathematical methods and creating new mathematical models. In this regard, the activities of students - future ecologists become conscious, efficient and more productive. As a result, their level of professionalism and competitiveness in the labor market increases.

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