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ВЛИЯНИЕ ТЕХНОЛОГИЙ НА РАЗВИТИЕ ОБРАЗОВАНИЯ
EVOLUTION OF TEACHING AND LEARNING THROUGH TECHNOLOGY

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Development of students' scientific knowledge on computer modeling while teaching inverse problems for differential equations

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Abstract. *Problem statement.* Currently, the higher school provides students of physical and mathematical training areas with fundamental subject knowledge, forms professional competencies, develops creative abilities and creativity, teaches them to use modern computer technologies to solve applied problems. One of such academic disciplines, in which students are taught to use computer technologies in solving applied mathematical problems, is a training course called "Inverse problems for differential equations." Such an academic discipline has been taught in some Russian universities in the form of elective courses since the 70s of the 20th century. The educational material of this training course includes advanced research results on inverse problems belonging to specialists from different countries, such as Germany, Italy, China, Sweden, Netherlands, Russia, Japan and other foreign countries. During the practical classes, much attention is paid to the use of computer simulation for the study of such applied problems. This circumstance implies the development of educational materials taking into account the professional training of university students, in which attention should be paid to the use of computer modeling in solving mathematical models of inverse problems. *Methodology.* The implementation of training of university students in physical and mathematical areas of training involves taking into account modern scientific achievements of world science in the field of inverse problems using computer simulation and implementing advanced pedagogical technologies in the classroom. *Results.* Students acquire scientific knowledge of computer modeling and master the wide possibilities of computer modeling in the study of inverse problems. *Conclusion.* The presence of scientific knowledge in the field of computer simulation and practical experience of its application for solving inverse problems gives students great advantages and opportunities to be successful specialists in the field of applied mathematics and to be in demand on the labor market in various spheres of human activity.

Keywords: inverse problems, differential equations, computer simulation, informatization of education, student, teaching

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Развитие научных знаний студентов по компьютерному моделированию при обучении обратным задачам для дифференциальных уравнений

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Аннотация. *Постановка проблемы.* В настоящее время высшая школа предоставляет студентам физико-математических направлений подготовки фундаментальные предметные знания, формирует профессиональные компетенции, развивает творческие способности и креативность, учит использовать современные компьютерные технологии для решения прикладных задач. Одной из таких учебных дисциплин, при обучении которой студентов учат применять компьютерные технологии при решении прикладных математических задач, является учебный курс «Обратные задачи для дифференциальных уравнений». Данная дисциплина преподается в некоторых вузах России в виде курсов по выбору с 70-х годов XX века. Учебный материал курса включает передовые результаты исследований по обратным задачам, принадлежащие специалистам разных стран, таких как Германия, Италия, Китай, Швеция, Нидерланды, Россия, Япония и другие страны дальнего зарубежья. На практических занятиях уделяется большое внимание применению компьютерного моделирования для исследования прикладных задач. Это обстоятельство предполагает разработку учебных материалов с учетом профессиональной подготовки студентов вузов, в которых необходимо уделить внимание использованию компьютерного моделирования при решении математических моделей обратных задач. *Методология.* Реализация обучения студентов вузов физико-математических направлений подготовки должно учитывать современные научные достижения мировой науки в области обратных задач с использованием компьютерного моделирования и реализовывать на учебных занятиях передовые педагогические технологии. *Результаты.* При исследовании обратных задач студенты приобретают научные знания по компьютерному моделированию и осваивают его широкие возможности. *Заключение.* Наличие научных знаний в области компьютерного моделирования и практического опыта его применения для решения обратных задач дает студентам большие преимущества, возможности стать успешными специалистами в области прикладной математики и быть востребованными на рынке труда в разных сферах человеческой деятельности.

Ключевые слова: обратные задачи, дифференциальные уравнения, компьютерное моделирование, информатизация образования, студент, обучение

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Problem statement. The theory of inverse problems is being developed by the efforts of specialists from around the world. These are such authors as A.B. Bakushinsky, R. Burridge, Y.M. Berezansky, D.G. Berriman, A.L. Buchheim, V.V. Vasin, I.M. Gelfand, V.B. Glasko, N.B. Ilyinsky, S.G. Crane, M. Levitan, M.M. Lavrentiev, A.I. Prilepko, V.G. Romanov, A.A. Samarsky, L.N. Sretensky, V.P. Tanana, A.N. Tikhonov, L.D. Fadeev, L.A. Khalfin, A.M. Cherepashchuk, V.A. Yurko, A.G. Yagola, R. Arkangeli, Y.M. Chen, H. Cordes, A.J. Douglas, H. Engle, D.W. Fox, T. Galli, G. Gerglotz, K.V. Grouch, M. Grasselli, M. Hanke, F. Joksn, M.H. Protter, O.N. Strand, E. Wichert, N. Wiener and other specialists (see, for example, [1–10]).

A teacher who conducts training sessions with students on inverse problems strives to achieve didactic learning goals. This is the formation of students' scientific knowledge on modern methods of studying inverse problems, including both analytical and approximate methods; this is the development of students' skills in choosing and using modern computer technologies to study inverse problems; this is the development of students' creative mathematical abilities in solving inverse problems.

Methodology. During the training sessions, the teacher strives to ensure that students gain in-depth knowledge of modern achievements of inverse problems, master not only the conceptual apparatus and methods of solving inverse problems, but also acquire in-depth knowledge in the field of applied mathematics and computational mathematics, which would allow students to effectively explore atypical applied problems (see, for example, [11–24]).

In practical classes, students are invited to independently investigate model inverse problems, which involves the use of modern approaches and mathematical methods to prove the existence of solutions, their uniqueness and their stability.

Students are informed that numerical methods are an effective method for studying inverse problems in cases where it is not possible to find their exact solution.

It should be emphasized that the teacher in the classroom introduces students to approximate methods of studying inverse problems. It is appropriate to emphasize that such specialists in inverse problems as A.S. Alekseev, A.S. Barashkov, B.M. Budak, A.L. Bukhheim, P.N. Vabishevich, A.V. Goncharsky, V.I. Dmitriev, S.I. Kabanikhin, M.M. Lavrentiev, G.I. Marchuk, V.G. Romanov, A.N. Tikhonov, A.M. Cherepashchuk, V.G. Yakhno and other specialists develop approximate methods for solving inverse problems.

Currently widely used various computer technologies allow not only to find accurate and approximate solutions to equations of mathematical physics, but also, if users wish, to display these solutions on the computer monitor screen in the form of tables, diagrams, graphs of curves and surfaces. By applying the most effective computer technologies to solve mathematical physics equations, students realize the role of computer technology in scientific research.

In practical classes on inverse problems, students are taught to apply not only analytical methods, but also methods of computational mathematics. Students master such important concepts of computational mathematics as finite differences, difference scheme, grid function, approximation of partial derivatives of a function, convergence of an approximate solution of a mathematical equation.

In practical classes on inverse problems, special attention is paid to computer modeling. Today, computer modeling technologies are widely used in scien-

tific research by scientists from around the world. With the development of modern information technologies that allow mobile research of various mathematical models, computer modeling has become one of the most effective tools for understanding the surrounding reality.

Currently, textbooks for students on computer modeling have been published and are available for study, the authors of which are V.D. Boev, L.A. Bulavin, T.N. Varfolomeeva, V.V. Vasiliev, L.A. Vorobeychikov, N.V. Vygornitsky, I.Yu. Efimova, N.I. Lebovka, R.V. Mayer, G.V. Ovechkin, P.V. Ovechkin, Yu.N. Pavlovsky, A.M. Rybnikova, S.V. Porshnev, L.A. Simak, G.K. Sosnovikov, R.P. Sypchenko, Yu.Yu. Tarasevich and other specialists (see, for example, [25–29]).

By drawing students' attention to computer modeling, it is possible to form new scientific knowledge in the field of mathematical modeling and computational experiment, which they had not previously studied and could only study by attending classes in special mathematical disciplines.

Results and discussion. Computer technologies allow us to implement visualization of the obtained solutions of inverse problems. In computer technologies, there are convenient tools with which you can perform various mathematical calculations, perform appropriate analysis, test hypotheses and other possibilities.

The use of multimedia and computer technologies by the teacher in lectures on inverse problems allows implementing a visual demonstration method of teaching. It is possible for students to demonstrate in detail and mobile all the stages of the exact or approximate solution of inverse problems, to state, if necessary, the theorems of the existence, uniqueness and stability of the solution of inverse problems, the results of the numerical solution.

In laboratory classes, students learn to use computer technologies to find solutions to inverse problems, independently carrying out research activities.

It is obvious that the effectiveness of students mastering scientific knowledge in the field of computer modeling is ensured, in particular, by the fact that:

– a teacher who conducts classes on inverse problems has experience in the use of computer technology in the study of mathematical models based on equations of mathematical physics;

– lectures, seminars and laboratory classes on inverse problems are conducted, including with the involvement of computer technology;

– students whose term papers or theses are devoted to inverse problems are involved in independent scientific work on the use of computer technology to solve inverse problems.

This, in turn, will allow students to form new scientific knowledge in the field of computer modeling, to master the extensive possibilities of computer modeling in the study of applied mathematical problems, which include inverse problems for differential equations.

We note such possibilities of computer modeling as:

– visualization of the obtained solutions of mathematical models of inverse problems for differential equations in a convenient form for studying (graphs, tables, diagrams, objects in motion, etc.);

– the possibility of multiple studies of mathematical models of inverse problems with various additional information about the solution of a direct problem of the corresponding mathematical model;

– conducting applied research without risk to the environment and human health, allowing further development of health-saving and environmental technologies for the implementation of applied research;

– realization of the scientific and cognitive potential of mathematical models of inverse problems for differential equations;

– the study of processes and phenomena in places inaccessible to humans (the bottom of the World Ocean, the deep layers of the Earth, space objects, etc.);

– the possibility of studying processes and phenomena taking place in the past and future time.

Students in the training sessions on inverse problems for differential equations master the main stages of computer modeling.

Let's note these stages.

1. Logical and applied analysis of the research problem.

2. Formulation of the mathematical formulation of the inverse problem.

3. Logical and applied analysis of cause-and-effect relationships of the object under study.

5. Selection or development of an approximate method by which the solution of the inverse problem will be found.

6. Implementation of this approximate method on a computer.

7. Analysis of new scientific information about the object, which is contained in the obtained approximate solution of the inverse problem.

8. Mathematical analysis of the conducted computational experiment based on computer modeling.

Conclusion. Currently, the potential of computer modeling allows us to conduct applied scientific research and identify new scientific knowledge. It is obvious that specialists with scientific knowledge and experience in using computer modeling in conducting applied research in various subject areas are in demand. Therefore, students with deep knowledge of inverse problems and computer modeling will undoubtedly be in demand in research organizations after graduation.

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