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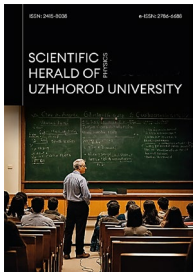

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Forming the competence of physics and mathematics students using information technology

Bela Sakibayeva*
Zhetysu University named after I. Zhansugurov
040009, 187A Zhansugurov Str., Taldykorgan, Republic of Kazakhstan

Spartak Sakibayev
Zhetysu University named after I. Zhansugurov
040009, 187A Zhansugurov Str., Taldykorgan, Republic of Kazakhstan

Abstract

Relevance. The relevance of the study arises as computers in educational institutions have ceased to be a mere subject of study and have become a tool for learning. The main purpose of using computer-based learning technologies is to increase the efficiency of the learning process. This task is also solved by increasing the motivation of students to study technical graphics. Graduates should be able to use graphics systems to create both blueprint and design documentation and to solve three-dimensional graphic modelling tasks.

Purpose. The purpose of the study was to identify the features of the formation of professional competence of non-humanitarian specialities through information technology.

Methodology. The methodological basis of the study was general theoretical methods, through which it was possible to determine the fact that the use of information and communication technologies in the classroom allows raising the level of information culture, realising the potential of each student, and forming the professional skills of future specialists.

Results. This article covered the main methods of using information technology in mathematics and physics classes, the features of the competency-based approach, the advantages of using innovative computer technology, and the types of technologies used. It has been found that the use of information technology in mathematics and physics classes affects: the activation of students' cognitive activity, development of mathematical logic, variability of reasoning, and concentration of students' intellectual activity on research and investigation.

Conclusions. The practical significance of the study lies in the fact that its findings and conclusions improve the training in the development of competence of students of physics and mathematics specialities using information technology in educational activities.

Keywords: computer technologies; creative potential; modernisation of education; collaboration; non-humanitarian specialities.

Introduction

The content of higher vocational education is being modernised to meet the modern requirements of all sectors of society. The current market needs competent specialists with sufficiently distinctive professional skills who are capable of finding a creative approach to any activity and of making creative decisions. Therefore, the task of a university professor is to train an active, competent, competitive, and innovative specialist who strives for continuous self-education. This objective can be successfully achieved through the use of modern computer technology in the education process. The ubiquitous spread

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*Corresponding author

of information technologies in every professional activity and the generation of modern types of communications in the digital world marked the beginning of a change in the usual education system and became the basis for the formation of a new information space. A computer in an educational institution has ceased to be just a subject of study, it has become a tool for learning. The main purpose of using computer-based learning technologies is to increase the efficiency of the learning process. This task is also solved by increasing the motivation of students to study technical graphics. Graduates should be able to use graphics systems to create both drafting and design documents and to solve three-dimensional graphic modelling tasks.

Ultimately, a computer should be the same tool for a student as a pencil and ruler. Whereas students learn the techniques and rules for drawing with a pencil, in computer graphics they simultaneously master the basic techniques and interface of the software, namely setting up the working environment, adjusting the drawing format, working with primitives, editing the drawing, object linking, working with blocks, layers, text and others. This allows a clear image of the product to be seen at each stage of drawing creation, which is very important in the learning process.

The didactic basis for adapting students to the application of computer technology in the educational process is the provisions of didactics, which establish requirements for methods, content, types of organisations and teaching and learning materials aimed at achieving the learning objective. The investigation is based on the results of the study by S. Babaeva [1], M.N. Bochkarev *et al*. [2], S. Skvortsova & M. Haran [3], embodied in innovative principles of the pedagogical process, modern understanding of the didactic support of the educational process, aspects of the digitalisation of the educational system, and methodological challenges of using computer technology in the educational and upbringing process. There is a requirement, based on an analysis of the general characteristics of information, its functions and types, its impact on student learning and education – information, which exists in various forms in the educational process, should be multifaceted at any stage of learning, professor-student interaction, and their actions. This requirement is the basis for selecting methods, forms of organisation and means of instruction designed to enhance the intellectual performance of students when they focus on the content of the process or phenomenon being studied rather than on the computer being used as a teaching aid.

In this regard, the following investigative problem arose: forming competence of students of physics and mathematics specialities by means of innovative computer technologies, providing students with training in the application of computer technologies in an educational activity. The solution to this problem lies in the preparation and development of appropriate technology.

The study analyses contributions by scientists and practitioners in the area of computer- and audio-visual-based computer-aided intensive learning systems and the theory of digitalisation of education, e.g. D.A. Buentello-Montoyaa *et al*. [4], J.P. García Vázqueza *et al*. [5], C. Attard & K. Holmes [6], S. Geybuka & Yu. Kovshova [7], A.S. Rusinov [8], T. Chikova & N. Savastenko [9].

The scientific novelty of the study lies in the development of the content of professors' activities on the use of computer technology in the educational process; the identification of optimal conditions for the formation of professors' skills related to the use of computer technology in their professional activities; substantiation of the possibility, necessity and feasibility of training, the considered professional competence; creation of an information database.

Materials and Methods

The use of information technology increases the information content of the lesson, influences its effectiveness, and makes it more dynamic and meaningful. The result of the use of information technologies in the learning process is a positive dynamic of the modernisation of the competence of students of non-humanities disciplines. Modern theoretical and empirical methods have been applied as part of the investigation. Through methods of analysis and synthesis, the authors have succeeded in identifying the components of the competency-based approach to teaching students of physics and mathematics using information technology, and integrating the inferences drawn into a coherent whole. It was determined that the use of information and communication technology (ICT) contributes to the formation of students' competence, increases interest in the subject being studied, motivates students to conscious learning, allows for objective control of students' knowledge and the quality of learning.

The methods of induction and deduction have allowed the authors to identify that, among a large number of methods for improving the effectiveness of education, the use of information technology currently ranks among the first. The advantages of using ICT in higher education for physical and mathematical specialities are as follows: both professors and students can use audio and video resources to integrate them into physics and mathematics classes; the possibility of using ICT does not depend on the place and time; easy creation of educational materials and their distribution among the audience; individual approach to each student and taking into account specific requirements; each student has equal access to educational materials; professors have the opportunity to create and disseminate innovative educational standards that are oriented towards the outcome of the educational process. The model of the educational process, using the abilities of innovative computer technology, makes it possible to organise different types of activities for professors and students quickly and interestingly, and to introduce a variety of methods and forms of information acquisition into the subject to encourage independent, cognitive learning activities.

The method of abstraction highlighted the main directions related to the relevance of effective use of information technologies in higher education institutions, among them: the formation of professional qualities of professors, creative, aimed at the self-development of individuals with creative views on modern didactics; modernisation of the educational process aimed not only at obtaining knowledge but also at the development of personal qualities of the student; analysis and systematisation of the features of methodological work in

educational institutions, identification of ways to improve them; direct participation in the creation of electives using information technologies for teaching students; study and analysis of previous pedagogical experience in ICT; participation in the implementation of state objectives in the area of digitalisation of education. The contributions of both contemporary researchers N. Padalko *et al*. [10], I. Bobrova & E.G. Trofimov [11], M. Dudyk [12], V. Sadkovyi *et al*. [13], O.W. Karupu *et al*. [14] have been reviewed. Which allowed for a suggestion, that the core content of science disciplines of mathematics and physics today need to be released from triviality, exaggerated detailing, obscuring the general logic of courses and the practical relevance of individual subsections. Given the current context, the most promising way out of the crisis is the consistent use of computer-based information and communication technology to modernise course content.

Results and Discussion

Information technology in education is called interactive learning, it has the feature of "responding" to the actions of the student and the professor, of "having a dialogue with them", which is a key property of computer-based learning methods. The computer can be used in almost all disciplines at any stage of educational activity: in a lecture class, practical, seminar, laboratory class and exams. However, the ultimate result of any pedagogical technology is that students have achieved a creative level of development in their independent practice of working with computers. The purpose of mathematics and physics studies at a higher vocational institution is not only to provide the student with a basic mathematics and physics education programme but also to equip them with the skills needed in their future career [3; 15-17].

For example, presentations play an important role in learning mathematics. They implement the principles of accessibility and clarity, they are aesthetically pleasing, and have an intermediary between the professor and the student – the computer – which often facilitates effective interaction. A presentation session provides a wealth of information and tasks, even in a short time, and the presenter can return to the previous slide at any time. Conducting classes using information and communication technology is a powerful stimulus for learning [18-21]. Nature has designed humans to trust their eyes more than the other senses, and about 80% of the information they perceive, and store is through their visual analyser. The pedagogical advantages of teaching with the use of information and communication technologies are the creation of presence effects, which increases the interest of students in the disciplines studied. To optimise the learning process, the presentation of new information is used as a source of relevant data and visual material. It should be emphasised that the students' attitude and motivation in ICT-assisted lessons are significantly higher than when using conventional paper materials and, consequently, the efficiency of learning the subject increases.

It is therefore effective to combine familiar forms of instruction with innovative ones in the teaching of mathematics and physics. They enable students to develop their professional skills to the best of their ability, build competence needed in their future work, and allow the professor to exercise their creativity and increase the effectiveness of the lessons being taught, complementing each other. The application of information technologies in the study of physics and mathematics disciplines implements the following objectives of the educational process: to improve the quality of knowledge on the subject, to continue the formation of information culture, to use the opportunities of each student to the full and to form professional competence of future specialists [6; 22; 23]. Information technologies can be used in training in the following ways:

– the use of supplementary material should be selective; the professor should not overload the class with the information presented through information technology;

– the use of ICT for the diagnosis of students' knowledge, tests, exams;

– creating and showing presentations;

– creative independent work outside of the educational institution;

– drawing diagrams, drawings, tables and making calculations on a computer;

– in physics classes, it is possible to use computer models to demonstrate substances or experiments that cannot be performed on university premises;

– using Internet resources;

– using e-textbooks, videos, interactive models, laboratory classes, exercises and a variety of tasks that require the visualisation of formulas, diagrams;

– creating reports, layouts, graphic drawings, and models by students, which can be a part of students' project activities;

– an interactive whiteboard can be used to visualise information.

The development of students' skills for engagement and achievement, the development of such qualities as professional versatility, a predisposition to change careers and to perform at a sufficiently high level are important goals of today's education system. Such personal qualities as mobility, determination, a sense of responsibility, the ability to acquire knowledge and use it in non-standard situations, and the ability to establish communication with strangers are increasingly in demand. Consequently, the main indicator of the performance of a higher education institution should not only be the individual's knowledge, skills and competence but also their ability to make decisions in specific life situations. This is the reason for many of the ideas behind the competence-based approach in education [1]. Competency is a commitment to mobilise knowledge, skills, and external resources to act effectively in different life or professional situations. Competence is the ability to act in a specific situation that is individually relevant and one’s capacity to perform a variety of tasks. Given these characteristics, a commonly applied distinction is drawn between these types of key competence: general cultural skills; value-semantic competence; social and work skills; pedagogical and cognitive abilities; communication skills; information skills; competence for personal self-improvement. The system of generally accepted principles for defining educational objectives, choosing the content of education, the learning process system and the assessment of educational outcomes is called the competence-based approach.

The use of information technology in physics and mathematics classes is an essential component of the competency-based approach. Information technology (computer technology) is about pre-searching and communicating the necessary material to the learner. Today, the information technology teaching methods used in the teaching process are: the method of information resources; the project method; and didactic games [8 24; 25; 26]. The method of information resources consists of students' work with textbooks, reference books, educational and popular science literature; this method is considered one of the most important teaching methods in didactics. Currently, these sources can be fully supplemented with electronic publications and resources. The main advantage of this method is that students can process learning information repetitively at a time and pace that suits them. Pedagogical research and innovative teaching tools successfully carry out such pedagogical functions: developing, teaching, educating, encouraging, controlling, and correcting. The most common forms of activity through information technology are the professor-assisted learning and self-study to acquire new knowledge and consolidate it. The main purpose of the information resource method is to consolidate and expand theoretical knowledge by guiding the student through a large world of different information that meets their intellectual needs.

The next method of teaching is the project method, which allows each student to be involved in active informative activities. Collective learning, which can take place both in pairs and in groups, is one of the forms of such independent work. The use of information technology shows much better results in the project method than the traditional reproductive and explanatory-illustrative methods. Students, working together in groups, create a plan of collective action, seek, analyse, and systematise sources of relevant information, discuss ways and steps to achieve the goal, assign roles to team members, propose ideas and consider them. Thus, all students in the group will be involved in the work and develop their cognitive activity. Working together helps students learn the elements of team communication and management [27-29]. The implementation of tasks in a project-based learning method using information technology makes it possible to:

– acquire problem-solving skills that may be required in their future careers;

– display creative skills, thereby enhancing creative potential;

– develop students' abilities to make informed decisions, self-organization, self-study and enjoy future work;

– create new motivation for students' learning;

– search for new information independently, analysing and systematising it, applying different ways of solving mathematical or physical problems, arguing their actions and deeds;

– develop each student's individual character, cognitive abilities, responsibility, discipline, time planning, decision-making and evaluation of the results of the work done [2].

An equally effective method implemented by means of information technology is the didactic game. Such games, introduced with the help of computer technology, can cope with various educational tasks. These have an effect on the formation and development of students' control and self-discipline skills. Games based on materials of varying complexity allow a differentiated approach to teaching students of different levels. During the game, the student learns some topics that are difficult to grasp in a conventional manner, analyses, summarises, compares, and draws conclusions of their own. The visualisation, presented as a game, helps to concretise the material studied [11; 30; 31]. This technique used in the session should be closely related to the topic, the objectives and goals set, and the information technology tools used, rather than simply entertaining the students. The presence of certain game constraints develops self-regulation in the player, based on obedience to the rules and fulfilment of a particular role. During the game, the student is confronted with a number of different conditions, which they need to understand, accept and rigorously follow in the future, applying this to the difficulties simulated in the game, which is especially important for students of non-humanities disciplines. Didactic games involving information technology are perceived by students as an opportunity to test themselves, their skills and abilities, and their readiness for real professional activity. Simulation games offer the best opportunities for this. The game allows students to make mistakes that cannot harm anyone during a physical experiment or mathematical calculations, analyse incorrect decisions, consider their causes, and consequences and draw the right conclusions that will later lead to a different result.

The use of ICT in the classroom should be standardised and reasonable, not detrimental to the learning objectives. For example, if the professor uses a multimedia course throughout the lesson to explain new material (shows presentations, animations, suggests solving test tasks), students become tired and lose interest in the activity. The constant replacement of a real physical experiment with a demonstration of computer experiments also leads to a negative attitude of students. Computer demonstration of physical phenomena does not replace a real physical experiment but complements it [14; 32; 33; 34]. For example, stereometry is an area of mathematics in the study of which ICT is especially relevant. The educator can actively use visual aids in stereometry classes. Modern 3D graphics allow students and professors to design digital models of geometric shapes, bodies, and their various combinations, move, rotate and resize them on the screen. This is especially important in the initial stages of studying stereometry, but also for illustrating geometric concepts and facts and solving the initial objectives of the course. However, later on, when students move on to more substantive tasks, it makes sense to first do the drawing independently, and only then offer their computer demonstration.

Many physical phenomena cannot be demonstrated in the classroom. For example, phenomena such as those related to the microcosm, or fast processes, or experiments with devices that are not available on university premises. As a result, students have a number of difficulties in learning because they are unable to visualise those things mentally. The computer can not only create models of such phenomena but also allows for changing the conditions of the process, "scrolling" with the optimum presentation of

the learning material for assimilation. Physics is an experimental science. It is hard to imagine studying it without laboratory practice. Unfortunately, the science classroom equipment does not always allow for complex laboratory work and the introduction of research that requires more sophisticated modern equipment. Information technology gives the professor the opportunity to conduct fairly complex laboratory experiments. In these, the student can change the initial parameters of the experiments at will, observe how the phenomenon itself changes as a result, analyse what they see and draw appropriate conclusions.

The use of ICT tools in the educational process significantly intensifies cognitive activity, develops personal qualities (self-organisation, creativity, etc.) and builds students' competence, favourably influencing the success and self-knowledge of the student's personality. The independent search for information on the Internet and the creation of presentations using various formulas, illustrations and tables transforms the educational process and contributes to a higher level of mastering of the information being studied. Such courses show the interrelation of the subjects under study, teach the empirical use of computer skills learned in theory, invigorate students' reflective processes and encourage them to acquire knowledge independently. Therefore, the application of information technology in mathematics and physics classes is a prerequisite for students to develop the competence required for their future professional activities. O. Kulikova & A. Knysh [35] considered the issue of the development of applied mathematical competence of economic university students in the conditions of the modern digital economy and came to the conclusion that individual competence form different systems of skills and are manifested at different levels when solving individually significant educational and professional tasks. The teaching of mathematical subjects can specifically promote certain competence of students. Passive, active and interactive methods of learning mathematics and their applications create conditions for the development of intellectual competence.

D.M. Makhmudova [36] was engaged in the investigation and development of methodological approaches to teaching students in mathematics and implementing the capabilities of information technology in the process of teaching mathematics in terms of developing students' cognitive interests. She determined the expediency of using mathematical information systems and the pedagogical goals of their use in secondary-level mathematics classes, formulated requirements for the structure, content of educational material and organisation of educational activities using information technology in mathematics from the standpoint of cognitive activity, the development of students' interests; determined the main directions of pedagogical education in the use of information technology in the course of teaching mathematics, along with methods and forms of organising the application of information technologies, especially information systems in mathematics, in the development of students' cognitive interest in the application-oriented aspect of teaching mathematics. D. Joshi *et al*. [37] investigated mathematics professors' responses to encouraging their students' use of information and communication technology for mathematics learning. The results showed that educators value the support given to students using ICT for mathematics learning in terms of encouragement and adaptation to the tools. professors' perceptions of encouraging students to use and adapt to ICTs significantly differed statistically between professors who had computers or laptops in their classrooms and those who did not, professors who had projectors in their classrooms and those who did not, and the types of schools in which they taught (e.g., public schools versus public schools) had a large influence on the survey results.

A. Biziuk *et al*. [38] have identified the quality of teaching technical and mathematical subjects in modern distance education. They believe some of the most problematic areas are communication, professor-student dialogue, personal issues in the professor-student dyad and the effectiveness of feedback. Their study examined the main ways in which student-professor feedback can be improved and the means of implementing such communication. The organisational and pedagogical requirements for the use of a system of individual distance learning elements in the process of vocational training have been finalised. Modern information technology and innovative teaching methods in specialist training have been described. The authors suggested the use of such elements as an interactive whiteboard, interactive interpretation of student comments in quizzes, both as a quiz or a forum and as a word cloud, since these features have a fairly positive effect on student competence formation, as has been proven in practice.

O. Ivanova [39] studied the issue of teaching higher mathematics to students based through a process of modular visualisation of mathematical information. She suggested that SMART lectures could be effective in teaching higher mathematics for the process of developing imaginative thinking, thereby improving academic performance. The author introduced the concepts of modular visualisation, visual learning, explained the basic tools of visual learning, interactive computer technologies, referring to the analysis of different approaches to their interpretation. It was concluded that the implementation of such an interactive form of organising visual education in higher mathematics as a SMART lecture contributes to the development of visibility in teaching higher mathematics, activates students in the educational process, thereby increasing the effectiveness of teaching.

N.V. Maiatina *et al*. [40] investigated the impact of information and communication technologies on the development of global planetary thinking of future specialists of diverse non-humanitarian specialities and concluded that the level of knowledge of the interviewed students was quite low. They developed courses in non-humanitarian disciplines using innovative technologies, which yielded results and increased the level of competence of students. The computer as an electronic assistant with specific functionality (speed, multimedia) and a well-thought-out method of organising the learning process has a chance of becoming one of the main tools for systematising and structuring knowledge and skills in mathematical and physical disciplines, developing competence, an outlook and improving a student's intelligence, for studying, among others, humanities disciplines, further education, and subsequent professional

activity. Therefore, the introduction of information technology in the learning process is an effective approach to improving the educational process, stimulating cognitive activity, and enhancing academic performance.

Conclusions

A new education system is now being formed in Kazakhstan as part of a new economic system, where one of the main resources will be highly qualified, mobile, and modern professionals. The key objective of education nowadays is not only the knowledge acquired but also the students' willingness and ability to take responsibility for their own and society's well-being. The ability to make decisions and achieve goals, the formation of professional mobility, and high-level work skills are important goals of modern education. Personal characteristics such as agility, confidence, responsibility, the ability to acquire knowledge and use it in non-standard situations, communication skills and the ability to communicate with strangers are increasingly in demand. The main purpose of using information technology in higher education is to promote the maximum formation of students' competence based on self-regulation and self-education: the development of a holistic scientific outlook, the scientific basis for the likely development of their future professional activities, promoting the development of students' creative abilities and the correct decision-making of their personal life position based on knowledge of human needs, traits, and abilities.

Because information technology based teaching methods differ significantly from traditional ones, professors need to develop new approaches to teaching and prepare electronic materials for classes, such as e-textbooks, illustrations, presentations, etc. Information technology allows professors to significantly modernise the specifics of presenting different types of knowledge. If all the didactic conditions of teaching are met, the computer not only attracts the attention of students but also motivates them to learn, forms cognitive processes, self-organization, responsibility, intelligence, attention, thinking, reveals creative potential, allows modelling complex physical and mathematical subjects, diagrams, tables, figures; automatically controls the quality of acquired knowledge; implements technologies of distance and personality-oriented learning. This gives the professor new opportunities to support and coordinate the student's personal development, to creatively explore and organise their work together, and to develop and select the best educational programme options. The professor becomes the main provider of subject-specific learning objectives, given the heterogeneity and importance of learning mathematics and physics.

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Conflict of Interest

None.

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Формування компетентності учнів фізико-математичних класів засобами інформаційних технологій

Бела Сакібаєва
Жетисуський університет імені І. Жансугурова
040009, вул. Жансугурова, 187а, м. Талдикорган, Республіка Казахстан

Спартак Сакібаєв
Жетисуський університет імені І. Жансугурова
040009, вул. Жансугурова, 187а, м. Талдикорган, Республіка Казахстан

Анотація

Актуальність. Актуальність дослідження зумовлена тим, що комп'ютери в навчальних закладах перестали бути лише предметом вивчення і перетворилися на інструмент навчання. Основною метою використання комп'ютерних технологій навчання є підвищення ефективності навчального процесу. Це завдання вирішується також шляхом підвищення мотивації студентів до вивчення технічної графіки. Випускники повинні вміти використовувати графічні системи для створення як креслярської, так і конструкторської документації, а також для вирішення завдань тривимірного графічного моделювання.

Мета. Метою дослідження було виявлення особливостей формування професійної компетентності студентів негуманітарних спеціальностей засобами інформаційних технологій.

Методологія. Методологічною основою дослідження стали загальнотеоретичні методи, за допомогою яких вдалося визначити той факт, що використання інформаційно-комунікаційних технологій на заняттях дозволяє підвищити рівень інформаційної культури, реалізувати потенціал кожного студента, сформувати професійні навички майбутніх фахівців.

Результати. У статті розглянуто основні методи використання інформаційних технологій на уроках математики та фізики, особливості компетентнісного підходу, переваги використання інноваційних комп'ютерних технологій та види технологій, що використовуються. Встановлено, що використання інформаційних технологій на уроках математики та фізики впливає на активізацію пізнавальної діяльності учнів, розвиток математичної логіки, варіативність міркувань, концентрацію інтелектуальної діяльності учнів на пошуково-дослідницькій роботі.

Висновки. Практичне значення дослідження полягає в тому, що його результати та висновки удосконалюють підготовку до розвитку компетентності студентів фізико-математичних спеціальностей з використанням інформаційних технологій у навчальній діяльності.

Ключові слова: комп'ютерні технології; творчий потенціал; модернізація освіти; співпраця; негуманітарні спеціальності.