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COMPUTER-BASED SYSTEMS OF PHYSICAL EXPERIMENT IN INDEPENDENT WORK OF STUDENTS OF TECHNICAL UNIVERSITY

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Abstract

Purpose: *The self-study activity of students is an important form of educational process under the conditions of rapid changes of technologies. Ability and readiness of future engineers for independent education is one of their key competences. Investigation of modern methods of planning, organization and control of independent cognitive activity of students while studying physics as effective means of complex forming of their professional qualities is the object of the research.* ***Methods:*** *We analyse the curricula of some engineering specialities in leading technical universities, existent methods and forms of organization of students' self-study, and own pedagogical experience.* ***Results:*** *Based on the theoretical analysis of existing methods of students' self-study, it was found that a systematizing factor of appropriate educational technology is the problem focused cognitive tasks. They have to be implemented by application of the modern technological devices integrated with a computer-based experiment. We define the aim of individual or group laboratory works; the necessary theoretical and practical knowledge and skills of students are rationalized; timing and form of presentation of the results are clarified after individual and group consulting. The details of preparatory, searching-organizational, operational, and control stages in organization of students' self-study with the use of computer oriented physical experiment are specified, these details differ depending on the didactic purpose, form of organization and students' individuality.* ***Discussion:*** *The research theoretical aspect confirms the determining role of subject-subject cooperation in forming of competences of independent learning of the future engineers. Basic practical achievements of the research consist of improving methods of using of digital learning systems, creation of textbooks that promote consultative and guiding role for the educational process, working-out of the electronic documents and lab reports*

Keywords: digital laboratory; educational physics experiment; independent student's work; laboratory works; technological competence.

1. Introduction

Technical knowledge becomes outdated and worthless very quickly in the current socio-economic conditions. The knowledge half-life is defined as the time after graduation during which professionals lose half the initial competence. It is believed that today the half-life of knowledge in science and design is about 5 years and in the technical and technological spheres is about 3 years [1]. Therefore, the ability and willingness of future engineers to self-education is a key competence of the modern professional [2]. Meanwhile, we know that planning, selection of organizational forms and methods, and monitoring system of independent educational activity are the weak points of the university education and one of the least considered problems of the educational theory [3].

Modern laboratory works are based on the integrated use of natural experiment and computer software and hardware systems often called digital laboratories [4]. Self-development of students during preparation for the experiment, analysis and interpretation of the results obtained and control of these phases by a teacher are up-to-date teaching problems whose solution is hard and complex task.

2. Analysis of research

According to the traditional definition, independent work of students is a variety of types of individual

and collective activity of students under the methodological guidance but without direct teachers' presence in specially designated time. This special system of learning is oriented to active methods of study and individualization based on needs and capabilities of students. The system develops creative skills of students and forms their responsibility for learning results.

The problem of the self-learning activities of students as the fundamental principle of study was considered by teachers from the end of the XVII century. The well-known German teacher Disterveg (1760 – 1866) stated that an independent educational activity is the way and also the result of education. Individual activity should be recognized as important form of educational process and the basis for development of critical thinking [6].

The world self-learning practice established a number of relevant education methods; the most outstanding method for Universities is the individualized learning system created by American psychologist and educator F. Keller in the sixties of the twentieth century (Keller Plan) [7]. We have to note that such concepts of the system as modular, context, personality and competence oriented education are the basis of modern educational paradigm. There are three typologies of self-learning in the higher school pedagogy: by the didactic purpose, by the form of organization, and the nature of the students' activity (Table. 1).

According to researchers, basis of stimulation of self-learning is knowledge of the mechanisms of perception, thinking and intelligence behavior. Well-known educators and psychologists developed and studied various concepts of active formation of mental processes in the mind (Davydov V., Dayal D. [9], D. El'konin [10], Posner G. [11]). They believed that core forming factor of self-learning is a cognitive task, which is characterized by the following factors: presence of cognitive or practical problems and questions and special time to resolve them; conscious, independent mental students' activity for proper and preeminent execution of the cognitive task; skills of independent work.

Investigations of the independent work planning and organization helped discover didactic, psychological, organizational, methodical, and logical aspects of this activity especially in the traditional didactic sphere. However, questions of motivation, procedural, technological support of independent learning of students as an integrated personality oriented educational system still need consideration.

Table 1. Classification of self-learning

Didactic purpose	Form of organization	Nature of the students' activity
Preparatory (actualization of the learned knowledge for successful further learning)	Individual (students perform self-learning according to their training facilities)	Reproductive (activity by a pattern, which is necessary for skills and technological processes mastering)
Recognizing (formation of ideas, reproduction of concepts, phenomena and objects essence)	Frontal (simultaneous execution of the same task by all students)	Reconstructive (choice of the activity methods, use of acquired knowledge and techniques in different situations)
Training (mastering of educational material and ways of activity)	Collective (interaction of students, distribution of functions, duties, taking into account the interests and abilities of every student)	Heuristic (independent analysis that includes work beyond the sample and suggest ways of the problem solving, heuristic conversations, questions formulation)
Generalizing-repetitive, control	Group (students are divided into mini group within which some problem is solved)	Creative (students are invited into a new study by observation of facts and phenomenon, put forward the hypothesis and methods of use of acquired knowledge, the scientific literature study)

3. The purpose of the article

Representation of the research of methods of independent learning of students during technical and natural sciences study with the use of computer-based physics experiment

4. The results of research.

At the heart of building a structural model of To investigate the general questions of volume, content and form of physics laboratory studies, we conducted a comparative analysis of programs for engineering profile bachelors for directions "Electronics", "Biotechnology" and "Automation and Control" at four universities: National Aviation University (Ukraine) [12], Warsaw Technology University (Poland) [13], Higher School of Mannheim (Germany) [14] and the University of Ben Gurion (Israel) [15]. These universities were singled out as being sensitive to new technologies and simultaneously processed in terms of didactics of higher education.

It was found that, in spite of the different bachelors' terms of engineering profile (7 – 8 semesters), the percentage of hours intended for use in laboratories is 35-50% of the total amount of classroom learning time of natural science and professional practical training. The programs of all universities emphasis is given to self-education of future engineers, which on average accounts for 40-50% of students' amount of study. For example, the learning process at the University of Ben Gurion is organized in such a way that the semester lasts 12 weeks and is ended by a long (about 6 weeks) self-education period.

An important practice-oriented feature of the educational process at the University of Ben Gurion is the fact that laboratory works on physics and some other technical subjects are allocated in separate courses, assessment of which is independent from lectures and practical lessons.

In the above mentioned foreign higher technical schools, the labs experiment is mostly natural with the use of computer for the results processing; experiments with the use of computer models of real objects are used exclusively at the absence of the necessary equipment or when a computer simulation serves as a learning aim.

We have chosen to investigate computer-based physics experiment as a powerful methodological tool for the integrated development of a wide range of professional and personal skills of future engineers. The main objective of physics and engineering disciplines study using computer-based physics experiment is to develop the technological competence of students as the ability and willingness of future engineers to solve professional problems using various skills. Obviously, such professional skills are based on continuous self-development, flexibility to the change of conditions and context of professional activity and readiness to solving problems that go beyond that.

The key feature of computer-based physics experiment is the use of a wide range of software and hardware, which includes a variety of sensors, analog-digital converters, digital and video analysis program; their selection can be changed in accordance with the intended didactic purpose, technological readiness of students etc.

At various stages of the learning process, students' independence is displayed in different ways: from simple reproduction, work by firm algorithmic scheme to independent creative activity. For transition from reproductive to creative level, students have to obtain ability to plan their learning activities, chose and process data from information sources, perform laboratory works without the direct assistance of the teacher, configure and verify an equipment, perform independently specific professional responsibilities in the classroom, analyze the components and sources of the measurement errors, make comprehensive conclusions.

Students should develop their independent thinking for the success and effectiveness of their mental activity. The most effective methods and means forming independence of thought are: the teacher ability to put questions aimed to self-understanding of the questions by students; forming their own point of view, finding interdependence, similarities and differences so that students can be able to make conclusions, generalizations; that help to the development of independent thinking and high mental activity. It is proved that a high level of analytical and synthesis activity of students appears if they independently discover the essential features of the new material and apply them in practical actions when they get the maximum opportunity for self-analysis and generalizations.

Teaching techniques that can activate independent cognitive activity include: specification of aims; disclosure of practical value of research and connections of new educational material with known before; interesting, logical, easy to understand presentation of problem by teacher; asking questions

to test students' attention, consciousness, and understanding of the subject and methodology of the experiment; separating zones for creative cognitive tasks; identification of professional context in the considered phenomenon.

Practical implementation of the abovementioned theoretical generalizations is done by the manuals developing [16] using which students can self-study physics, control the learning, and prepare for laboratory works. The leading role belongs to various computer integrated teaching and supervisory tools, which include the students' digital electronic laboratory report document [17]. Opportunities of a computer also are widely used by the authors for stimulation students' self-activity as they create computer models of phenomena and processes during physics study [18].

Depending on the time and place, the nature of self-education management, the participation of the teacher and the methods of control of self-education results, students' self-education is divided into the following types:

– self-education during basic classroom training (lectures, seminars, laboratory work, tests and examinations);

– traditional self-education at any convenient time with / without supervision of a teacher in a variety of creative contacts and scientific groups, online communication, individual consultations with / without the use of web resources, processing of the data obtained during the experiment, skills extending during the use of the equipment and software, etc.;

– information oriented self-education during the homework of project, research and creative nature, performance by students, for example, filming, review, and analysis of video recordings of physics phenomena and processes.

These types of self-education in today's educational environment are mainly based on computer-oriented forms of learning. Therefore, teachers should focus their efforts on planning the optimal methods of self-education during the computer-oriented laboratory works fulfillment on the basis of a reasonable ratio of classroom and home work. The determining factor of the work activation is a high level of motivation, which has to be based on the performance of the tasks related to professional activity of the future engineers.

Independent work of students consists of certain stages and corresponding activities. At the preparatory stage of organization of independent work, teacher analyzes the laboratory works content, their timing, the possibility of software and hardware, scientific and practical interests of the teaching staff and students, regulations etc. The investigations are the base for formation of the content of the students' independent work for each laboratory work during the semester. Tasks are formed on the base of individual characteristics and cognitive capabilities of students. Therefore, the preparatory stage includes analysis of their preparation and skills among which is programming using commonly known software usually used for errors calculation, extrapolation of experimental physical values (MatLab, Mathematica, Microcal Origin, etc.)

At the research and organizational stage, the aim of individual or group laboratory work is defined, the theoretical and practical knowledge and skills of students are rationalized, individual and group consulting is conducted, the timing and form of presentation of interim results are specified.

At the motivational-activity stage, the teacher provides positive motivation of individual and group activities, checks intermediate results, encourages students to self-control and self-correction, mutual verification of the results.

Control and evaluation stage includes individual and group reports and their estimation. Reports should be made in a standardized writing or electronic form including charts, tables, calculations, etc. Laboratory works also includes many opportunities for application of active learning methods on the basis of individual approach; they may include elements of scientific research that can be performed by a student optionally for the rating increase.

Thus, we can classify the main requirements of self-learning during the computer-based physics laboratory works:

– forms, methods and means of using are chosen on the basis of the course, the level of students' physics, technical and informatics knowledge and didactic purpose;

– amount of the work increases gradually according to development of the skills of self-education;

– forms of self-education change from simple to more complex;

– creativity of the work must grow through active involvement of the methods of generalization of practical experience and scientific research;

– self-education must be systematic under permanent control (in the form of monitoring) and

regular guidance (mainly in the form of consultations) by the teacher.

Credit-modular technology provides precise timing of individual work, content and scope of which are clearly presented in syllabus of the discipline (it defines all the parameters of the course, supporting literature and Internet sources, control tasks and questions, the consultations schedule. It undoubtedly optimizes independent cognitive activity of students. In addition, it is important to establish the requirements and general expectations, i.e. the teacher has to aim students to the necessity of homework, the time limit obedience, self-education and responsibility.

5. Conclusions

The role of the teacher changes significantly towards the subject-to-subject interaction in today's educational environment. Active, learner-oriented teaching methods have to be designed to stimulate independent cognitive activity of students using modern methods of physics and technical experimentation under systematic advisory and directing support of the teacher. As a result, modern teacher really becomes an active researcher.

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Компютерно орієнтована система фізичного експерименту в самостійній роботі студентів технічного університету

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Постановка проблеми: В умовах стрімкої зміни технологій виробництва здатність і готовність майбутнього інженера до самоосвіти є однією з його ключових компетенцій. Сучасна методика планування, організації і контролю самостійної пізнавальної діяльності студентів у процесі навчання фізики і технічних дисциплін є дієвим засобом комплексного формування професійних якостей і складає мету проведеного дослідження. **Методи:** В основу дослідження покладено аналіз навчальних планів і програм підготовки фахівців деяких інженерних спеціальностей у провідних технічних університетах, теоретичний аналіз існуючих типологій самостійної роботи студентів, які відрізняються за дидактичною метою, формою організації та характером діяльності, а також власний педагогічний досвід. **Результати:** З'ясовано, що системо утворювальним чинником відповідної педагогічної технології є проблемно орієнтоване пізнавальне завдання. Його виконання повинно здійснюватися з використанням сучасних техніко-технологічних засобів, поєднаних з натурним експериментом. Виокремлено і деталізовано підготовчий, пошуково-організаційний, мотиваційно-діяльнісний та контрольно-оцінювальний етапи в організації самостійної роботи студентів з використанням комп'ютерно орієнтованої системи фізичного експерименту. **Висновки:** В теоретичному аспекті дослідження довело визначальну роль суб'єкт-суб'єктної взаємодії у формуванні компетенції самоосвіти майбутніх інженерів. До його основних практичних здобутків належить поглиблення методики використання цифрових навчальних комплексів, розроблення навчальних посібників, які сприяють консультативно-спрямовуючій організації навчального процесу, та електронних документів лабораторної звітності.

Ключові слова: лабораторний практикум; навчальний фізичний експеримент; самостійна робота студента; технологічна компетентність; цифрова лабораторія.

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Компьютерно ориентированная система физического эксперимента в самостоятельной работе студентов технического университета

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Постановка проблемы: В условиях стремительного изменения технологий производства способность и готовность будущего инженера к самообразованию является одной из его ключевых компетенций. Современная методика планирования, организации и контроля самостоятельной познавательной деятельности студентов в процессе обучения физике и технических дисциплин является действенным средством комплексного формирования профессиональных качеств и составляет цель проведенного исследования. **Методы**: В основу исследования положен анализ учебных планов и программ подготовки специалистов некоторых инженерных специальностей в ведущих технических университетах, теоретический анализ существующих типологий самостоятельной работы студентов, которые отличаются по дидактической цели, форме организации и характеру деятельности, а также собственный педагогический опыт. **Результаты:** Установлено, что фактором, образующим систему соответствующей педагогической технологии, является проблемно ориентированное познавательное задание. Его выполнение должно осуществляться с использованием современных технико-технологических средств, объединенных с натурным экспериментом. Выделены и детализированы подготовительный, поисково-организационный, мотивационно-деятельностный и контрольно-оценочный этапы в организации самостоятельной работы студентов с использованием компьютерно ориентированной системы физического эксперимента. **Выводы:** В теоретическом аспекте исследование показало определяющую роль субъект-субъектного взаимодействия в формировании компетенции самообразования будущих инженеров. К его основным практическим достижениям следует отнести углубление методики использования цифровых учебных комплексов, разработку учебных пособий, которые способствуют консультативно-направляющей организации учебного процесса, и электронных документов лабораторной отчетности.

Ключевые слова: лабораторный практикум; самостоятельная работа студента; технологическая компетентность; учебный физический експеримент; цифровая лаборатория.

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