The Use of Computer Technology as a Way to Increase Efficiency of Teaching Physics and Other Natural Sciences

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Abstract. The use of computer technologies for increasing the efficiency of physics teaching is discussed. Proposed approach includes the development of professionally oriented teaching, the use of multimedia lecture courses, the use of Learning Management Systems (such as Blackboard Learn and MOODLE), webinars, etc. It is proposed to organize distributed educational system in a form of Grid infrastructure joining educational facilities of 4 St. Petersburg universities. This Grid infrastructure can provide equal access to all kinds of resources for the students and lecturers in order to teach and study physics more efficiently.

Keywords: Computer technology · Teaching physics · General physics · The concept of modern science · Multimedia lecture courses · Computer learning management system · Blackboard learn · MOODLE · Webinars

1 Introduction

Learning physics is the basis for formation of the scientific worldview for students of natural-science specialties. Nobody doubts it. Physics is the basis of the future student's profession in the subject area and in the area of application of different methods in measurement practices.

Some people think that teaching professional knowledge of physics is not necessary for humanitarians. However, the world of our culture is full of things inextricably linked with the achievements of physics. All incomprehensible things cause human alertness and fear. There is a process of alienation of things from people, as a result – world carries the threat. This must be overcome at the mental level. Basic knowledge of physics should be as natural to the humanities, as the knowledge in the humanities to "techies".

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In addition, learning physics allows the students of humane specialties to get acquainted with specific natural-scientific way of thinking, allows to enrich their intellectual sphere and also to form the materialist worldview.

Improving the efficiency of teaching physics to various categories of students the authors follow the concepts of physics as an empirical science. This means that the physics is formed by the certain natural phenomena, and while the science develops, the phenomena get the explanation in the system of causal relationships existing in the nature.

Physical experiment plays the exceptional role in the search for such explanations. It presents specially organized investigation process allowing identifying these relationships most definitely.

The key statement of the purpose of scientific research belongs to Galileo: *"…to measure everything that can be measured and make measurable what is not measured…"*. This idea is consistent with the task of developing a system of concepts in physics, which has quantitative measure and characterizes the observed phenomena, and then, allows developing mathematical theories of different degrees of generality based on the abstraction of the concepts.

Our teaching experience has shown that the most difficult matter in learning physics is to create a clear distinction in the learning phenomenon, concepts describing this phenomenon, its models in these concepts and mathematical description of these phenomena and, most importantly, the practical need for such a distinction.

It is very difficult for a student to abstract himself/herself from a phenomenon, to solve the task with the help of the theory and to come back to the reality. This lack of distinction hinders the solution of the tasks that, as a rule contains a description of the situation close to the real circumstances and makes students and in the future, experts, essentially helpless in any unusual situation requiring the simple knowledge of physics.

However, it is very difficult to overcome this gap in the normal course of teaching. Indeed, at first it is necessary to show the phenomenon in its entirety, then to show the process of forming a model of the phenomenon, show the transition-model theory and to show by the "feedback" the effectiveness of the theory and also its limitations.

Computer technologies are able to solve the problem now. A large number of easily controlled multimedia subjects can be used during a lecture: pictures, videos, sounds, design in real-time, etc. Educational programs in interactive mode can be widely used during practical studies.

The possibilities of computer technology are limited only by the experience and creative activity of a lecturer. The exchange of such an experience is of great importance at present when computer technologies are not sufficiently implemented in teaching process.

For several years, the authors have been developing a specific approach to the teaching physics, the concept of modern science, laboratory workshop, as well as special courses for students of natural specialities and humanities taking into account the specific educational programs [1–9].

Teaching physics for different universities, authors make sure that in order to maximize the efficiency of teaching physics it is necessary to organize adequate environment, which should comprise all kinds of learning materials and computational resources of

different universities in order to provide equal and the most comfortable access to them. Distributed educational system can be organized as Grid infrastructure joining the best educational courses and computational facilities in the field of physics elaborated in Saint Petersburg State University, Saint Petersburg State Pediatric Medical University, Russian State Hydrometeorological University and Saint Petersburg Electrotechnical University "LETI". This Grid infrastructure can provide equal access to all kinds of resources for the students and lecturers.

2 The Features of the Proposed Approach to Teaching Physics and Concepts of Modern Natural Science for Students of Science and Humanities

The specificity of the method proposed by the authors encloses the integrated use of multiple approaches to the teaching physics, other natural sciences and the concept of modern science.

Firstly, teaching discipline should not deter by its complexity at least at the stage of the first acquaintance. This provides effective assimilation of any material by students. Therefore, the authors aim to make physics accessible to all by seeking to set out a full course of general physics by clear and accessible language. Of course, teaching the course of the general physics implies using of the adequate mathematical apparatus. The distinctive feature of the presentation of the material is the constant matching of physical phenomena with similar appearances described in different sections of the course. Some of the most important provisions are considered from the different points of view and are presented in the different sections of the course. This approach makes it easier to understand and to remember the material [9–12].

The authors also find it possible to follow the ideas expressed many years ago by the outstanding Russian physicists Nikolay Umov (1846–1915) and Yakov Frenkel (1894–1952) about teaching physics at higher school.

Great scientists and authors of the fundamental tutorials emphasize that a good printing course composed by lecturer makes it unnecessary to present all the material in the form of oral lectures. This leads to irrational waste of time by students. The role of professors and lecturers in this case is firstly in the organization of consultations (individual and group), in which the discussion on difficult course issues arising in the process of consultation can evolve into a full lecture [13].

Later (June, 1963) similar thoughts were expressed by the famous American physicist Richard Feynman (1918–1988) in his preface to the printed Lectures on Physics: «*I think, however, that there isn't any solution to this problem of education other than to realize that the best teaching can be done only when there is a direct individual relationship between a student and a good teacher—a situation in which the student discusses the ideas, thinks about the things, and talks about the things. It's impossible to learn very much by simply sitting in a lecture, or even by simply doing problems that are assigned*» [14].

In order to provide such form of education, it is necessary of organize special educational environment, providing equal access to teaching facilities (textbooks, training

manuals, virtual laboratories) for students and lecturers. It is necessary to join resources of different universities each having their own unique facilities to teach physics the most efficiently. The environment should be organized as Grid infrastructure functioning. The functioning Grid infrastructure will be selection of the best educational courses in the field of physics elaborated for St. Petersburg State University, St. Petersburg State Pediatric Medical University, Russian State Hydrometeorological University and St. Petersburg Electrotechnical University "LETI". Effective feedback should be organized in order to improve the courses and organize them into the joint educational program.

3 The Use of Multimedia Lecture Courses

At present it is not enough to have only "good printed course". This printed publication can and should be supplemented with the advanced multimedia materials [5, 7, 15].

Training courses developed under this approach contain examples that may be of particular interest for the young reader. Imaginative visualization obtained by using multimedia materials is also widely used in order to bring the "theoretical" science in everyday life.

The important feature of the teaching courses is the combination of fundamental quality and profilization, appearing in the choice of priorities and examples of the application of physics in geology, biology, soil science, meteorology, ecology, etc.

The main feature of these courses is the degree of coverage of practical issues and their relevance. Another feature of the courses is that a large amount of background material allows the use of this knowledge during laboratory and practical studies. Links to Internet sites are provided where students can find additional and more detailed background information [9–12].

At present developers of e-learning resources focus on the new opportunities to work remotely, provided by the network and multimedia technology. Educational materials are developed now as Java-applets, characterizing by the exceptionally high level of interactivity, allowing a remote user to not only change the quantitative parameters of the modelled system, but also to determine its qualitative composition, essentially creating own original computer experiment.

4 Teaching Physics to Medical Students

Medical specialties along with the specialties which indirectly use medical and biological knowledge occupy a special place among the many natural sciences and humanities, which contain physics and the concept of modern science in the learning process.

All physiological processes occurring in the human body are governed by the general physical laws. Furthermore, most diagnostic methods as well as many methods of medical treatment are based on the use of physical phenomena and processes.

Nearly all medical systems are based on physical principles and, in fact, they represent physical devices. Medicine uses the results of theoretical and experimental achievements in physics.

Training an athlete and a coach requires knowledge of the functioning of the human body mechanics, the forces and moments acting on the body and its parts during the performance of various sports movements. Knowledge of physics is widely used in the training of specialists in sports medicine.

Medicine uses the results of theoretical and experimental achievements in physics. Thus, physics is of exceptional importance for medicine as a whole and for the formation of the future physician especially. The necessity of medical biophysics, together with elements of general physics used in physical methods of diagnosis and treatment, the principles of appropriate equipment – are the contents of physics taught in medical schools [16].

The authors have accumulated experience of teaching physics to medical students in St. Petersburg State University (Department of Medicine, Department of Dentistry and Medical Technologies), and in St. Petersburg State Pediatric Medical University, and have wrote several training manuals, taking into account this specificity [17, 18].

It is possible to highlight professionally oriented questions in each of the sections of general physics – the basic methods of definition of physical quantities in medicine; the specificity of physical phenomena and processes in medical practice; the use in medicine of physical phenomena, processes, devices (used in diagnostics for research use in clinical practice); the description of the principle of operation of medical devices.

Use of professionally oriented physical problems in the teaching of future doctors positively affects learning outcomes of students, promotes the development of creative personality of future specialists, the formation of student's valuable attitude to the medical profession. Thus future physicians and biologists need to know the basic details of vision [16–18], proteins [19], photosynthesis [20], effect of physical factors on biosphere [21, 22], etc. Professionally oriented physical tasks can be used in the classroom when new material, revision, consolidation and generalization are studied, in the classroom and in extracurricular organization of independent work of students. The use of professionally oriented physical tasks gives one the ability to individualize the learning process [23, 26, 27].

Now it is very important to give medical students a basic knowledge about telemedicine. The main purpose of telemedicine is medical service of the remote patients who have appeared far from the medical centres and have the limited access to medical services. The technical base of a telemedicine is modern technologies of transfer and reproduction of data that promotes videoconferences and transfer of high-quality digital images at a distance in an effort to render more perfect reanimation aid, the fastest transportation of the patient and accelerated medical decisions. Telemedicine is impossible without the experts having skills of work in remote locations. Medical school students can acquire such skills in the process of training within our grid segment, performing virtual labs, studying the educational materials in remote access.

5 The Use of Learning Management Systems

Under the proposed approach, the authors have developed multimedia presentations for different specializations (biological, medical, geological), including illustrations,

animations, movies, as well as corresponding printed manuals [9–12] and webinars. Blackboard Learn-Learning Management System (LMS Blackboard Learn) [28] is used as a platform for creation, storing and presentation of these educational materials. Blackboard has been installed in the St. Petersburg State University from late 2011. Nowadays it is used for the registration of all student' written works and all University teachers must possess the skills to work with Blackboard Learn.

Blackboard represents a virtual learning environment and course management system developed by Blackboard Inc. It is Web-based server software which features course management, customizable open architecture, and scalable design that allows integration with student information systems and authentication protocols. It may be installed on local servers or hosted by Blackboard ASP Solutions. Its main purposes are to add online elements to courses traditionally delivered face-to-face and to develop completely online courses with few or no face-to-face meetings.

Learn distance learning system – MOODLE (acronym for Modular Object-Oriented Dynamic Learning Environment) [29], which is similar to Blackboard, is used in the Russian State Hydrometeorological University.

MOODLE is free and open-source software learning management system written in PHP and distributed under the GNU General Public License. Developed on pedagogical principles, MOODLE is used for blended learning, distance education, flipped classroom and other e-learning projects in schools, universities, workplaces and other sectors. With customizable management features, it is used to create private websites with online courses for educators and trainers to achieve learning goals. MOODLE allows extending and tailoring learning environments using community sourced plugins.

Both LMSs (Blackboard and MOODLE) have much in common (the main differences are listed in Table 1) and according to LISTedTech, both dominate the market for current LMS usage. But the main difference is that Blackboard Learn is a fully commercial product and MOODLE is open-source software using the "freemium" payment model (one gets the basic elements for free, but must pay for extra options). So, this is for you to decide what is better: MOODLE (powerful free solution, but tailoring it for one's specific needs will require extra programming and extra expenses) or Blackboard (fully loaded, but closed-source expensive product that cannot be easily tailored).

Table 1. Blackboard Learn vs MOODLE comparison

	Blackboard Learn	MOODLE
Payment model	Proprietary	Freely licensed open-source software
Course assignment	Weekly activities tab	Activity list on a single page
Managing content	Manual	Automatic
Features	Extra features are included in price	Limited options, free plugins database
Vendor model	One company	Many supporting companies and vendors
Help options	Forums, Knowledge Base, Live Tech Support	Forums, Knowledge Base

Let us compare the main features of these two LMSs.

The main features of Blackboard:

- administrative reporting;
- course catalogue;
- custom branding, fields and functionality;
- data import/export;
- exam engine;
- goal setting;
- grading;
- individual plans;
- multiple delivery formats;
- skills tracking;
- student portal.

Blackboard Learn is considered to be a great value for money, especially for large institutions with a lot of resources.

The main features of MOODLE:

- assessment implementation;
- collaboration management;
- discussion forums;
- file exchange;
- grade management;
- internal messaging, live chat, wikis;
- lesson planner;
- student roster/attendance management.

MOODLE is one of the most popular LMSs, mostly used by institutions with between 1,000 and 2,000 full-time students.

So, if one needs a powerful system and has the resources to pay for it (as St. Petersburg State University with more than 30,000 full-time students) Blackboard will be a good choice. If the budget is limited, but the ambitions are still high (the case of Russian State Hydrometeorological University with about 5,000 students) MOODLE will be a good choice.

In the process of study of a discipline not only traditional technologies, methods and forms of learning are used, but also innovative technologies, active and interactive forms of classes: lectures, practical classes, consultations, independent work, lectures with elements of problem representation, testing, etc. In the educational process active and interactive forms of conducting classes are widely used (conversation, interview, testing, discussion (with "brainstorming session" and without it), etc.). The independent creative work of students is also the important factor is. Good results are obtained by carrying out part of the lectures in the format of conferences, when the students after listening to another section of the general physics course, are preparing reports on the basic physics of natural phenomena and processes occurring in living systems [1–6, 8, 15].

A feature of these courses is the large number of examples that illustrate not just the proposed material, but are taken from actual tasks which the future specialist will regularly encounter in their daily practice [4].

Direct physical demonstrations during lectures on general physics or the concept of modern science would be, of course, ideal (for presenting physics not as some abstract from the reality, but as a science on fundamental laws of nature), but absolutely unrealistic in modern conditions of physics teaching. These demonstrations are impractical not only due to their high financial costs and low mobility (demos require expensive equipment, specialized personnel, storage conditions, etc.), but also a significant amount of time (preparation and display of demonstrations consume a considerable part of lecture time). The obvious way out of this situation is the active use of lectures, videos, interactive computer demonstrations, etc. (as with the use of pre-prepared programs, and access to the Internet and the use of specialized web-sites) [5, 7, 15].

LMS Blackboard Learn and LMS MOODLE promote effective independent work of students by providing access to electronic tutorials, manuals, by realization of effective feedback to lecturer via interactive testing, video conferences, on-line discussions.

The independent work of students requires not only training manuals on general physics (in print or digital formats) [9–12, 24, 25, 30–32], but also handbooks [33], and more in-depth studies of some sections of the course [33–45].

6 The Basis of Special Educational Environment for Teaching Physics

Infrastructural prototype of the distributed educational system which can be considered as Grid segment, consists of 4 sites located in St. Petersburg State University, St. Petersburg State Pediatric Medical University, Russian State Hydrometeorological University and St. Petersburg Electrotechnical University "LETI".

Each Grid-site base configuration consists of minimum 5 computer systems: Configuration server, Computing Element (CE), Storage Element (SE), User Interface (UI) and Working Node (WN).

User Interface element provides access to the Grid segment resources. User logins into UI computer in order to choose Grid resources, install the task for execution, get output data and transfer data if necessary.

Configuration server provides semiautomatic installation and configuration (both initial and secondary) of all base control elements.

Computing Element is the main working point on the local site. CE provides common interface for the computational resources lying beneath. Among its functions is task launching and task scheduling.

Working nodes provide user task implementation. A site can contain several working nodes. Storage Element provides the user with the universal access to the available databases.

The Globus code will be used as the basic software for Educational Grid System. The main function of the Grid infrastructure is to provide access to the educational resources located in different universities. Educational resources can be of different

types: electronic textbook, virtual laboratory, data base, intelligent system. User should not care about the place where the resource is located and how to find it. In future the Grid education environment should possess advanced means such as GUI for applications-experiments composition, API to create modules for meta applications.

The first step of the educational Grid infrastructure functioning will be selection of the best educational courses in the field of physics elaborated in the 4 selected universities.

Thus there is the collection of audio tracks fragments of real lectures, read to the students at the Faculty of Physics of St. Petersburg State University and the videos of real experiments and natural phenomena which cannot be reproduced in lecture rooms [46]. A series of electronic media collections "Physics: model, experiment, reality" has been developed, each collection dedicated to one of the relatively isolated areas of modern physics.

Besides educational electronic courses St. Petersburg State University possesses essential computational resources located in Resource Centre "SPbU Computer Centre" which provides access to expensive research equipment and associated software that can be used for installation of virtual laboratories, visualization facilities and data warehouses.

Russian State Hydrometeorological University has gained substantial experience with the virtual laboratories. The university constantly substitutes old laboratory equipment with appropriate software for imitation laboratory workshops in mechanics, optics, thermodynamics and other sections of physics. Working with the software is much more familiar for modern students thus their interest to practical studies increased greatly. So in the section "Molecular physics and thermodynamics" students can perform following virtual laboratory operations: "Determination of dew point at various absolute humidity", "Determination of warmth of transpiration of fluid on pressure of saturated steams", "Determination of a specific heat capacity of a solid body", "Determination of a specific heat capacity of gas at constant pressure by a method of a flowing heating", "Determination of adiabatic index at the adiabatic expansion of gas", "Determination of adiabatic index on velocity of a sound in gas", "Determination of a thermal conduction of gases by a method of heated lines", "Determination of a thermal conduction of a solid body (plate)".

St. Petersburg Electrotechnical University "LETI" is famous for the work in microelectronics. So its staff can provide electronic textbook and manuals in the field of solid phase physics and electronic chips creation.

Lecturers and students of St. Petersburg State Pediatric Medical University can be the acceptors of the Educational Grid Segment facilities. Though being very important general physics is not profiling discipline at the University. Thus their laboratories and visualization facilities are of inferior quality in comparison with the related equipment at other universities. But this advanced equipment and software becomes available at the remote access. Such educational regime allows to train students skills needed in the future to work with telemedicine systems.

7 Conclusions

Thus, the use of modern computer technology for the development of modern multimedia interactive courses and webinars can significantly improve the effectiveness of teaching and learning of general physics and other natural sciences by the students of scientific, technical and humane specialities. We propose to organize special educational environment in the form of Grid segment, which should comprise all kinds of distributed learning materials and provide equal and the most comfortable access to them. Grid infrastructure functioning will be the selection of the best educational facilities in the field of physics, including textbooks, virtual laboratories and databases elaborated in St. Petersburg State University, St. Petersburg State Pediatric Medical University, Russian State Hydrometeorological University and St. Petersburg Electrotechnical University "LETI".

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