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Электронные обучающие курсы по математике в высшем образовании

В статье рассматриваются современные образовательные платформы и системы электронного обучения для организации учебного процесса в высших учебных заведениях. Описаны мировые тенденции в области электронного обучения. Рассмотрен полипарадигмальный подход как основной методологический подход для проектирования электронных обучающих курсов по математике, который был расширен за счет включения подходов электронного обучения, а также личностно-ориентированного подхода, направленного на индивидуализацию обучения. Представлены принципиально новые формы и методы обучения реализуемые в условиях внедрения ЭО и ДОТ. Выделены наиболее удобные для разработки электронных обучающих курсов системы управления обучением, в том числе распространённая виртуальная обучающая среда с огромным функционалом Learning Management System Moodle, широко используемая в мировых вузах. В качестве примеров рассмотрен процесс организации электронного обучения математике в Венском техническом университете Австрии и Сибирском федеральном университете России. В работе обосновано, что при внедрении электронных обучающих курсов по математике повышается эффективность самостоятельной работы студентов, появляются принципиально новые возможности для развития и выявления способностей обучающихся, которые пригодятся им в дальнейшей профессиональной деятельности. Обозначены перспективы развития электронного обучения за счет создания принципиально новых технологических решений, направленных на разработку адаптивных обучающих систем и курсов, обеспечивающих индивидуализацию обучения в электронной среде.

Ключевые слова: электронное обучение, электронный обучающий курс, полипарадигмальный подход, образовательные платформы, системы электронного обучения, LMS Moodle, формирование математической компетентности

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E-learning courses in mathematics in higher education

The article is dedicated to modern learning platforms and e-learning systems designed for educational process management in higher educational establishments. Various relevant global trends in e-learning are described. The article considers the polyparadigmatic approach as the primary methodological approach to develop e-learning courses in mathematics, which has been extended due to the inclusion of e-learning approaches as well as the person-centered approach aimed at individualization of learning. The implementation of e-learning and distance education technologies allows putting completely new forms and methods of teaching into practice. The article also singles out the most convenient learning management systems for developing e-learning courses. Moodle Learning Management System is commonly believed to be a virtual learning environment with huge functionality, being used in universities world-wide. E-learning management process in teaching mathematics at Vienna University of Technology (Austria) and at Siberian Federal University (Russia) is given as an example. It is proved that the implementation of e-learning courses increases the efficiency of independent seatwork as well as brings out completely new opportunities for revealing and developing abilities of students, which will be useful in their future professional life. The article presents the prospects for the development of e-learning by means of creating completely new technological solutions aimed at the development of adaptive learning systems and courses which provide individualization of learning in e-learning environment.

Keywords: e-learning; e-learning course; the polyparadigmatic approach; learning platforms; e-learning systems; Moodle LMS; mathematical competence development

Introduction

Intensive development of Information and Communication Technologies (ICT) has a considerable impact on modern society, bringing particular changes into social sphere, culture and education. E-learning and Distance Education Technologies are actively formed under the influence of ICT in education. They become integral parts of educational process and are used as effective teaching tools for different disciplines in higher educational establishments [1, 2]. The federal law of the Russian Federation "On Education" determines the necessity of developing and functioning of "electronic educational environment including electronic educational resources and e-learning courses (ELC), the aggregate of educational technologies, appropriate technological facilities which provide for the fact that students master educational programs completely regardless of their location" [3]. The creation of electronic educational environment, the development and implementation of e-learning courses when educating modern "digital generation", living in the world of electronic culture, is an integral part of education today, concerning all higher education disciplines including mathematical ones.

The aim of the article is to study modern learning platforms and e-learning systems in order to maintain educational process in higher educational establishments as well as to present original approach to the development and implementation of e-learning course in calculus, basing on Moodle LMS. The future prospects of the e-learning course providing individualization of learning are mentioned.

Materials and Methods

The methodology of design and development of e-learning mathematics courses in higher education is largely determined by traditional approaches to teaching mathematics.

The concept of polyparadigmatic approach is among modern mathematics training concepts which contribute to developing students' mathematical competency [4]. According to the concept, teaching mathematics can be regarded as an open consistent cluster of teaching approaches, the essence of which consists in the complex and optimal use of the approaches having different didactic potential. The leading role in the cluster belongs to the competency-based approach which determines learning objectives [5].

Ranking next in its didactic potential are the fundamental, contextual, interdisciplinary, subject-informational approaches that promote to form the content of mathematics teaching which determines their effectiveness. Thus, in accordance with these approaches, teaching content must include substantive, basic and long-living knowledge, accompanied with interdisciplinary knowledge and professional context as well as the use of the ICT, as it is shown in the research [4], teaching content based on the polyparadigmatic approach promotes developing mathematical competence and, consequently, it can be taken as a basis for developing the content of e-learning courses in mathematics.

In our opinion, proceeding to educational process management in electronic environment, it is essential to extend the open cluster of the polyparadigmatic approach by complementing it with the approaches of e-learning as well as including the person-centered approach aimed at individualization of learning.

Thus, the methodological platform of the design and development of e-learning courses in mathematics in higher educational establishments is formed by the complex use of the extended cluster of the polyparadigmatic approach in teaching mathematics.

Learning platforms and e-learning systems

Let us consider online learning platforms and e-learning systems designed to create educational environment in higher educational establishments. They can be distinguished into the following groups:

- memory platforms (for example, Wikipedia, the free encyclopedia, or www.mathnet.ru, a mathematical portal), with the main objective to provide public access to scientific and educative information (articles, publications, web-pages);
- resource storage platforms (for example, Wikimedia), which main goal is to collect, store, describe and exchange digital educational resources and other multimedia data;
- open (source) expert systems, designed for storing and structuring scientific and expert knowledge and subsequent decision support as well as solving problem situations in the course of education;
- learning management systems (for example, Moodle, Wikiversitet), which integrate and structure scientific information for executing educational process, creating and developing interactive didactic materials, implementing various scientific projects and monitoring educational outcomes.

Creation and distribution of educational materials on the Internet has a wide range of instruments: from electronic guides, problem books and textbooks to special web-centered educational environments.

As for Russian actively developing projects, "National platform of open education" https://openedu.ru/ is worth mentioning. This modern learning platform established by the Association of Leading Universities of Russia: Moscow State University, Saint Petersburg State University, the National Research University Higher Schools of Economics, Siberian Federal University and others, offers the best

online-courses held by leading professionals of the Russian Federation.

The widest currency in global education is gained by educational systems and services applied for E-learning and Distance Education Technologies management which can be classified as follows:

- Learning Management Systems (LMS),
- Course Management Systems (CMS),
- Learning Content Management Systems (LCMS),
- Virtual Learning Environments (VLE),
- Managed Learning Environment (MLE),
- Learning Support Systems (LSS),
- Learning Platforms (LP),
- Authoring Programs (AP).

Among the categories of educational systems and services listed above Learning Management Systems (LMS) have gained significantly extensive use due to their larger functionality and are designed for mass teaching [6]. Moodle, Blackboard, e-College, WebCT etc. serve as examples of LMS.

Their common feature is to include teaching content, monitor and control educational process, save statistics of achievement and website section addressing, record the time it takes a student to complete a particular part of the course. These systems provide an opportunity of authorized access and team learning organization as well as to actualize communication between participants in the educational process.

The right choice of a learning management system is the key factor for successful building an educational environment and assuring quality in educational process. The requirements for the choice of the system are determined by objectives of educational process, needs of educational establishments, students and teachers and system administrator teams which control the setup, adjustment and maintenance of software.

Regardless of the type, the following requirements are imposed upon learning platforms: reliability and stability, safety, compatibility, modularity, usability and administrative convenience as well as authorized access provision.

The use of small interchangeable knowledge objects – training modules in modern learning platforms and systems is of immediate interest. These are small information blocks that can be re-used for educational purposes. It is necessary that the platform supports this kind of functionality, i.e. allows identifying knowledge objects and enables a course author to put knowledge objects and learning objectives together.

Let us consider Moodle (Modular Object-Oriented Dynamic Learning Environment, moodle.org) which is a freely available open source learning management system.

According to the research conducted by K. Hicks, Moodle LMS is the most popular virtual learning environment with a huge functionality [7]. Due to high flexibility in creation and adjustment of e-learning courses and owing to its usability and open source, Moodle LMS is widely used to develop online courses, web-supporting e-learning courses and e-learning courses which implement blended learning. In the current context of personalization of e-learning, the main advantage of Moodle is an opportunity to create an individual educational trajectory and to facilitate education [8].

Moodle LMS is based on the concept of "social constructivism pedagogy" which is focused on the interaction between students and teachers. An important feature of Moodle is modularity which ensures its continuous development driven by the implementation of additional modules, including interactive ones, also allowing development of various e-learning courses with the application of the most advanced methods of e-learning. Moodle LMS is a web-centered environment which allows students and teachers to manage and to facilitate educational process in any place equipped with Internet access.

Moodle offers a range of opportunities for creating and storing materials, monitoring students' learning achievements and organizing communication between the participants in the educational process. Due to the huge number of settings, the flexibility of the system ensures adaptation to certain user needs. Teaching content in Moodle LMS is structured in courses which can be facilitated in different ways of content presentation.

World trends in e-learning

E-learning technology-based educational reform is brought to the level of state policy in many countries at the present time. In France the highest priority of the country's educational system is claimed to be the implementation of Information and Communication Technologies in all the spheres of educational process. The USA has long acclaimed the move towards educating via the Internet with the use of e-libraries. In Finland, Ireland, South Korea there are special national programs basing on e-learning, which is the key instrument of modernization of education. In the Republic of Kazakhstan e-learning is seen as the key direction of innovative development of the educational system. By 2020 it is planned to cover 90% of educational establishments with e-learning [9]. In the Russian Federation about 11 million people are expected to join open online courses by 2025. In the next 2-3 years online courses will cover the huge part of Bachelor's and Master's degree programs.

The development of the modern educational system is caused by the influence and application of ICT in all spheres of activity of educational institutions and the widespread use of Internet technologies. These processes predetermine considerable changes in traditional approaches to educational process [10].

As an example, let us consider e-learning in mathematical disciplines at Vienna University of

Technology (TU Wien) basing on the use of the following electronic educational environments:

MTA (Maple T.A.). Developed by Maplesoft, this is a web-based platform which can be integrated with Moodle LMS environment;

MMT. University's own development which has turned into a successful commercial project. This web-based platform is designed for e-learning.

There are two levels of mathematics education at this university: AKMATH (foundations) и GMMATH (basic).

During the first semester at TU Wien students study the foundations of mathematics the second and the third semesters are to be reserved for the basic level and the fourth semester is for special sections of mathematical disciplines. Singling AKMATH out, the teachers and authorities of TU Wien set out the following goals and objectives: ensuring the mathematical training common level of first-year students; teaching a large number of students with the use of e-learning technologies; the unification of the course content and length of study for students of various majors. All majors at TU Wien study the foundations of mathematics AKMATH with the application of e-learning technologies.

This course is divided into modules which include such topics as vector calculus, plane and solid geometry, complex numbers and so on. Each module contains a 1.5 hour long formal lecture as well as two hours of formal practice session alongside with classes with the use of Maple T.A. As for independent seatwork, it is up to every student to decide how long it will take him or her.

All students are obliged to take a placement test before the start of the course. Basing on the results, teachers analyze the topics that have to be paid the closest attention. They also conduct final tests to determine the attained level of mathematical competency in AKMATH e-learning course.

The basic course of mathematics GKMATH at TU Wien has the following requirements: completion of at least 60% of practical assignments of the course; independent seatwork in electronic environment (problem solving); solving routine problems and cases in class at the board; completing three tests in Maple T.A. (at least two of them must be passed successfully).

Analyzing the TU Wien experience of the use of e-learning technologies, it should be noted that the use of electronic educational environment, which is an integral part of modern education, allows creating and developing new approaches, methods and educational models that will enable preparing students to life long learning.

In many Russian higher educational establishments Moodle LMS is the core of electronic educational environment. E-learning system (http://e.sfu-kras.ru) based on Moodle LMS successfully works at Siberian Federal University at the present moment. The University carries out the project of the development of e-learning courses for all academic disciplines for all modes of study.

Let us consider the application of e-learning through the example of the e-learning course on calculus which was developed and implemented at the Institute of Space and Information Technology of Siberian Federal University. This course provides blended learning [11]. Blended learning is a model based on the integration and mutual complementation of traditional learning and e-learning which implies substituting a part of traditional classroom training with various kinds of educational interaction in electronic environment [12, 13]. It is assumed that at least 30% of time, which is spent on mastering the discipline, is reserved for e-learning course activities. Moodle LMS is used to organize pre- and post-classroom unsupervised student activities, to increase communicativeness of educational process on all stages, to hold consultations and discussions via forums and chats, to perform ongoing and intermediate monitoring as well as to run both personal and team students' project activities. The course is designed for first-year students.

E-learning course "Calculus" [14] includes the following components:

- the syllabus and discipline roadmap;
- the electronic hyperlinked lecture compendium;
- the electronic glossary;
- the practice session guideline for students;
- lecture-based tasks for independent work, which are checked automatically online;
- group work module tasks equipped with the guideline completed with the help of "Seminar" Moodle LMS element;
- self-training tests as well as interim and final assessment tests on each module which are checked automatically;
- interaction facilities for the participants of educational process: forums, teachers' feedback on assignments, students' mutual review on assignment results;
- means of integrating various educational environments (e.g. links to external resources);
- the student guideline to complete the course;
- the teacher guideline.

Calculus is taught during the first semester. It is divided into three modules: Introduction to Calculus (theory of limits, continuity of functions), Differential Calculus of One Variable Function and Integral Calculus of One Variable Function; it includes 18 lectures which corresponds to the amount of academic weeks in the semester. Besides, it is 36 hours long, has 27 practice sessions (54 hours) as well as 54 hours of student unsupervised activities. The discipline ends with an examination.

The structure of the e-learning course includes the possibility of studying the electronic lecture compendium which allows students to put their questions (as well as to answer other students'

questions) on the forum. Analyzing the information on the forum, the teacher answers the questions raised involving students in a discussion apart from presenting the material during the lecture.

During the designing of the e-learning course special attention was paid to the development of a methodology to conduct training sessions.

As it was mentioned above, the polyparadigmatic approach, being a cluster of educational approaches, integrates them in order to reach the goal of developing mathematical competency. In compliance with the contextual approach, which is included into the polyparadigmatic approach cluster, the e-learning course on calculus contains professionally oriented educational mathematical problems related to students' future career. Solving these problems allows students to strengthen gained knowledge.

It is also possible that the polyparadigmatic approach is enlarged with some other approaches which have a smaller level of didactic commonness than, for example, the contextual approach and do not directly determine the teaching content. The task- and project-based approaches serve as the examples. In the e-learning course they are also used at the end of each module.

We determine the objective of each lesson as to provide understanding of the theoretical material of the discipline, including it into students' knowledge system, to develop skills of applying knowledge in solving both applied and professionally oriented problems, to gain the experience of working in team and presenting results of learning activity. All the assignments of the e-learning course are divided into the ones that are checked automatically and the assignments with the possibility of mutual reviewing, subsequently checked by the teacher or the curator.

The example of automatically checked assignments are the test assignments of the e-learning course which are represented in different types: multiple choice, true/false, matching, short answer, write a number, essay, calculating, etc. Students' academic records are registered in the electronic gradebook.

Project activity assignments with mutual reviewing are created with the help of "Seminar" Moodle LMS element. The seminar includes the following phases: the adjustment phase, the presentation phase, the mutual reviewing phase, the grading phase and the summing-up phase. The rigid sequence of actions is determined for teachers and students to follow [15].

To begin with, the teacher must go through the adjustment phase. The phase implies the description of the main rules and criteria for students to follow, placing assignments, setting the dates for the rest of the seminar phases.

During the presentation phase students place their performed work in Moodle LMS. The works are distributed among students to be checked. Work distribution is performed automatically or/and manually by the teacher.

The mutual reviewing, being the next phase, allows strengthening acquired mathematical competencies by practice.

The grading phase implies receiving two grades for their activity in the electronic seminar. The first grade denotes student's personal work, the second grade is received for reviewing. The grade for work is calculated regardless of the evaluation methods, the result is the average value of all the grades given by the reviewers. It should be noted that the teacher can manually re-evaluate any work as well as act as a reviewer. Besides, the system setup allows raising the profile of any reviewer.

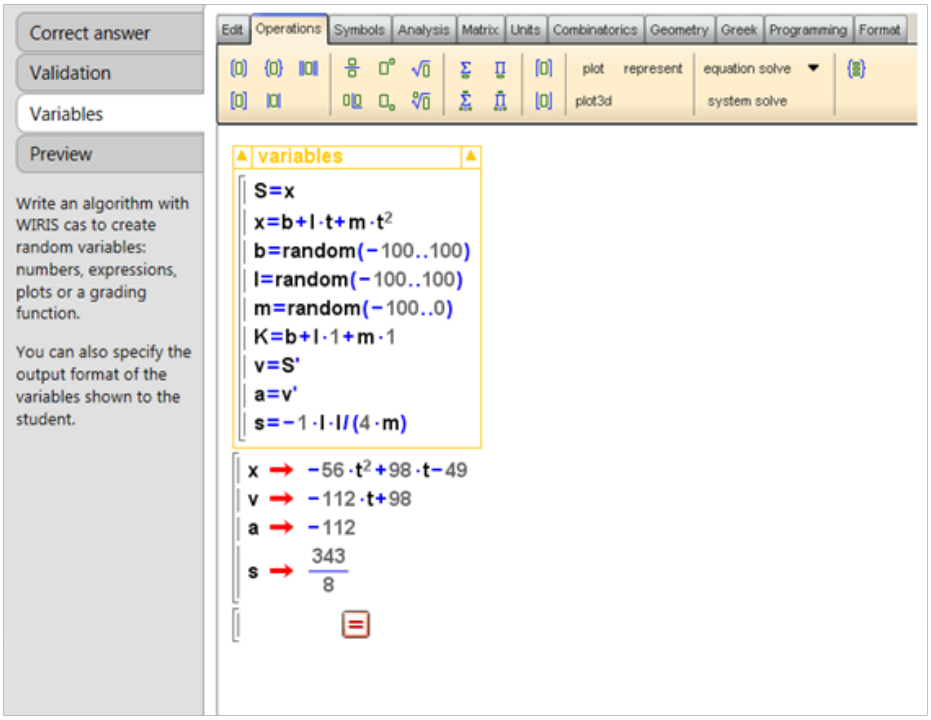

Fig. 1 The example of problem development in WIRIS

These examples of learning assignments in Moodle LMS show limitations in variability and require that the teacher updates assignments frequently. These problems may be avoided by the use of WIRIS editor, which can be integrated with Moodle LMS. WIRIS editor is a formula editor (also referred to as an equation editor) which allows developing assignments of different complication level, provides automated variability and full-scale (graphic) visualization [16].

Let us consider the example of a mathematical problem in Moodle LMS with the use of WIRIS editor. When developing an assignment, one must determine the type of the answer (a test, a formula, a number), the type of matching the correct answer with the typed-in answer (equality, equivalency, literal equality) and others. Additional settings are also possible, for example, reduction or factorization of the typed-in answer to match it with the correct answer.

Figure 1 illustrates the example of developing the problem of finding the acceleration as well as the path covered by body ***S*** from motion onset to stop, knowing that the body moves by law $\boldsymbol{S(t) = -t^2 - 52t - 29}$. Programme implementation allows setting initial function coefficients (set in the problem situation) randomly as well as determining correct answers for them. Thus, the problem variability is reached (Fig. 1).

Apart from the e-learning course assignments given above, there are also self-training test with unlimited attempts for each module so that every student can strengthen the skills out of class.

The final assessment is the exam consisting of two parts: the practical part which implies solving problems in the e-learning course and the theoretical part – in the form of colloquium.

The advantages of the Moodle LMS-based e-learning course on Calculus developed at Siberian Federal University are its consistency, integrity, variability and usability in educational process for both teachers and students.

To assess efficiency of the educational process implementation of the developed e-learning course the academic record comparison with the use of Mann – Whitney U-test was made between the control group and the experimental group before the onset of studying and after it. The students were offered to take a placement test and a final test assessed in points. In doing so hypothesis H_0={point distribution in the control group and the experimental group is equal} under the alternative hypothesis H_1={point distribution in the experimental group takes a bigger value}.

Hypothesis H_0 testing in points showed no significant difference in the level of mathematical training of these groups. U_{emp} = 139, U_{cr} = 81 at the significance level 0.05. As $U_{cr} < U_{emp}$, the hypothesis of the insignificance of the sample difference is accepted, i.e. it is confirmed that the point distribution in the control group and the experimental group is equal. The comparison of the points for the final test showed a different result: U_{emp} = 67.5. As $U_{cr} > U_{emp}$, with a probability of 95% better academic record in the experimental group can be affirmed. It proves that the implementation of the e-learning course has made it possible to raise the level of mathematical competency development for all students.

Conclusions

The article considers modern learning platforms and e-learning systems designed for educational process management in higher educational establishments. World trends in e-learning are described. The most convenient learning management systems for e-learning courses development are singled out. E-learning management process in teaching mathematics at Vienna University of Technology (Austria) and at Siberian Federal University (Russia) is given as an example.

It is noted that the rapid development of ECT modernizes effective didactic approaches to teaching mathematics. The implementation of E-learning and Distance Education Technologies allows putting completely new forms and methods of teaching into practice. The concept of the polyparadigmatic approach, acting as the basis for the content development of e-learning courses in mathematics, has been extended due to the inclusion of e-learning approaches, as well as the person-centered approach aimed at individualization of learning. It should be mentioned that the implementation of e-learning courses increases the efficiency of independent seatwork as well as brings out completely new opportunities for revealing and developing abilities of students, which will be useful in their future professional life.

In spite of the remarkable progress in developing e-learning courses and the gathered experience of e-learning, it is worth mentioning that e-learning still has certain disadvantages. For example, the person-centered approach, being included into the polyparadigmatic approach cluster, is not fully implemented in electronic environment. Despite the possibility of organizing learning regardless of time and place, the variability of teaching content, personal communicative assistance from the part of the teacher, students' specific features, particularities and traits are not taken into account.

The issue of individualization of learning can be solved considerably by means of adaptive e-learning courses. The development of such courses will allow building an individual educational trajectory for every student as well as forming personal scope of educational materials (e-learning content and e-learning course assignments), which best corresponds to students' personal characteristic.

Thus, the promising trend of e-learning development is the creation of completely new technological solutions in the form of adaptive learning systems and e-learning courses which provide individualization of learning in electronic environment.

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