

Aspects of distance learning to mathematical disciplines

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Abstract — The article is devoted to a topical problem of modern education – the development of electronic textbooks, designed for all forms of education: full-time, distance and open education, and the basic requirements to them. The article analyzes the components of the electronic textbook and methods to improve its efficiency. The structure, design and interface of electronic «Mathematical Analysis» textbook and the possibility of its use in all forms of education are demonstrated as an example.

Keywords — *distance learning, interactive textbook, testing system, mathematics*

I. INTRODUCTION

In the context of widespread computerization of the modern information society particularly notable trend is the use of computer technology and the use of network resources in the learning process.

High efficiency of electronic aids in training is due to:

- their mobility allowing to easily and promptly find the information;
- their agility and clarity in the presentation of the required information (animation, videos, etc.);
- the possibility of impartial control, assessment of students' knowledge through testing with strict evaluating system;
- prompt feedback between an instructor and a student.

The development of computer technology in education has become the basis for the modern universal education technology – distance learning.

Distance learning is considered a separate form of education, implementing educational technologies, based on extensive use of evaluative training methods, problem oriented and research methods, combined with maximum use of advances in information and communication technologies, which are difficult to implement in traditional teaching.

In case of distance instruction the student acquires knowledge independently using provided to him electronic information material. The teacher acts as a conductor of information and a coordinator and helps student's master knowledge and applies it in practice.

Distance learning today is actively used in higher education by, for example, disabled people and those who want to be educated in the metropolitan institutions but who do not have the opportunity to change their place of residence at the time of training.

Training in a remote format takes place using the materials posted on the university website: such as e-books, video-records, web-conferences, as well as offline-conversations, e-mail or Skype application.

Elements of distance learning are also used in full-time education, combining independent cognitive activity of students with sources of information, operational and systematic interaction with the teacher and group work of students – the so called blended learning [1].

II. THE ELEMENTS OF DISTANCE LEARNING

For successful implementation of distance learning in high school a set of software products that provide a virtual learning environment of distance education should be developed [2,3].

Software products necessary for distance learning include:

- developed electronic educational methodical and information materials on the entire range of disciplines;
- electronic manuals with elements of the interactive dialogue;
- testing programs and database of test tasks on studied disciplines.

Electronic textbook is one of the basic software tools in the system of distance education, realizing all the advantages of the electronic format as compared with the printed edition.

The electronic textbook may contain video, audio attachments, and other interactive tools. It should have a user-friendly navigation system – an active table of contents – and built-in quality of mastering knowledge control means (test elements).

The use of electronic textbooks in the educational process increases its informative capacity, enhances motivation and energizes learning activities of students.

An electronic textbook is effective if:

- it ensures a quick search of the necessary information;
- there are demos and models (it relates, explains, and demonstrates);
- it provides for adaptation to the individual basic level of students and to the purpose of training;
- interactive student-teacher dialogue is possible;
- there are elements of control and self-control;
- it takes into account the features and capabilities of the electronic and mobile devices for which it is intended.

The last requirement implies the creation of a simple and easy-to-use software shell for the teacher to edit and complete textbook, taking into account the features of electronic or mobile devices used. The development of the software shell is possible in two ways: using freely available platforms such as Math-Bridge, Moodle, Drupal, Blackboard, SAKAI, or by creating your own shell that takes into account the specifics of a particular discipline and the purpose of teaching.

The article [4] describes the remote teaching of students from different countries using the Learning Management Systems Moodle, beginning with preparing study materials, delivering lectures by foreign lecturers, practical tasks and ending with an examination. The work of Sosnovsky, Girenko & Galeev [5] is devoted to the description of the intellectual learning system Math-Bridge, used as an instrumental platform for informatization of mathematical courses, e-Learning platform for online courses in mathematics. The paper [6] presents the advantages and disadvantages of such platforms as Blackboard, Math-Bridge, Geo Gebra and Learning Space, which the authors call e-learning systems, as well as recommendations for their use in the educational process.

The authors of the work [7] described the MCIEC (motivation, context, interaction, evaluation, and connection) model for two sections of mathematics, Linear Algebra and Theory of Probability and Mathematical Statistics. They used an open source Xerte Online Toolkits (XOT) platform to build the e-learning environment in this work. The interactive dialogue in the demonstrated application is carried out through interactive windows that the student must fill in with the appropriate mathematical symbols, resulting in correct mathematical sentences.

In the past the authors tried to implement a similar idea but abandoned it due to the fact that such approach to mathematical language training requires a lot of time, a large amount of software. Besides that the “step-by-step” solution can be “simulated” only in a limited series of simple mathematical tasks. The value and novelty of this work, in our opinion, consists in introducing videos into the program,

showing the use of the sections of mathematics learned in practice. This stimulates the creative potential of students and increases their motivation to study mathematics.

All the above platforms have their limitations as for mathematical disciplines. They are associated with a large number of formulas included into the text, they are often unsuitable or very difficult to use, such as the Math-Bridge platform. The development of the original proper shell based on its own instrumental environment taking into account all the needs and characteristics as well as the specifics of the discipline being studied, seems to be more in demand and effective in the conditions of the university. Learning Management System, i.e. a site with administration elements on which all distance learning materials are placed should be developed using freely available platforms, for example Drupal [8].

The purpose of the article is to discuss the methodology for developing an electronic textbook built on based its own program shell. In its discusses issues of effectiveness of electronic textbook and ease of its use.

III. METHODOLOGY OF THE ELECTRONIC TEXTBOOK DEVELOPMENT

The structure of the electronic textbook

The distance education system requires revision of discipline curricula and construction of the whole educational process within the framework of a fundamentally different, modular structure, which was first described by John Russell's [9] and which was further developed in the research by P. A. Yutsyavichene [10].

Structuring of educational material in the form of closed packages – modules-allows the student to study it as a series of modules, their sequence being different for different specialties and even selected by the user himself. In addition, the modular arrangement of educational material promotes the systematization of the acquired knowledge.

The evolvement in the last decade of e-learning and particularly remote teaching makes it necessary to break each module into lessons corresponding to the lectures of the course, and to choose as distance learning unit one web-page (screen) of a lesson (fig. 1). This structure of the discipline eliminates the need to scroll significantly complicating the perception of information from a computer screen.

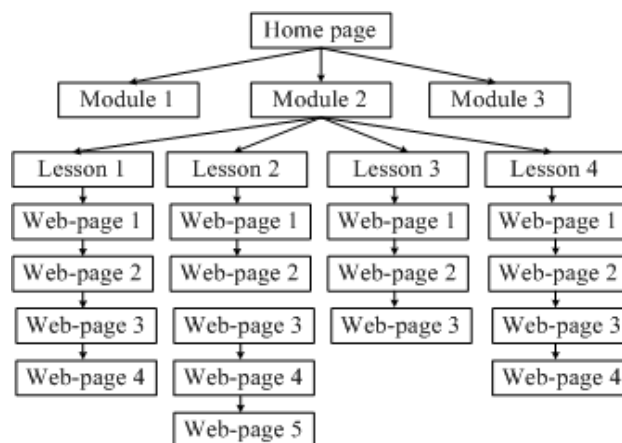


Fig. 1. Structure of the electronic textbook

Web-page should include everything that relates to the curricula section of classes: definitions, theorems, remarks and demonstration tasks. It should fit into the computer screen as far as possible and be read without additional scrolling. The transition from one lesson to another (from one web-page to another) must be performed using a well-designed communication system – the interface.

The interface of the electronic textbook

In electronic textbook the pages are turned by pressing the button and thus it should include specially designed communication system between the pages of e-books – web-pages. Such a communication system is called interface. Minimum criteria to be met by any pro-interface software product: site, software application and, in particular, the electronic textbook – principles usability, named by Jacob Nielsen heuristics, were formulated yet in 1993 [11]. The principles of usability, well known to every web programmer, are often not taken into account by the developers of electronic textbooks.

The main principles for electronic textbook interface are:

- minimization principle;
- the principle of uniformity;
- awareness of the system status;
- matches the text and format of the device for which it is intended.

The first principle urges to get rid of the redundancy in the texts, as well as of the redundancy in the design elements. According to the second principle in the electronic book, unlike in the case of the classic textbook, one should not be afraid of repetitions. On the contrary, each term and each notion should be repeated uniformly throughout the electronic textbook. On the one hand it contributes to the rapid and sustainable memorizing of the basic notions of the studied subjects, and on the other hand makes it easier to navigate through the pages of the textbook on the awareness level.

The principle of awareness about the state of the system, as applied to electronic textbook, means that one can easily understand the basics of functioning of the program, on the basis of structured lists of the basic functions that allow one to find the required information quickly and easily.

An interface of the electronic textbook on «Mathematical analysis», developed by the authors at the Department of Mathematics, Military Space Academy named after A. F. Mozhaiskiy and of St. Petersburg State Marine Technical University, may serve as an example.

The mathematical analysis. Part 3	
Module 1. Numerical and functional series. Fourier series	
1.1. Numerical series	
1.2. Functional series. Fourier series	
Module 1. Integral calculus of functions of several variables. Field theory	
2.1. Multiple integrals	
2.2. Curvilinear and surface integrals of the 1 - st kind	
2.3. Field theory	
Total tests	
Login in the system of test	

Fig. 2. Tutorial homepage with main menu

The initial page of the textbook (fig. 2) contains a list of all the modules of the course. Navigation by sections and lessons of the module takes place via the drop-down menu for each module section – list of lessons (fig. 3).

Lesson 1. Functional series	
1.1. Functional series and its region of convergence	
1.2. Uniform convergence of functional series	
1.3. A sign of uniform convergence Weierstrass	
1.4. Properties of uniform convergence series	
Lesson 2. Power series	
2.1. Power series and its region of convergence	
2.2. Abel's theorem. The structure of the region of convergence of a power series	
2.3. Finding the region of the convergence of a power series	
2.4. Problems for independent solution	
Lesson 3. Taylor and Maclaurin series	
Home paper	
List of modules	

Fig. 3. Module content

One can return from this menu to the home page with the list of modules. Web-page of every lesson in its turn contains some element of the interface: a list of web-pages of the content (fig. 4) from which one can come back to the list of lessons of the modulus (fig. 3). The pages of the textbook are connected with one another through the system of hypertext links by logic, visual and intuitively clear methods. The interface of the textbook enables the student to choose easy-to-use methods of work with learning material.

The pages of the textbook are connected with one another through the system of hypertext links by logic, visual and intuitively clear methods. The interface of the textbook enables the student to choose easy-to-use methods of work with learning material.

The latter usability requirement means taking into account all the technical capabilities of the electronic or mobile device for which the application is developed: the size and resolution of its screen, the principle of access to electronic materials, the size of RAM, etc.

The content and design of the electronic textbook

Numerous investigations indicated that students read better from a screen than from a printed page. This should be taken

into consideration when developing the electronic text book. The text should be worked out for the Internet considering all its special features as well advantages. So called hypertext is used in software products designed for the Internet. It is an environment divided into web-pages and media-files. They are interconnected through hypertext links [12].

Given the characteristics of the type of hypertext on the computer screen, it is recommended to divide the screen into 2 – 3 pieces (strips, bands), and place the main information part in the middle (the three-band placement) or the right (with two-band placement) side of the screen. Other bands are used for lists of program functions, bookmarks, footnotes, etc.

Figure 4 shows a browsing window of the electronic textbook on «Mathematical analysis», developed at the Department of Mathematics, Military Space Academy, named after A. F. Mozhaitskiy, and of St. Petersburg State Marine Technical University. The screen of the lesson is divided into two parts: the main information part is on the right; menu with a list of web-pages through which to navigate the topics of the lesson under study is on the left. Menu includes a button to move to the list of lessons of the module being learned. One of the advantages of hypertext electronic textbook is the

opportunity to use color to highlight different parts of the background of theoretical material.

Figure 4 shows one of the possibilities of the arrangement of a text on the screen. The main part of the information (definitions, concepts, theorems) opens directly in the transition to the appropriate web-page (screen) and is highlighted in yellow. Additional information (proof of theorems, illustrative problems and their solutions) is set off by calm gray and is opened by pressing the appropriate buttons. The proposed form of presentation of studied material on the screen is convenient to read and contribute to better learning and memorizing.

The authors deliberately rejected the introduction of hyperlinks within the material being studied, because the frequent transitions from one page to another and back again defeats the purpose and effect of memorizing the material being studied, and one can easily «get lost» among the abundance of references and footnotes. It is much more rational to use a well-designed interface (user friendly), and to use pop-up windows (frames) for links, which is easily implemented using HTML – technologies.

2. Functional series	
Content	Lesson 2. Power series
<p>Lesson 2. Power series</p> <p>2.1. Power series and its region of convergence</p> <p>2.2. Abel's theorem. The structure of the region of convergence of a power series</p> <p>2.3. Finding the region of the convergence of a power series</p> <p>2.4. Problems for independent solution</p> <p>The list of lessons "Functional series"</p>	<p>2.3. Finding the interval of the convergence of a power series</p> <p>The interval of convergence and the radius of convergence</p> <p>The interval of convergence of the power series $\sum_{n=1}^{\infty} a_n(x-x_0)^n$ is as follows: $(x_0 - R; x_0 + R)$.</p> <p>The interval of convergence of the power series $\sum_{n=1}^{\infty} a_n x^n$ is as follows: $(-R; R)$, where the radius of convergence $R = \lim_{n \rightarrow \infty} \frac{a_n}{a_{n+1}}$.</p> <p>A task 1 (+)</p> <p>Inequality to find the interval of convergence</p> <p>The interval of convergence of a power series can be found, Using d'Alembert's sign or Cauchy sign, ie, inequality:</p> $\lim_{n \rightarrow \infty} \frac{ u_{n+1}(x) }{ u_n(x) } < 1 \quad \text{или} \quad \lim_{n \rightarrow \infty} \sqrt[n]{ u_n(x) } < 1.$ <p>A task 2 (+)</p> <p>A task 3 (+)</p> <p>A task 4 (+)</p>

Fig. 4. Window view of the electronic textbook

The elements of self-control

Control and self-control elements of the proposed electronic textbook not only check the learning level of students, but also contribute to the stability of the knowledge they have received using training system and testing system.

The training elements of the textbook "Mathematical analysis" are sets of tasks for independent solution (fig. 5) placed at the end of each lesson. The set of proposed tasks covers all the studied material of the lesson. It is provided with answers and supplemented with "tips" in the tasks of increased difficulty. An important and time-consuming part of creating electronic textbook is to develop a test system and a base of test tasks. The test system includes elements of the interactive dialogue teacher – student.

The study of each module of discipline should end with session of testing, because the results of the test session show the volume and level of the knowledge gained by the student. The test system can be used as an element of personal monitoring of students' knowledge, and applied using cloud technologies under teacher supervision.

The test system can be developed on the basis of text editors Maker, ACT-Test, as well as Black Board platform [13] or in the Moodle virtual learning environment [14]. Papers [8] and [15] describe in detail the testing system developed on the basis of the Sakai platform

However, for a number of reasons the use of the above-mentioned electronic resources does not solve all the problems

arising from the formation of mathematical tests. Therefore, program of testing based on HTML and JavaScript technologies, which together with the test database is embedded in the proposed electronic textbook, was designed

at the Department of Mathematics of the St. Petersburg State Marine Technical University.

2. Functional series	
Content	Lesson 2. Power series
<p>Lesson 2. Power series</p> <p>2.1. Power series and its region of convergence</p> <p>2.2. Abel's theorem. The structure of the region of convergence of a power series</p> <p>2.3. Finding the region of the convergence of a power series</p> <p>2.4. Problems for independent solution</p> <p>The list of lessons "Functional series"</p>	<p>2.4. Problems for independent solution</p> <p>Task 1</p> <p>Find the interval of convergence of the power series $\sum_{n=1}^{\infty} \frac{x^n}{2^n \cdot \sqrt{n+1}}$.</p> <p>Answer</p> <p>$[-2; 2)$. Convergence of absolute except for the point $x = -2$, in which the conditional convergence</p> <p>Task 2 (+)</p> <p>Task 3 (+)</p> <p>Task 4 (+)</p>

Fig. 5. Tasks for the independent solutions

Back [3/20]	Forw	It took: 0:0:19	Test 3. Numerical and functional series > Go to the home paper
Question:			
Which of the series: 1) $\sum_{n=1}^{\infty} \frac{1}{\sqrt[3]{n^2+1}}$ 2) $\sum_{n=1}^{\infty} \frac{1}{\sqrt[3]{n^4+n}}$ 3) $\sum_{n=1}^{\infty} \frac{1}{2n+3}$ 4) $\sum_{n=1}^{\infty} \frac{1}{\sqrt{3n+2}}$ convergence ?			
Response options:			
<input type="checkbox"/> A	2		
<input type="checkbox"/> B	4		
<input type="checkbox"/> C	3		
<input type="checkbox"/> D	1		

Fig. 6. The window of the test program

Entering the system of testing is carried out from the initial page. Figure 6 shows the testing session window where the trainee should select the correct answer from several offered.

Numeric and functional series > 5.1. Test: Numeric and functional series

Test back [20/20] forv Passed: 0:5:43

Result:

Tema: Numeric and functional series

Conclusions/evaluations:

Points: 15 из 20

Your ranking: 0.75

(50% - 100%) - Credit: yes

(65% - 79%) - Your assessment: 4

You are encouraged to read the following topics:

- 1.5. Signs of comparison
- 2.5. Power series and its convergence region
- 2.6. Determination of the convergence interval of the power series

Fig. 7. The announcement of the test results

The test results are announced after the session (fig. 7). They include the grade, the number of correct answers, recommendations for re-study the certain sections of the textbook as a hyperlinks, which one can use to move to these sections.

After reviewing the material, the knowledge of which proved to be inadequate, it is possible for the student to take the same test again. The possibility of memorizing is excluded because questions and answers are shuffled each time you log in. If the test is passed without any errors, the student can go to the home page using the appropriate button and continue to study the material.

The developed test system is in general an element of personal monitoring of students' knowledge. It may well be applied to test a student or a group of students by a teacher in real time using the «cloud technologies». Stirring test questions and answers at each entering the test system eliminates the «cheating», that is why the whole group of students may be offered the same version of the test.

The need to change the order of questions and alternative answers each time you enter the test, even for one student, is stated also in the work [16]. This provides a higher level of individualization and eliminates memorizing correct answers when re-taking the test.

Tests need to be updated from time to time. Wherein a better option is to turn a hand-maintained pool of questions into a database. A database adds what we call «delivery time flexibility» [17].

question2i	23.10.2005 19:00	Firefox HTML Doc...
question2q	05.11.2015 0:37	Firefox HTML Doc...
question2q-v1	05.11.2015 0:39	Firefox HTML Doc...
question2q-v2	05.11.2015 0:40	Firefox HTML Doc...
question2q-v3	05.11.2015 0:40	Firefox HTML Doc...
question2q-v4	05.11.2015 0:41	Firefox HTML Doc...
question3i	23.10.2005 19:00	Firefox HTML Doc...
question3q	05.11.2015 0:42	Firefox HTML Doc...
question3q-v1	05.11.2015 0:44	Firefox HTML Doc...
question3q-v2	05.11.2015 0:44	Firefox HTML Doc...
question3q-v3	05.11.2015 0:46	Firefox HTML Doc...
question3q-v4	05.11.2015 0:47	Firefox HTML Doc...

Fig. 8. HTML – files of questions and answers

Figure 8 shows the «repository of questions and answer choices» in the testing program. If necessary, HTML files are replaced with new ones from the database.

IV. THE PROGRAMMING LANGUAGE AND IMPLEMENTATION OF THE PROGRAM OF THE ELECTRONIC TEXTBOOK

Programming Language

Developed in accordance with the generally accepted rules electronic books create a virtual learning environment that implements all forms of learning, using the tools and techniques of other subject domains [18]. In the proposed electronic text book the classical mathematics and computer science are integrated into one domain – the computer math.

The most popular to date language used in electronic products is hypertext markup language HTML. This language is integrated in all common web browsers and enables the binding of web-pages with hyperlinks.

HTML in conjunction with Java Script programming language provides opportunities to create interactive programs to work with the user in real time, enables one to create an attractive and intuitively clear interface by inserting a background of individual elements of hypertext and graphics illustrating and explaining the meaning of the material.

Proposed e-textbook, developed on the basis of its own original shell, opens under any browser on any wired (computer) or wireless (tablet, smart phone) networked electronic device with a minimum set of requirements and in any operating system. It has a fairly small volume, does not require large RAM and can be downloaded to any electronic device.

The implementation of the program part of the electronic textbook

The development of electronic textbooks for distance education should be carried out by professionals, i.e., teachers of relevant departments of universities and colleges. When implementing such projects there are two approaches: mastering of web-based programming by teachers of Departments or cooperation of the teachers of the Departments with web-programmers.

Years of experience of the authors in the development of electronic resources for distance education have shown that the first method is preferable for several reasons:

1. Lack of knowledge of HTML technologies of the teachers complicates the correct formulation of the problem to the programmer.

2. The teacher does not understand vocabulary of web-programmers and it complicates the implementation of the tasks, which increases the work on the textbook.

3. Training materials should be adjusted periodically, as software products for the Internet are very quickly becoming obsolete.

Learning of programming by teachers is much more effective approach and it enhances educational paradigm and could be seen as a new source and incentive for improving teacher's skills.

At the same time, it is very important to have a well-developed program shell that takes into account the specifics of the educational material and corresponds to the set goal of training. Using program shell of their own, teachers can edit the electronic textbook, as well as create a new one, filling the template with educational material, how it is shown in the works [19, 20].

Usability principles, which all e-learning resources should meet, are especially important when developing applications for mobile learning (m-learning) using wireless devices (smart

phones, tablets, etc.), which is the next step in the development of distance learning. [21]. Adaptation of electronic applications for their use on smart phones is described in detail in work [1].

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