ForMath
Intelligent Tutoring System in Mathematics

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Keywords: Inteligent Tutoring System, e-Learning in Mathematics, Learning for Visually Impaired People.

Abstract: The paper presents main ideas, aims and implementation of ForMath — intelligent tutoring system in mathematics which is a project developed at Silesian University of Technology. Up till now, the project has contained mathematical problems for engineering students, but in the future it will be adapted to other courses. The proposed platform has both the advantages of e-learning courses and innovative elements such as interactivity (hints or theory on the user's request, suggested individual path, remedial sessions when necessary) and the accessibility of the system for students with disabilities.

1 INTRODUCTION

Modern higher education requires the enrichment of traditional forms of education by attractive, student-friendly and custom offers, fusing and structuring knowledge. Time limited during the course of program studies and the growing difficulties of assimilation of science, mainly mathematics, increase the importance of students' work to which they were not adequately prepared by their high school. This situation raises the need for a multi-faceted tool that will enable the furthest reaching possible contact with the subject. Education using Web technologies allows for greater flexibility and the individualization of teaching, which is a chance to break the barriers of time and social access to university education at the highest level.

In the 1990's, dissemination of the Internet resulted in a rapid development of e-learning, as well as in the teaching of mathematics. Many e-learning platforms have been created, mainly in the United States, but also in Europe. In Poland, with some delay, e-learning is also beginning to play a role in the educational process. Some universities have e-learning platforms where academics place their courseware. Still, not enough attention is given to e-learning in mathematics, although even here the situation is beginning to improve. The project Development of distance learning programs at the course - Computer Science, funded by the European Social Fund (of the Sectoral Operational Programme Human Resources Development 2004 - 2006) exemplifies this tendency. Scientists from leading Polish universities (University of Warsaw, Jagiellonian University, Poznan University of Technology and Warsaw University of Technology) are involved in the project. Courseware for e-learning courses of the main branches of mathematics have been developed by mathematicians at the Jagiellonian University (Ważniak, 2006). Wroclaw University of Technology has also been using e-learning to complement traditional educational systems for several years and is one of the leading universities in this area (Eportal, 2011). Until now, theoretical materials with a set of interactive exercises in algebra and mathematical analysis, as well as repertory of mathematics were implemented.

A very serious problem that touches all technical universities is a poor background in mathematics among students beginning the engineering education. Our experience of many years of teaching was also confirmed by PISA (the Program for International Student Assessment) investigations (Łobos and Macura, 2010). In the case of Poland, there is another factor that intensifies this 'poor background problem'. A part of an adjustment of Polish Tertiary Education System to Bologna Process was a division of engineering studies into 2 cycles. This change has resulted in reduction of the number of hours assigned for teaching mathematics with unchanged tertiary curricula. In such a situation an intelligent tutoring system in mathematics as a part of blended learning seems to be the best solution. Although Silesian

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ForMath - Intelligent Tutoring System in Mathematics.
DOI: 10.5220/0003899901180122
In *Proceedings of the 4th International Conference on Computer Supported Education* (CSEDU-2012), pages 118-122
ISBN: 978-989-8565-06-8

University of Technology has a remote education platform, it is, as majority of e-learning platforms, not interactive. Therefore we have been working out a system of remote interactive education in mathematics and this paper describes the main ideas of our system.

2 AIMS OF THE PROJECT

The project ForMath - intelligent tutoring system in mathematics aims to create an interactive platform for supporting education in mathematics. It can be used by technical students to self-study selected fields of mathematics and expanding knowledge in these fields. The platform is primarily a collection of exercises, in which there is a possibility to appeal to theory (e-books), or get hints on how to solve a specific problem (at any stage of solving the exercise). It contains exercises of varying difficulty within different branches of mathematics. Errors and mistakes made by students are registered, analyzed and then become the basis for preparing individual exercise lists tailored specifically to the student's level of knowledge. In the case of repeated difficulties the student is directed to remedial exercise sessions.

The platform is aimed at different audiences: students, candidates for college, high school students and active engineers. It also enables competency improvement of the young academic teachers. The remote system can be a useful tool in long term learning programme as well. For example, it would be helpful for alumni of other faculties, not necessarily engineering, or any person who wants to refresh or extend his/her mathematical knowledge.

The project also considers the needs of people learning disabilities, particularly blind and visually impaired. One of the research tasks is to interpret mathematical symbols and formulas allowing their reading by blind persons. The remote teaching of blind and visually impaired students is one of the elements of innovation in the project.

By design the platform is built simultaneously in two languages: Polish and English. Courses taught in English are increasingly popular in Poland, where foreign students study as well. An option associated with the English language is meeting the needs of Polish-speaking students studying in English, who have difficulty with assimilating specific concepts and terms (including mathematical), familiarity with which is already required during the first year of studies. This module enables them to listen to terms, phrases and mathematical formulas recorded by the teacher. Not only students will benefit from this offer, but also academic staff preparing to teach in English (especially doctoral students and young assistants).

During the project, pedagogical and cognitive research are conducted, which help in choosing the best learning solutions. This platform exploits elements of the constructivist theory of learning that focuses on student activation and motivation and application of the principle 'the more we know, the more we can learn' by adjusting the difficulty level to the level of knowledge of the learner, and gradually increasing the difficulty subsequent exercises (ImprovingMathematicsEducation, 2006; Lubina, 2005).

In the long term, the platform will be expanded and developed to build an interdisciplinary teaching tool. Additionally, the platform is planned to create modules from other scientific disciplines (e.g. mathematics for economists, statistics, physics, chemistry and mechanics, etc.).

3 COMPARISON OF MATHEMATICAL EDUCATIONAL PLATFORMS

There are numerous e-learning platforms relative to (Karczyński, 2011; Khamsi et al., 2011; Husch, 2001) that offer well-prepared theoretical content (in the form of e-books, presentations, animations or video films) and exercises with ready-made solutions, however we are developing the ForMath system. ForMath has the advantage of implementing a 'check, correct and learn' as you go system. Essentially teaching the student step by step as opposed to only recognizing the end results which other popular systems use currently. There are also systems based on some type of interactivity — they give hints or explanations at some stages of the process of problem solution (Ważniak, 2006; ALEKS, 2011; Bogacki, 2009; Melis, 2011) Additionally some of them provide assessment to the student which motivates him/her to think and work.

An interesting educational software is ALEKS (New York University and University of California) (ALEKS, 2011) which uses flexible and easy to use answer input tools. ALEKS contains topics in mathematics that are lectured at elementary, middle and high schools. The system individually and continuously assesses each student. At the beginning it assesses the student's current course knowledge by asking him/her 20-30 questions. Then the platform offers a choice of topics that a user is ready to learn. After the choice of topic student gets practice problems that teach the topic. All questions are algorithmically generated (so they are unique) and require a 'free response'. Unfortunately, the system does not recognize typical student mistakes. If a student does not understand a particular problem, he/she can always access a complete explanation. The explanation offers also some additional theory if necessary. However, even if ALEKS recognizes that a part of solution is correct, it presents the same explanation as for user who does not know how to start to solve the problem. When the student gives sufficient amount of correct answers to a given topic, ALEKS considers that the student has learned the topic and the student chooses another topic to learn.

Another example is ActiveMath (DFKI, Saarland University) (Melis, 2011) — the intelligent and interactive project. It is a web-based, multi-lingual, learner-centered system for mathematics which contains different topics realized at schools, universities and it is also a good tool for life-long learning. It helps the student in self-regulated learning, can adapt to individual knowledge and personal interests and learning goals. The system also presents information on student improvement. The user of this platform has to fill in the input field with the final result of his/her calculations. In the case of a correct answer, the system informs the student that the answer is correct and shows the complete solution. Otherwise it suggests to try again or to ask for some hints. By clicking several times on the 'hint' button, one may obtain the complete solution.

In Poland, the platform (Ważniak, 2006) is very popular. It was built by a few leading Polish universities and it offers e-learning courses for mathematics (among other) at the level of secondary and tertiary education. The systems offers attractive theory (e.g. with animations), practical tasks, and tests. There are hints on request or, in case of more complex exercises, the plans of solution. It is also possible to see the complete solution. The student can solve the exercise on his/her own, eventually using the hint and then comparing his/her solution with the one presented by the system.

The Infinite Series Tutorial (the part of (Bogacki, 2009) developed by Przemyslaw Bogacki from Old Dominion University), presents a little different approach and for this reason it is remarkable. The student has to choose the answer (i.e. converges absolutely, converges conditionally, or diverges) and then give the reason of his answer (the proper convergence test). Then the system discusses the student's answer, eventually suggests the other possible solution paths. So in the case of an incorrect answer, it is possible to try again or to give up and see the complete solution. The tutorial also collects information on numbers of solved tasks.

Our platform differs from other already exploited ones. In the described systems (Ważniak, 2006; ALEKS, 2011; Bogacki, 2009; Melis, 2011) the student does not know what kind of error he/she has done, only comparing his/her solution with the one given by the system, he/she can find the mistake (only in the case he/she has chosen the same solution path as is given by the system), but it is too late to continue the solution on his/her own. Let us stress the main differences in the approach to solving exercises that appear in our and described platforms. In our system the two main paths are offered. The first one is the path of checking the answer, and the second is the path of hints. The student that needs more help can choose this path of hints and then is lead step by step through the solution of a problem. He/she has to make some calculations on his/her own and then fill in the input fields. The system verifies the correctness of each step, recognizes typical mistakes and then informs the student about his mistakes, gives more hints or explanations. It allows the student to correct immediately his/her error and continue the calculations. In many points of this path of solution there is a possibility to abandon this main path, finish the exercise on one's own and check the answer. In the case of checking the answer, the system examines the correctness of the solution (if possible) by giving some additional questions.

4 IMPLEMENTATION

To implement our system we use LaTeX, PHP, C and JavaScript languages.

4.1 Main Ideas

The main idea of the system is as following: a student logins into the system and can choose a problem to learn. After some sessions, the system would be able to propose some problems according to the difficulties and errors made by the student. To make it possible the system registers the student's activity. One distinguished action is to solve one problem.

A solution of a problem is divided into pages. Each page is presented to the student with contents and some possible actions to be taken. He/she can make a decision: choose some expression from a list or write some number/text to an input field. Afterwards, the student can chooses an action to be taken by clicking on a button, although occasionally there will only be one button present. Each button is related to one or more pages. If there are more pages then the choice depends on the previous decisions made

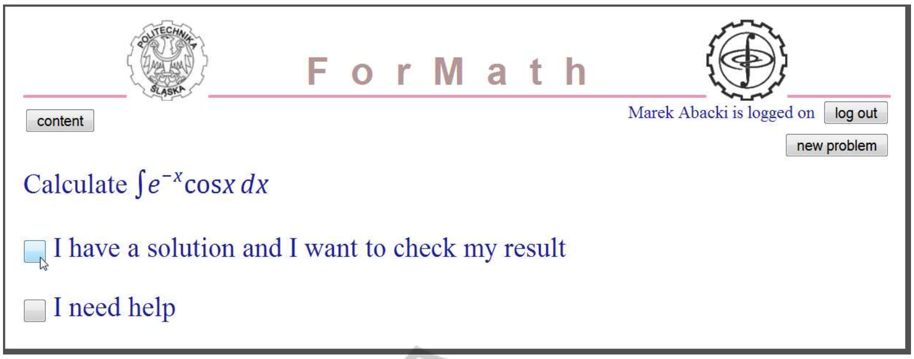

Figure 1: Screen shot of running system.

by the student. Thusly, we can describe the solution as a graph, and the student is moving through that graph choosing a his/her path. Of course, there are some terminal pages, and after reaching those pages, the student may move to another problem or log out.

4.2 Preparing of a Problem

Each problem with its correlated solution is written in one file in LaTeX. We use a dedicated package 'jtr' designed for this system by Authors. Each page is described as an environment 'solutionPage'. The page contains some text with mathematical formulas and lists of choices or input fields. Moreover, this page has an environment 'fieldsOfChoice' with some button description. On the terminal pages there are no special button descriptions although there are standard buttons on each page: 'log out' and 'new problem'.

Images can be put into a page with 'img' environment, and compiled with imLaTeX (a new special program prepared by M. Żabka to simplify drawing function graphs in LaTeX files, now in its' pre-release version) concurrently. The files are loaded into folders and compiled. The compilation uses LaTeX, imLaTeX (with MinGW and GD) and specifically dvipng to translate mathematics to png files. It is possible to use MathJax for equations instead dvipng and get benefits of MathML for visually impaired persons. A system that uses MathML was described in (Tsonos et al., 2009). Eventually we get some PHP files (one for each page) and some graphics with equations and graphs, as well as the pdf file with documentation of all the system pages of the problem.

4.3 Runing the System

Let us look closer at how the system runs. Teachers give the system access code to their students. Thusly after logging into the system, student's activities are saved into data base. The student can choose a group of problems and a new problem in the chosen group or the system can propose a new problem to solve. So a PHP file with the start page is presented to the student. He/she can try to solve the problem or can go to the hints pages which lead to the solution for the problem. Depending on the page, the student reads the texts and if necessary, makes choices or puts a number or letters into the input field. Afterwards he/she should press one of the buttons (or sometimes only one button). The system checks the choices and

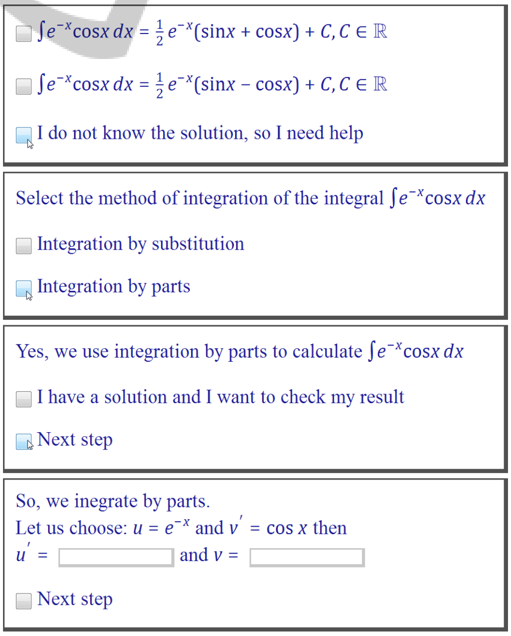

Figure 2: Screen shots, possible steps of a solution.

input fields and directs the student to an appropriate PHP file with the new page according to button descriptions on the source 'fieldsOfChoice' environment. Some JavaScript code controls the behavior of the page. At the same moment, the choices are saved to the data base. Fig.1 and Fig.2 show a sequence of screens, chosen by a student for calculation of an integral (this shows one of the possible solution paths).

There are some standard buttons on each page: 'log out' button, which ends the session, 'contents' button, which presents contents of a problem to the student, as well as a 'new problem' button, which breaks the solution of the current problem and allows the student to choose another one. On the terminal page, only text is present and the student can choose only a standard button.

5 SYSTEM ACCESSIBILITY FOR PEOPLE WITH DISABILITIES

Currently, there are approximately 20 thousand impaired students at Polish universities and over 200 mostly visually impaired at Silesian University of Technology.

Our system and mathematical e-learning content are designed conform to web content accessibility guidelines from the Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C). The ForMath will be accessible for blind and low vision people. All graphical user interface (GUI) components will be alternative accessible by keyboard and assistive devices. The mathematical content (formulas, graphs, etc.) will be described and accessible for screen readers.

We plan to make system accessibility tests with impaired students and pupils from the educational centre for the blind in Laski near Warsaw using mainstream accessibility tools and software like screen readers, screen magnifiers, and Braille displays.

Research with participation of visually impaired persons will be referred to the understanding of mathematical expressions according to applied methods of interactive reading, expression of verbal descriptions and synthetic speech parameters.

The research will be carried out with the participation of both the visually impaired and totally blind and with the different levels of mathematics knowledge. Test materials will be modified based on the conclusions of the analysis previously performed experiments.

Evaluation results will be collected using questionnaires completed both by students and teachers assisting in the research. The conclusions of the accessibility research will be consulted with the experts in the area of impaired persons education.

Research results will help improve the accessibility of the developed system for the needs of disabled people.

6 SUMMARY

The ForMath project is a comprehensive, attractive and student-friendly platform for remote interactive education. Successes of the ALEKS platform (ALEKS, 2011), although it covers primary and secondary education, give hope that the proposed tutoring system will be useful for engineering students.

The interactive platform ForMath will cover tertiary education in mathematics and will contain a repetition module at the secondary level. Our years of experience in teaching students show that such an interactive tool will support the education valuably. The ForMtah is intended to be more advanced than other available educational platforms. The continuous analysis of errors, hints on each stage of solution, different problem solving solutions (when possible), suggesting a personal path of learning as well as the module for blind and visually impaired users are the elements of innovation in the project.

Proofreader: Jerome Keys.

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