An Approach to Combine Learning Entities to Support Mathematics Curriculum in Schools*

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Abstract

Mathematics learning seems to be demanding and time-consuming task for many learners. No doubt, that information and communication technology (ICT) is an attractive tool for students at any level of learning and it can provide an effective atmosphere for understanding mathematics, especially of calculation, shapes, notation, and proof. Question is how to combine mathematics teaching content, approaches, curricula, and syllabus with new media. This contribution presents a multilayered, systematic, complex, mixed approach of teaching mathematics in basic (lower secondary) schools using the Geometer's Sketchpad (Klotz, Jackiw, 1988). Our research has been developed in order to integrate the main factors that can make influence on teaching school mathematics: development of digital content, preparation (adaptation) of learning tools, and networking. To highlight these ideas the paper describes a few years' investigations in three directions: adaptation (and localization) of software (the Geometer's Sketchpad, virtual learning environments, such as Moodle and ATutor), preparation of e-content for teaching mathematics using the Geometer's Sketchpad, and development of learning environment, i.e. establishing networking among teachers and students.

Mathematics teachers teaching in lower secondary school have an opportunity to select suitable ways of using ICT in their lessons. They can use dynamic mathematical examples matching National mathematics curricula, presented on CDs. All these examples are executed using Geometer's Sketchpad software; therefore, students can explore, change the parameters, and observe the dependences of mathematical results. Another suggested way is to use examples, presented in the virtual learning environment course to visualize propositions, to help understanding mathematical symbols and to organize discussions of mathematical topics. The former way is more aimed at doing mathematics, but it requires more time and individual pace. The latter way is universal and is aimed at using networks and learning via collaboration; students can continue exploring the examples at home, to discuss them with classmates and teacher independently of geographical location and time.

More research is still needed (and planned) to obtain a detailed image of applying the approach and its impact on students' learning outcomes.

Keywords

teaching mathematics, dynamic software, dynamic sketches, software localization, networking, virtual learning environment

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1. INTRODUCTION

The constant development of technology has unleashed new challenges in education. Its use is a strong element for knowledge construction support. This makes it possible for the teacher to adopt a new role, as a mediator and facilitator of the student's learning.

Following D. Watson (2003), the teacher often falls between two classifications – that of a conservative resister of changes, and that of a pioneer and interpreter of changes. To be a pioneer researcher should be active player in school and educators society.

In Lithuanian mathematics educators community there are substantially different situation. Teaching mathematics takes strong position in education policy and particularly in school community. Many students and parents consider mathematics knowledge as key success for future life.

However, understanding of teaching mathematics is mostly based on academic approach – this is extremely enhanced by national (state) school leaving mathematics exam which accepts almost every higher school. Considering that, most part of our mathematics teachers can be considered as traditional teachers who are neither "resisters" nor "pioneers".

Traditional mathematics teachers like to teach and train up following curricula and textbooks. For motivated students this is good enough approach – students have opportunity to build up the basics of mathematical knowledge. However, the most part of students try to swot up mathematics propositions (by hiring co-repetitors, etc.) and to pass exams.

How we can make mathematics studies easier for both students and teachers? There are a lot of suggestions falling between deep "rethinking of mathematics" by S. Papert (1980) and gaming (Kahn et al., 2006).

Our developed approach links together a traditional way of teaching mathematics with facilities of new media. Thus, we have decided not to enforce our traditional teachers for sudden changes (and provoking the resistance) but to offer them our help by developing curricula supported and flexible tools.

Before starting to elaborate the curricula supported approach of teaching mathematics in schools, we put a lot of attention on investigation of external factors. First al all, cultural environment plays an important role in teaching any subject, either in informatics, or in mathematics (Dagiene et al., 2006). Teachers and their teaching methods, learning environment and tools are the most important issues for student (Fig. 1).

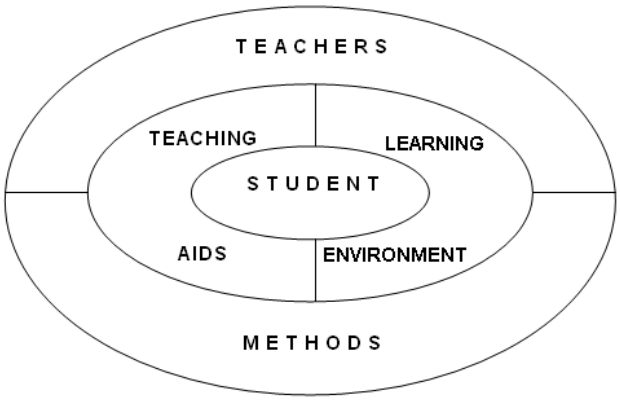

Fig. 1. A framework for teaching and learning using ICT

2. DEVELOPING DYNAMIC SKETCHES AND SCHEMAS FOR VISUALIZING MATHEMATICAL CONCEPTS

The developed approach of improving teaching mathematics consists of three main parts: 1) creating digital material to support mathematics curricula, 2) adapting (and localizing) software and electronic educational aids, 3) developing collaboration and network among teachers and students (Fig. 2).

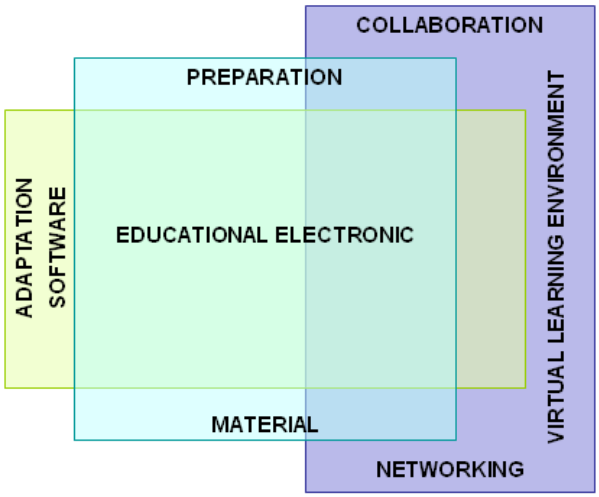

Fig. 2. A multilayered approach of teaching school mathematics

The central part is to provide students with a proper e-material that would fit the National mathematics curricula and Educational standards as well as students and teachers needs. These issues will be discussed in this section.

Widespread known dynamic geometry software, for example Cabri and Geometer's Sketchpad has been developed as a constructivist learning tool. Screen drawings in this software can be purely visual as they can be constructed using in-built tools based on Euclidean geometry. The dynamic geometry environment is completely defined by a set of primitive objects (point, line, segment, etc.) and of elementary actions (draw a perpendicular line given a point and a line, parallel line, etc.). It allows an organised set of primitive actions to be turned into a complex one using macro-constructions. The drawings produced at the surface of the screen can be manipulated by 'grabbing' and 'dragging' around any point having sufficient degrees of freedom (Balancheff, 1996).

Concerning on investigations of C. Hoyles (1998), dynamic geometry software is a powerful tool for proving theorems and propositions. She brings forward an idea about a culture of proving in school mathematics: "… we need to design new learning contexts…".

Basing on these theoretical investigations, a group of researchers has started implementing a set of tools for teaching mathematics in Lithuanian schools. In 2000, the Geometer's Sketchpad was localized and overspread to schools all over the country. In parallel, methodological courses for teachers of mathematics were organized, and a website aiming at providing help on using this application has been developed (http://www.ipc.lt/emokykla/vartai/dinamine_geometrija/index.htm).

Few years later, a study on use and implementation of teaching with computer aids in Lithuanian comprehensive schools was performed (Study…, 2003). The results were disappointing: only 26% of teachers indicated that they were trying to do

something using the Geometer's Sketchpad. Only 7% of students prescribed that they were taught some topics using this software during lessons. It shows usual situation for initiative teachers…

The main reasons why most teachers do not use educational computer means are lack of time for preparation of lessons (drawing sketches, developing scripts, etc.) and knowledge-based mathematics curricula – no references on using ICT.

It is true that many teachers are overcrowded by running lessons and they do not have any free time for experiments using software.

Innovative teachers have developed some sketches, suggested some plans of lessons, etc. It is an episodic experience, some teachers (again, usually innovative), take examples and enrich their lessons. It was clear that we needed to create such a material that all teachers could use it if they wished.

After discussions, an idea of developing dynamic tool for supporting school mathematics curricula was brought. The main goals were to revise some parts of mathematics curricula, to create sketches that are needed according to the National mathematics curriculum and to provide instructions on implementing those sketches in their lessons. It was decided to start with lower secondary school (or upper level of basic school), i.e. 9^{th} grade.

The mathematics curriculum of 9-10 grades was analyzed and the topics that can be directly visualized by the Geometer's Sketchpad were selected (Dagiene, 2006). The following topics were chosen and sets of sketches were developed: linear and quadratic functions, systems of linear equations, similarity of triangles, solution of quadratic equations, circle and circular disk. A year later, similar actions were applied to 10^{th} grade curricula (Jasutiene et al., 2005): graph of a function, set of equations and inequalities, quadratic inequalities, trigonometrical functions of acute angles, exploration of triangles.

All sketches were developed implementing united methodology: 1) a short description, containing the information on what to do with the sketch and where attention should be paid, was provided together with sketch; 2) sketches were dynamic, i.e. it's possible to drag objects, change parameters and therefore the possibility to go back to the initial state always remains; 3) there is a help provided to user and upon the demand the answers can be given as well.

Two types of dynamic sketches have been developed: 1) visualizing theory and 2) visualizing problems. The dynamic sketches that visualize problems have several properties: 1) one dynamic sketch embrace a whole group of problems and 2) in many cases, they widen the problems' conditions.

All sketches are provided on CDs with descriptions that help to use the sketches, theoretical material of a textbook, and recommendations on how to solve certain tasks regarding mathematics' textbook in efficient way (Fig. 3).

In years 2003-2005 more than 800 dynamic sketches were developed: compact disks "Mathematics 9 with Geometer's Sketchpad" and "Mathematics 10 with Geometer's Sketchpad" (Jasutiene et al., 2003, 2005).

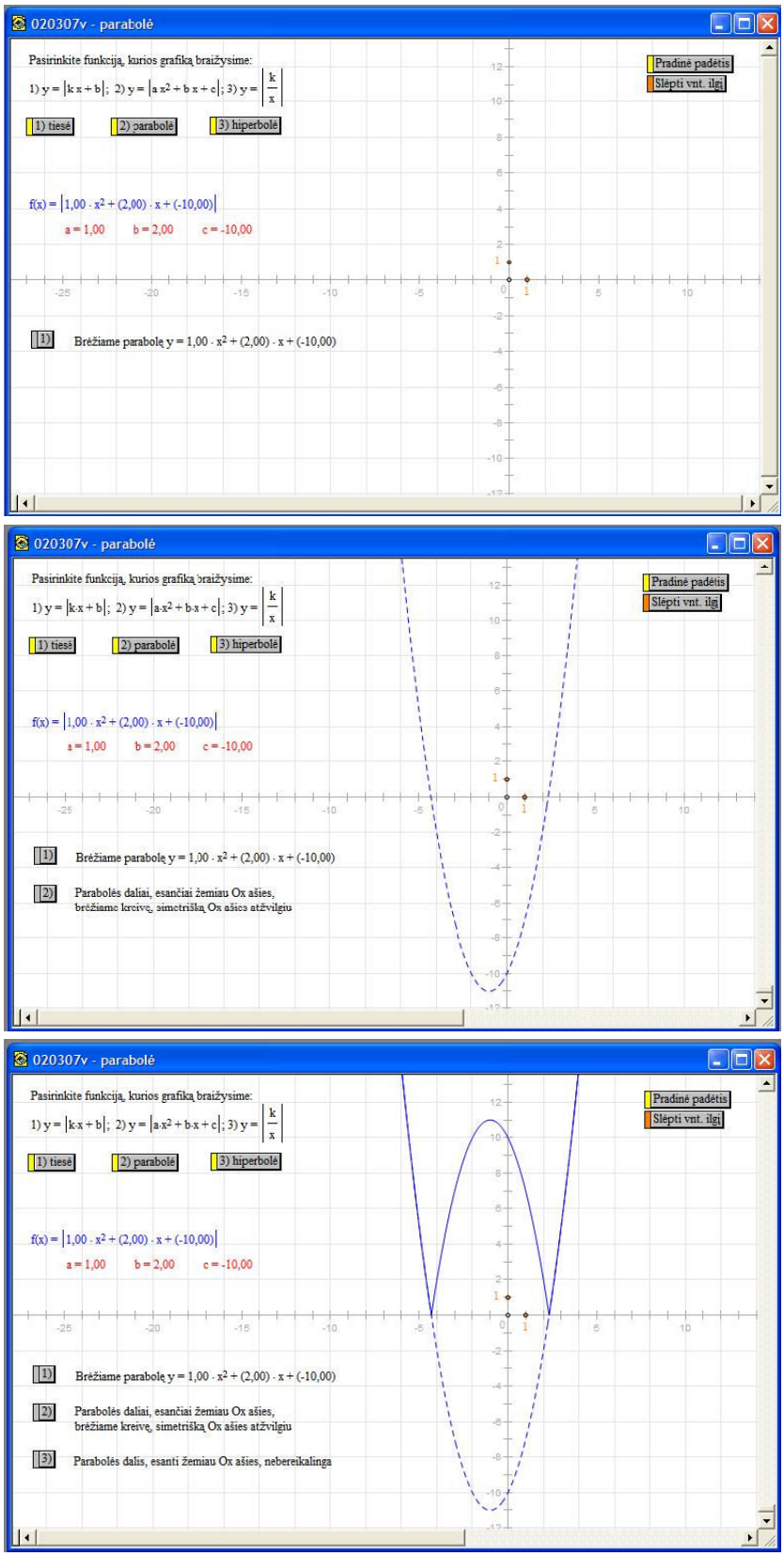

Fig. 3. An example of step by step way for drawing graphical function

Teachers could use constructivist methodology – learning mathematics by investigating sketches and schemas presented on CDs. However, suggested approach seems to be too sophisticated for traditional mathematics teachers. Most

of them do not want to vast time during the lessons waiting for students while they are investigating sketches and making conclusions. They must convey a lot of mathematical propositions and proofs because of national mathematics exam – students and parents trust teachers with good assessment.

3. SOFTWARE ADAPTATION FOR EDUCATION COMMUNITY NEEDS

It is common known that research in mathematics education can become effective in two ways: by implementing its results through the development of curricula, guidelines, recommendations, materials and assessment modes by various media – the technological model of innovation – and by improving of competencies of mathematics teachers. Educational computer aids as well as software for teachers and students play important role in teaching mathematics. Let us discuss some criteria that educational software should meet.

Education should be viewed as culture-undertaken. We need to consider both cultural account of teachers and students using technology and development of culture-based software and educational computer aids.

Software should meet users' requirements. That's why adaptation of software is very important. We will use the term "adaptation" for referencing to software preparation to fit particular group of users. If software is prepared in foreign language, then at first it should be localized. Therefore, we can state that localization is one of the key parts of adaptation.

Localization is especially important for educational software, because: 1) students should concentrate on the subject of learning (e.g., mathematics), but not to pay a lot of their attention while trying understand text written in foreign language; 2) students should see perfect messages, texts and think using correct concepts of the subject (educational software indirectly influences school student's language habits and culture orientation).

Software localization can be relatively divided into two parts: 1) translation of the dialogs, messages, electronic help system and other program's text into Lithuanian, 2) adjustment of program for Lithuanian environment (locale), e.g. adding charsets and setting appropriate locale-specific program settings by default.

According to these requirements, the Geometer's Sketchpad has been localized: all texts and electronic help system are translated into Lithuanian, some mathematical notations are adjusted e. g. comma has been chosen as a decimal separator (in the USA, the point is used), determined Lithuanian formats of date and time.

The Geometer's Sketchpad is localized; however, adaptation to Lithuanian mathematics teachers needs is still not satisfied. The main problem is electronic help system – it should be enriched with tasks that would be more suitable for our mathematics curricula.

If we wish to use virtual learning environment (VLE) for teaching mathematics, it should be adapted for Lithuanian mathematics teachers' community.

These works started in 2006. At first, two open source virtual learning environments (ATutor and Moodle) were selected and localized.

VLEs have many locale-sensitive elements: calendars (first day of a week, date and time formats), numbers (decimal and thousands separators), personal names, telephone number format, composition of strings, etc. Almost all of them were adapted for Lithuanian locale during localization. However, some problems are still unsolved (decimal separator, composition of some strings) because of lack of solutions for internationalization in the original VLE software.

Nevertheless, localization of VLE depends not only on adjustment of its own source code. As far as VLEs mentioned here are web-based, they are connected tightly

with other components at a server side as well as at a client side (Jevsikova, 2006). Server's software and VLE are server-side components. A web browser at the client side provides access to the server. Learning content is placed inside VLE. The server software with its own settings and a web browser form an environment of VLE, and client's operating system is the ultimate environment of all those. Interoperability between those parts is a source of additional problems for localization. For example, it was not enough to set correct date and time formats in VLE's source only. Web server should also use correct locale settings, but server software is not internationalized enough to totally support Lithuanian locale either.

We have localized web browsers (Mozilla Firefox, Mozilla, Opera, etc.) as well that schools use for VLE access (Jevsikova et al., 2004). However, we need more investigations on server software and its locale settings.

Next steps in adaptation of VLE for Lithuanian mathematics teachers community are preparation of educational content for learning and teaching mathematics that could be put inside localized VLE.

4. NETWORKING AMONG TEACHERS AND STUDENTS

Student's needs for communication are constantly rising: they consult with each other via network while prepare their homework, they choose various entertainments on the Internet, they make chats on various topics, etc. It is clear that we are networked society, whether we wish to recognize this fact or not. Access to knowledge is changing. B. Cornu is talking about "collective intelligence" which can be approached through a network of persons with relationships which enrich each of them and make them more efficient, and which help to solve problems (Cornu, 2003).

Both teachers and students are members of networked society and should accept new challenges. Networking enriches the resources available for the teachers; networking enhances collaborative learning and working among teachers and students.

Among the new tools for networking, available for teachers and students, virtual learning environments are essential. That is why the third part of our approach is designed to transform developed sketches and schemas of teaching mathematics into VLE.

We use multilayered approach to meet teachers' and students' needs best, so that it would be suitable for either traditional or innovative teachers.

Methodologically excellently prepared additional e-material for mathematics, 9-10 grades, is split into pieces (learning objects) and is prepared for their use in virtual learning environment. Additionally, dynamic sketches are transformed into static images that can be used for illustration of particular task or topic.

All current Lithuanian learning objects are tagged with metadata according IEEE LOM (Learning Object Metadata) application profile used by European Schoolnet. In 2006, starting implementing common European learning objects repository, LOM application profile has been adapted for Lithuania and online database of learning objects and their metadata has been developed. This approach will help: 1) teachers to find and select appropriate learning objects for particular subject, topic, students' age group, etc., 2) developers of learning content to reuse learning objects in new educational contexts and scenarios.

In our case, dynamic and static sketches with short descriptions, theoretical material of a textbook, and recommendations on how to solve certain tasks regarding mathematics' textbook in efficient way, are enriched with valuable metadata and put into repository. In parallel, having in mind that very few teachers would have enough

time for composing content of learning objects themselves, we prepare ready for use learning courses in VLE Moodle, conforming National mathematics curricula. Schools can either access these courses located on central VLE servers, provided by Lithuanian Ministry of education and science, or import them into VLE located on a local school's server.

The content of courses is categorized by the curricula topics and include short theoretical material, static sketches that can be used for illustration of particular task in class activities or for learning at home, discussion forum and real-time chat where students can consult with each other and with teacher and work collaboratively.

In addition to this, each course has a section of links to dynamic sketches presented as the Geometer's Sketchpad (GSP) files for extra work and exploration. However, this requires the Geometer's Sketchpad software to be installed on a local computer. Therefore, it would be more convenient to transform the sketches into format that supports interactivity and can be implemented directly in the VLE accessing with web browser only, e.g. simple dynamic sketches can be exported in Java using "JavaSketchpad" applet for the Geometer's Sketchpad.

5. CONCLUSION

Mathematics teachers teaching for 9^{th} and 10^{th} grades students have an opportunity to select suitable ways of using ICT in their lessons:

1) They can use examples, presented on CDs. All these examples are executed using Geometer's Sketchpad software; therefore, students can explore, change the parameters, and observe the dependences of mathematical results.
2) They can use examples, presented in the VLE course to visualize propositions, to help understanding mathematical symbols and to discuss mathematical topics.

The former way is more aimed at doing mathematics, but it requires more time and individual pace. The latter way is aimed at using networks and learning via collaboration and is universal; students can continue exploring the examples at home, to discuss them with classmates and teacher independently of geographical location and time.

More research is still needed to obtain a detailed image of applying the approach and its impact on students' learning outcomes.

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Biographies

Valentina Dagiene is a head of Department at the Institute of Mathematics and Informatics and a professor in Vilnius university. She is an author of more than 100 scientific papers and about 50 textbooks. Her main research focus is informatics didactics, implementation of ICT in education, localization of software. She works at various expert groups of the Ministry of Education and Science in Lithuania and abroad.

Egle Jasutiene is an assistant at the Institute of Mathematics and Informatics. She is a teacher of mathematics and informatics at the Vilnius Jesuitical gymnasium as well. She assists in localization of software for schools; uses those and others software in her lessons at school; wrote some articles and books about use of software; made two educational CDs for mathematics with join authors; read some courses for teachers.

Tatjana Jevsikova is a PhD student in informatics at the Institute of Mathematics and Informatics. She is an author (or a co-author) of more than 10 scientific papers as well as methodological works and books in the field of software localization and ICT in education. Her main research areas are (educational) software localization, web-based applications, e-learning, virtual learning environments and standards.