Development of E-Content for Teaching Mathematics

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Abstract

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As stated in numerous papers, teachers of the 21st century should be primarily oriented towards guiding the students through the learning process. In this process information and communication technology (ICT) plays a significant role and more and more e-resources are available. But analysis of the existing resources often reveals that their authors do not use the opportunities offered by new technologies. All too often e-resources are monolithic blocks. This demands that the teacher takes them as a whole, precisely in the order they were written in. Many resource authors namely forget (or neglect the fact) that most of those resources are used with a teacher as the students' guide. Teachers are the ones who should personalize the content towards a specific student's needs and towards the didactical situation in question. Therefore, resources should be prepared so that they can be easily adapted. The selection of proper technologies and tools for managing e-learning content, for creating and modifying e-learning content, is essential to ensure basic support and popularization of e-learning.

This paper, presents guidelines for preparing e-materials based on the idea of a "modular, interactive e-content" concept, using open-source solutions and open standards as well as some projects where e-materials have been prepared primarily in the terms of ease of adaptation, modification and guidance provided for the target group. Some preliminary resources can already be seen at http://www.nauk.si.

1. Introduction

We are witnessing the process of transition into the Information Age Society. The world is changing rapidly, but the educational system is not keeping pace. The currently prevailing educational model is still the same as the one that was established in the 19th century to meet the needs of industrial economy ([12], [1], [4]). One of the basic characteristics of this model is that the teaching process is organized in classrooms with groups of children, who are all taught in the same way, using the same approach and the same teaching materials. On the other hand, we live in a society where everything is individualized and personalized. But still all the students in a classroom are taught in the same way. If we take into account that not all are able to learn at the same pace, in the same environment, following the same learning path, and using the same methods, it soon becomes apparent that an individualized approach is absolutely essential. Just as everything else, education needs to be customized.

We will not discuss different opinions regarding organizational issues of the educational process such as: is the existing course model still sustainable, is the formal division of students into different classes of equal size and age still appropriate, and other similar issues. Instead, we will focus on an issue that is crucial to the development of education as well, although it may not possess the immediate media visibility and is consequently not as highly politicized. The focus will be on the teaching materials used in the educational process. The two main challenges are to

provide support through teaching materials that will establish the appropriate role of technology and to realize the requirement for the individualization in the educational process.

The role of the teacher in the 21st century has been redefined. There is less and less "ex cathedra" lecturing. As stated in numerous papers and books ([10], [5], [2]), this new role means that teachers at all stages of education should be oriented towards guiding the learner through the learning process. They are no longer "walking encyclopaedias" or "talking textbooks" ([11]) – this role has recently been successfully replaced by the internet. Instead, teachers are planners, strategists, researchers, pedagogical diagnosticians, work organizers, counsellors, tutors, etc. Their main task is to guide a learner through pieces of information (teaching resources) towards knowledge, with the requirement to concretize the educational content and adapt it to the interests and abilities of a particular learner ([9]). Students are different, but the existing educational practice and the materials that support it are changing very slowly. Schools are still using materials developed to teach the students of decades ago. However, the students of today are actually very different from their predecessors in the way they think and work ([8]). Thus one of the key questions in the process of reinventing the teachers' role is: **In this phase of transition towards the redefined role of the teacher, are there any resources available that support the teaching process?**

2. *Organizing and using teaching resources*

The phase of organizing teaching resources which are to be used in the teaching process is one of the fundamental steps in the learning process. Here the teacher actually makes the decision how the learning process will be performed. In this step several factors, such as the class we are teaching, the pedagogical situation and other numerous issues that influence the learning and teaching process are taken into account. Here the appropriate approach towards technology to be used is extremely important. Its importance is neatly summarized in the Teaching Matters booklet: A handbook for UTS academic staff from Institute for Interactive Media and Learning, University of Technology, Sydney [7]. "*The most effective kind of learning experience is determined not by the technology available, but by considering what is most appropriate for the students, the subject and the learning objectives and then selecting the most appropriate technology to use, be it a book, an online discussion, a multimedia simulation, or a workplace experience.*"

It is very rarely that a teacher makes a decision to take a particular textbook and use only that particular book from the first page to the last one. Teachers usually choose combinations of different materials. So the final outcome of this organizational process is a pile of resources. As the teacher's role is to be the guide, he or she also provides prescriptions that may go somewhere along the lines of:

- Start on page N_1 of textbook X.
- Follow the explanation and then turn to page N_2 in the workbook for exercises.
- To see examples of how this can be used in real life situations, see handouts you were given.
- Then continue on page N_3 of textbook Y.
- ...

It is either that, or the teacher uses technology to "glue" resources together; from simple accessories like sticky tape and scissors to more sophisticated ones like the Copy and Paste functions of the software when resources are available electronically.

Only rarely is a teacher in a pedagogical situation where there is an "ideal" resource that can be used without any change whatsoever. Why is that the case? The reason is quite simple: Authors of resources (workbooks, textbooks for example) envisage a hypothetical (ideal) pedagogical situation with hypothetical students. The actual teaching process, however, is always at least slightly different and never exactly the same as the hypothetical one the author had in mind. Since a good teacher should use resources in the most appropriate way, he or she is forced to combine and adapt the resources.

3. Concerns when using ICT resources for teaching

What about e-resources, e.g. resources that assume the use of modern information communication technology (ICT)? As more and more teaching resources are available in this form, we should expect the teacher's task in managing the resources to be getting easier. Unfortunately, this is not usually the case.

There is namely a conflict between the possibilities technology provides, the teachers' wishes and the e-materials available. All too often the "modern" e-resources are monolithic blocks (or at least their main parts are), constructed in the way an ordinary textbook or workbook would be. This demands that the teacher takes them as a whole, precisely in the order they were written in. Many projects focusing on the development of e-resources are complete portals where navigation through the resources must be followed in the exact way the author(s) had imagined. Teachers are facing web portals with embedded flash animations, heavy and sophisticated usage of frames, applets without the source which are impossible to adapt, etc.

Too many resources are created from the point of view that the student is the final and independent user, where the author prescribes the way the resource is to be used. However, students are not usually exposed directly to the task as there is a teacher present in most cases, and that teacher is then the one who serves as an intermediary between the task and the student. As the teacher's obligation is to adapt the resources to the learner's needs, this particular teacher is actually in a worse situation than when using a classic "paper based" resource. The reason behind this apparently paradoxical situation is that the e-materials in question are often so technologically "closed" that there is no such tool as scissors that are used when recombining classic, printed materials. Teachers often encounter problems if they want to use only a part of the content, not to mention the fact that it is not usually possible to adapt the materials at all.

The process should be changed from building e-resources in an unchangeable way to the resources being prepared in such a way that modifications are easily accomplished. If an analogy to toys is used – a ship made of Lego® bricks has a far greater pedagogical potential as pre-constructed, unchangeable models.

4. A different approach in math resource development

As mentioned before, the pedagogical situation the author envisages does not always fit its purpose. Let this be illustrated with a simple example. As part of a teaching resource we (as authors) want to illustrate the Thales' theorem and to construct a suitable show of the construction steps supporting the theorem. Several possibilities exist; three of them are depicted in the following pictures

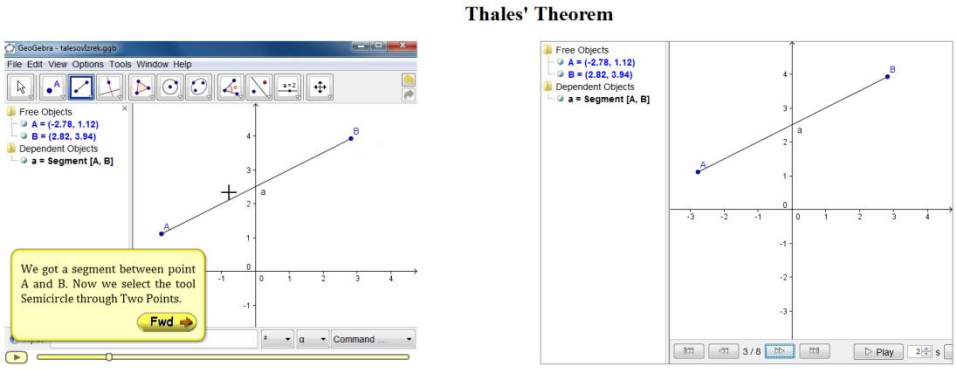

Figure 1: Video instructions and a GeoGebra Applet with construction steps.

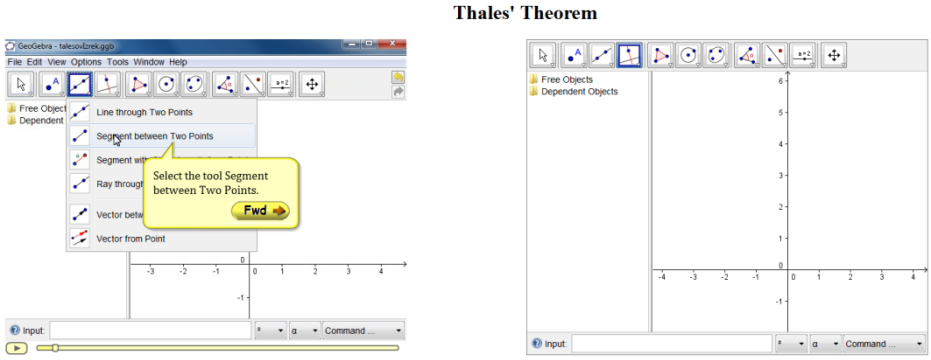

Figure 2: Video instructions and a GeoGebra Applet for practice.

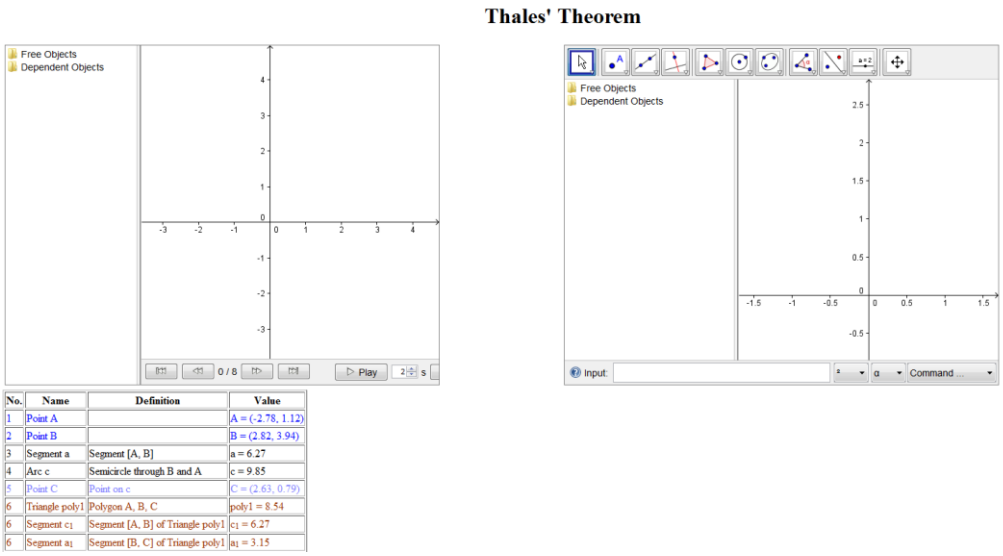

Figure 3: A GeoGebra Applet with construction and a GeoGebra Applet for practice.

Even more examples of illustrating the Thales' theorem were prepared, using other tools as well (Cabri Geometre, C.a.R., or similar). Each of the approaches proposed has it merits and drawbacks. As we were supposed to have only one such resource, we were faced with a tough decision: which one of the proposed solutions should be chosen. When a group of teachers were asked which one was the most useful for their teaching and should thus be chosen for our resource, the responses

were not uniform at all. As can be expected, the teachers rated the usefulness regarding their typical pedagogical situation. As these were different, so were their opinions.

The question that arises from the example above is evident immediately. Who should decide on "the proper" part of the resource and how is this decision to be implemented? Is it the author or a teacher or even the end user (a student)? Should the part be fixed or should it allow personalization? Is not the teacher the one who comes into direct contact with the student and therefore the one who should decide which materials would be appropriate for the situation given? So why not use the possibilities offered by new technologies and at least give the teachers the chance to adapt the materials to their and their students' needs.

The teacher is the one who must adapt the resource to a concrete teaching situation and to a particular student. The author creates a resource for an ideal situation, however, the teacher teaches in the "real world". Therefore, e-materials should be flexible. They should enable the teacher to change and recombine them. Nowadays, there are technical means that enable such combining. The teacher should have control over the resource. The author should merely be an initiator of the resource in various forms. Therefore e-materials should be constructed as a combination of building blocks that can be recombined.

Our final decision in the example mentioned above was to choose a model, but provide instructions for interchanging building blocks with other ones (provided as add-ons). Everything has been technically realized in such a way that changes are easily accomplished. In this way far more possible pedagogical situations have been covered and the teachers are allowed to fulfil their role as the student's guides.

The selection of proper technologies and tools for managing e-learning content and the establishment of a user-friendly and easy-to-use environment for the creation and modification of the content are essential to ensure the support and popularization of e-learning. The possibilities that new technologies offer should be exploited to (at the very least) give the educators the chance to adapt the materials to their own and their learner's needs. Therefore, a new concept of how to create e-learning content evolved; namely, by "putting the teacher back into the game". This means that lessons should be made of small learning blocks or, as they are called, "knowledge objects". The primary concern of the authors of e-materials should be to offer:

- basic building blocks,
- pre-combined models (that can be corrected or recombined) and
- plans for the construction of new models.

What represents a basic building block certainly depends on the particular learning situation. It can be a short explanation of a concept, a picture, an animation, a short video clip, a question, an exercise, an interactive game, etc. But there is more. The basic building blocks themselves should offer the possibility of being adapted, too. The teacher should be able to reword a question, change the explanation slightly, add a link to another material on the topic in the feedback, and so on; in short, the teacher should be able to improve (to adapt) the building block itself.

The main idea behind the new concept is that the teacher will take teaching materials from online sources available already and then change and combine them to make a lesson that suits his or her style of teaching and/or the current situation in the classroom. As he or she will be using the resulting content in different situations, the underlying system will offer different ways of export, which conform to the most important up-to-date standards and possible pedagogical situations. In

numerous occasions the teacher perhaps needs the content to be on paper, in another situation that same content should be part of a virtual learning environment, in yet another set of circumstances a standalone web page on a mobile phone. Of course all formats do not bear the same functionality. But the content is the part that is the most important. And teachers are the ones who should decide whether a certain function is needed at a certain time or not.

If our ideas were to be summarized, two major points can be stated:

- **The teacher must be in control.** Every teacher has a unique teaching style. What is more, the way a teacher teaches differs from class to class. Therefore learning materials should not be limiting and prescriptive as to the way they can be used. The author should provide a sample of the resource, but this resource should be easily deconstructed, adapted, changed. And if the teacher believes that the order of the given answers in a task should be different, that should be as easily accomplished as possible.
- **An e-resource should only be a sample combination.** A pre-constructed resource should only present one of several patterns of usage. This construction should show one of the possible uses of atomary (basic) building blocks to construct a whole. However, the complete resource should be available in a technically easily adaptable way.

5. A practical example

In this part we will show how the concepts described above should be used in practice in preparing modern, high quality mathematical educational e-materials. Some preliminary results can already be seen on the http://www.nauk.si portal or in the http://gradiva.nauk.si repository.

Motivated by interviews with numerous teachers, who expressed their wish to be "in control" of the resources and following the analysis of the before mentioned research, an informal research group called NAUK was established. The word "nauk" means "advice" or "study" in the Slovenian language, and it is also an acronym for NApredne Učne Kocke – Advanced Learning Blocks.

One of the aims of the group was to create an innovative web-based application for managing and serving e-learning content tailored to the needs of teachers. Instead of the author-learner relation, the three-way author-teacher-learner relation has been introduced. Teachers can choose between various animations, worksheets, question banks, dynamically generated questions and thus develop their own learning path. Each resource is supported by a brief explanation and a short preview. All resources are also freely downloadable in various formats.

The NAUK group is currently involved in several projects in progress that strive to make e-learning content for high-school mathematics, elementary- and high-school physics, elementary-school logic, all pre-faculty levels of computer science classes and faculty-level mathematics. Creating a repository of e-learning content – see Figure 4 – from four different fields of knowledge (on different levels), promises a greater range of users but also demands a greater responsibility from the group.

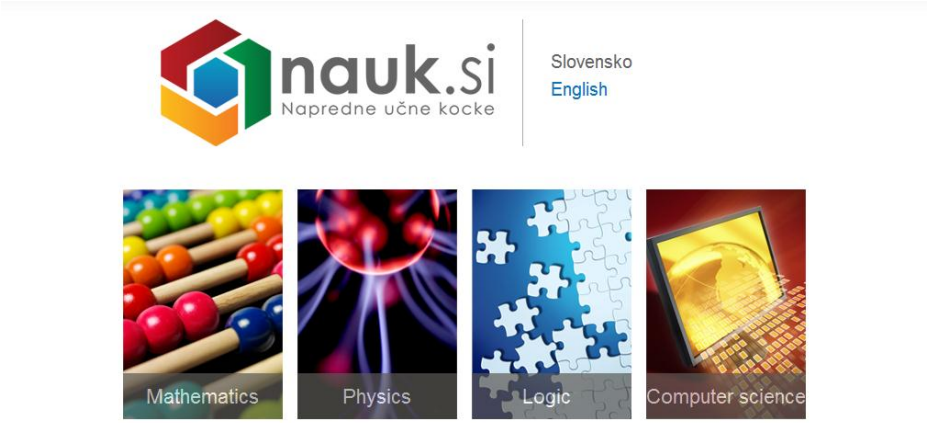

Figure 4: The entry page to the NAUK repository

The basic idea of NAUK's approach can yet again be easily compared to the popular Lego® bricks; see Figure 5. E-learning material should be built by creating: basic / simple building blocks, predesigned e-learning material which can later be customized, by using instructions for preparing customized e-learning material combining simple building blocks.

Figure 5: Analogy of the NAUK learning blocks paradigm with the LEGO® bricks (Sources: http://en.wikipedia.org/wiki/File:Lego_Color_Bricks.jpg, http://commons.wikimedia.org/wiki/File:Lego_Creator_4838_-_Mini_Vehicles.jpg, http://commons.wikimedia.org/wiki/File:LEGO-beschrijvingen.JPG)

Since the process of creation and modification of interactive elements should be as simple as possible and at the same time provide automatic – computer based manipulation in the not so distant future, the NAUK group decided to use a similar mark-up syntax as that used by well-known wiki environments, e.g. by Wikipedia. Of course, NAUK's syntax contains additional tags, thereby enabling the addition of various multimedia elements and links between existing e-learning materials, adding responses to user input, etc. An example of the syntax is shown in Figure 6.

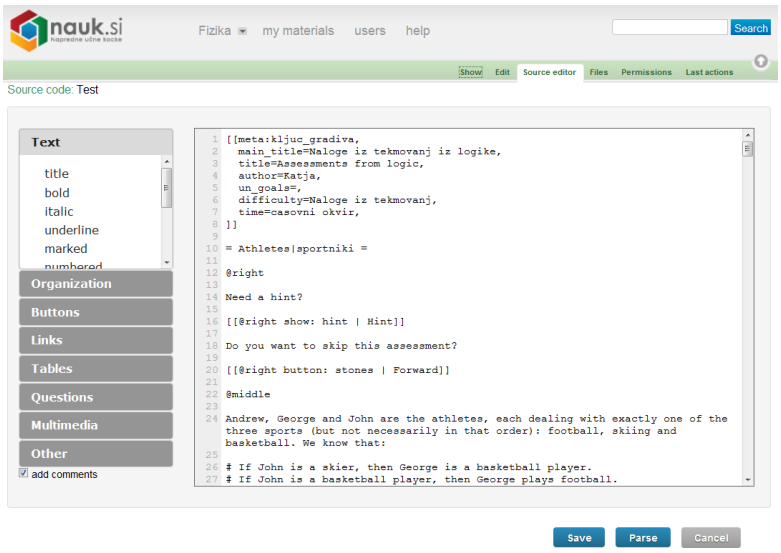

Figure 6: Example for the wiki-like syntax

By using the NAUK services the teacher is able to take an existing content from the repository, adjust or supplement it, and publish it immediately in the repository. The other important functionality of the repository is the possibility of exporting the content in the SCORM or Common Cartridge standard. The teacher is able to use the e-learning content exported in SCORM in his/her own virtual learning environment. Thus, by using the NAUK export service the requirement for technical knowledge of the author (teacher) becomes obsolete.

The teachers do not have to take care of the appearance (representation) of their teaching material, but only of the content, interactivity, multimedia add-ons and their place within the learning path of the e-learning material. An example of such an exercise can be seen in Figure 6 and the automatically generated presentation in Figure 7. The presentation is generated automatically when the teacher enters the type of items that he or she wishes to include, e.g. some text, a matching type question, a hint button with text for the hint and a jump button.

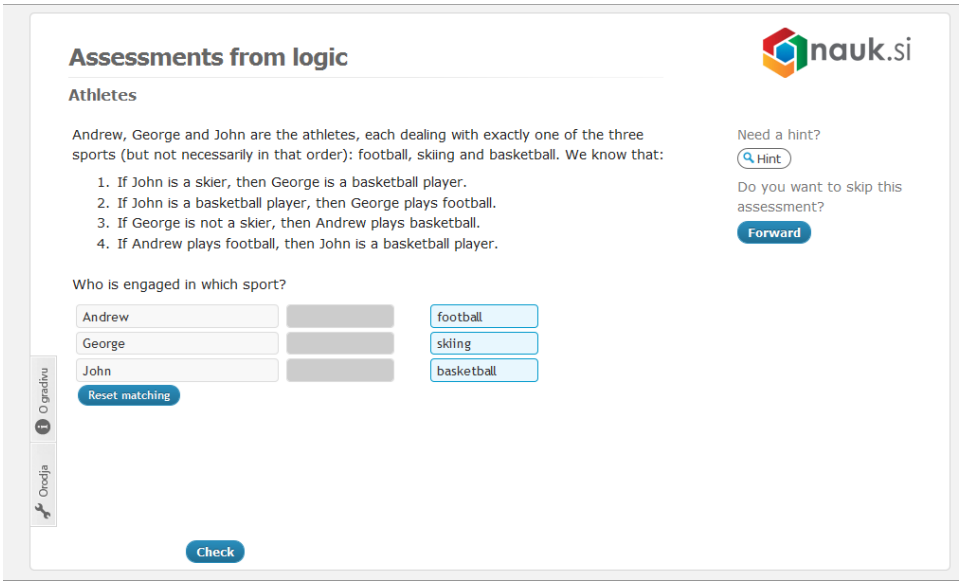

Figure 7: An assessment in logic built with wiki-like syntax.

6. Further work

Informal interviews with many teachers as well as the first reactions of users have shown that the concepts and solutions similar to the one described above form a valuable approach that will provide higher quality teaching and learning. The NAUK project group determined that it is wise to invest further efforts in upgrading the concepts demonstrated. Therefore the project group intends to build a web based community, where it will be possible to give opinions and comment on the existing materials and grade them.

Since word of good ICT solutions in the field of education spreads quickly ([3]), all members involved in the NAUK projects hope for the success of the solutions and concepts presented, but are also aware that further development in this area relies heavily on the satisfaction of another group of end-users – the students.

7. Conclusions

Teaching resources should be designed in a flexible way, supporting appropriate use of different ICT tools. An appropriate view of e-resource preparation should include the whole process of their design, usage and modification. Teachers should have the possibility to adapt resources respecting the knowledge, skills and needs of their students. They have the right to and at the same time want to be included in the e-learning process when preparing the content for students.

8. References

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