

Visualization in Teaching Computer Science and Mathematics

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Abstract: In this article we present several possibilities of the use of educational software for visualization in teaching computer science and mathematics. The ICT help to achieve a higher quality, expertness, and effectiveness compared to the teaching resources and tools, which have been used until now. We show some examples of computer aided education in subjects of mathematics and computer science. This teaching is connected to the goals described in the new Slovak Curriculum ISCED 2 for education of these subjects at the secondary education. The place of different tools, such as Imagine, Baltie, or GeoGebra as a tool for teaching and learning will be discussed. The relationships between mathematics, informatics, and other subjects, which are supported by educational software, are a very important part of integration of ICT in education.

Keywords: visualization, educational software, teaching computer science, teaching mathematics

Introduction

The information and communication technologies (ICT) bring new opportunities to make teaching and learning more effective and attractive. The computer is used not only to review (practice) the study materials, to create and enhance the skills and habits for the algorithmic solving of different tasks, but it can also significantly facilitate the development of student's individual work through the individualization of tasks. It is possible to assign each student with a task of various difficulties and with different time amount, which is needed for its solution. It is also possible to use computers while solving application tasks from the actual practice, which are usually difficult because of time consuming numerical computations. These computations can be carried out by the computers with

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the appropriate pedagogical software, whereby the chances are developed, which aim the education at understanding of discussed concepts together with their utilization in practice. The concepts can be actively sought by students, whether through the individual or group work.

An important advantage of use of ICT in mathematics and informatics' teaching is a reinforcement of a role of visualization. Its importance can be seen especially in the following aspects (Gunčaga, 2008):

Firstly, the visualization can often provide a simple and effective approach to the discovering of the results, to the problem-solving, and discovering of the structure of a model itself, whereby students get new information. The visualization of relations and causalities within a single model allows us to derive new results in other fields and areas of science through models, which are isomorphic with the existing model (completely or only partially).

A second aspect results from the necessity and importance of exploitation of various teaching styles within the teaching process. A geometric approach, which leads to the acquisition of skills and knowledge through the graphical objects and visual geometric realizations, can be an appropriate supplement (although not an unconditional basis) of verbal-logic style, which is often preferred by the teachers.

Last aspects are the actual trends of the study of models that can be realized through the educational software (Computer Algebra Systems, Dynamical Geometrical Software). These systems help to easily discover the universal coincidences and rules followed by the model, what is often realized at the expense of decrease in the common algebraic thinking. However, they allow to dynamically change parameters of image (graphs of functions, geometric shapes), thus making it faster and easier for the students to find dependences while adopting new knowledge.

Concerning these relatively new challenges but also the unprecedented opportunities of ICT, the requirements for training and practical work of teacher are changing. It is necessary for the teachers to be trained in the spirit of these new tasks as soon as in their teacher's education. They have

to know not only the new methods of using ICT for teaching, but also how to achieve the objectives of their subjects.

Musa et al. (2013) showed that an important aspect of computer aided education is the computer animation and visualization. Within the framework of science education, it can bring forward the following points:

- Can be considered as one of the main tools available for teachers to use to promote effective learning nowadays.
- An effective approach while looking for the results, solving the problems, and discovering the very structure of the model.
- A visualization of relations in the model allows an inference of new results in other areas and fields of science subjects at school.
- Support of digital competences and basic competences in science and technology.

The pedagogical software is a tool for learning, exploring, and experimenting for students. A student needs to understand the issues and create the correct ideas of the used concepts. Otherwise, he is unable to understand the ideas that are based on these concepts and apply them in practice. In the science it is not possible to succeed with formal know-how obtained from the superficial, mechanical learning by heart.

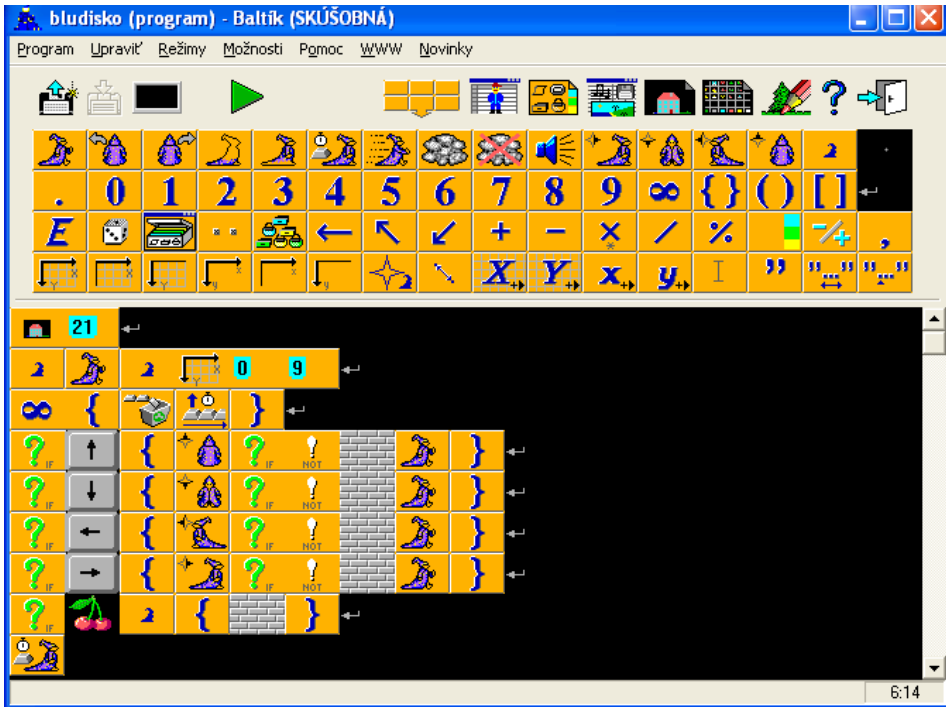
Educational Software

In this section we briefly introduce the educational software, which we use in our work with pupils and university students - future teachers for secondary education.

The first example for educational software is Baltie (<http://www.sgpsys.com/en/whatisbaltie.asp>). Baltie is an educational graphic oriented visual programming tool for kids, children, youth, and adults. Baltie is also a name of the main character of this software - a little wizard keen to execute miscellaneous commands and to conjure pictures (tiles) in his environment (fig. 1). With Baltie's help, children will quickly realize computer program. Baltie can be used also for exercising logical thinking. It makes no demands on child's knowledge, only requirements are playfulness and imagination.

Gülseçen et al. (2013) showed, that children programming environment is a way from the first touch with the computer, through the understanding of its working, to mastering the most important methods of software creation.

Figure 1: Environment of software Baltie

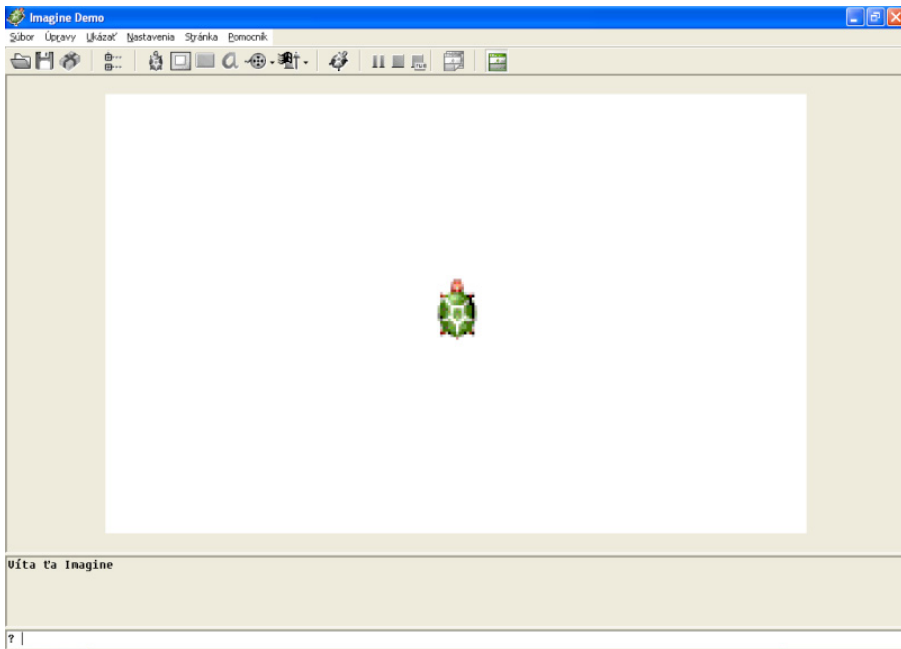


The second software, which we will present, is Imagine. Imagine (<http://imagine.input.sk/>) originated in 2001 as an indirect successor to the Comenius Logo. It is an object language driven events. “The hero” (a main character) is a turtle, which can change its shape, draw to the area. The aim of the authors was to create a modern programming environment that is easy to control for an experienced user, but also for an absolute beginner – a pupil at primary and secondary school. The advantage for younger pupils is that they may not write a coherent program that focuses on the solutions of all possible situations, but many small sub-programs, sometimes referred to as one statement, that will be automatically called

during various events, for example a mouse click, drawing, collision with other objects, etc. It is possible to define different subroutines for the various objects and their events. Environment has an integrated simple editor background graphics, multimedia, and internet (fig. 2).

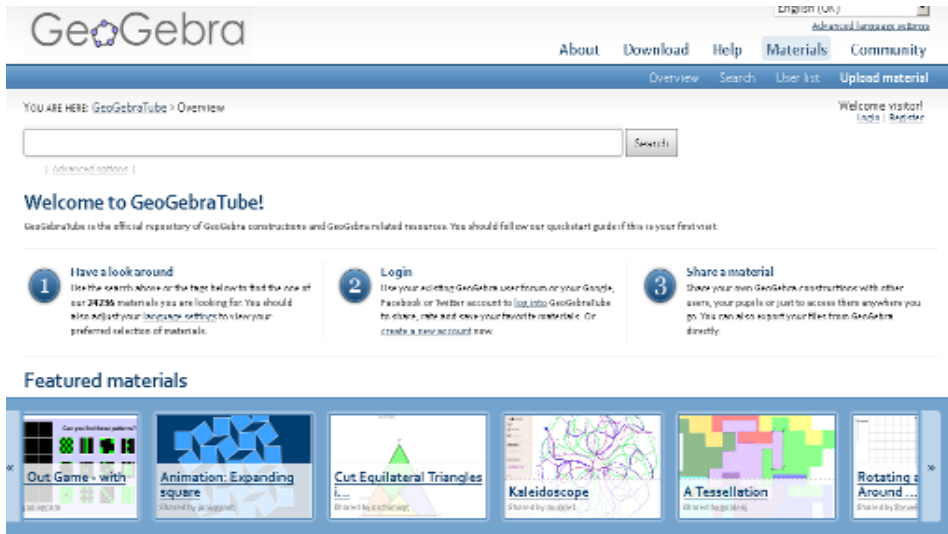
An interesting new feature is the possibility to publish the projects on the Web: using the Imagine plug-in, we can run the finished projects from the network in an Internet browser. The component of the Imagine is also a bitmap editor that is used to prepare the images, especially for the LogoMotion shapes of turtles, but also to create great-looking animations.

Figure 2: Imagine - basic environment



Finally, software GeoGebra connects features of a computer algebra system, dynamic geometric software, and a spreadsheet. Its big advantage is a user friendly nature and possibility to create dynamic HTML websites with interactive pictures (see Hohenwarter & Lavicza, 2010). Materials developed by GeoGebra can be found on the website GeoGebra Tube or on the older website GeoGebra Wiki.

Figure 3: GeoGebraTube (<http://www.geogebra.org/>)



The latter contains also some materials created in multiple languages (<http://www.geogebra.org/>). These materials and applets use the interactivity and dynamic character of software. Moreover, the materials follow different topics, for example calculus and geometry (e.g. topics of an exponential and logarithmic function, cube or hexagonal prism, constructions of triangles, parallelograms). Naturally, the website contains also materials for teaching natural science and computer science (fig. 3).

Visualization of Plants

We can use some type of educational software for visualization in the science education. Natural phenomena can be represented by students through computer visualization. Louca (2005) showed that the objective is to help students to learn with and about the models and modeling in science. Modeling is a reasoning skill, which refers to development of the ability to construct and improve models. We solve the tasks, which require the work with different representations of a given problem.

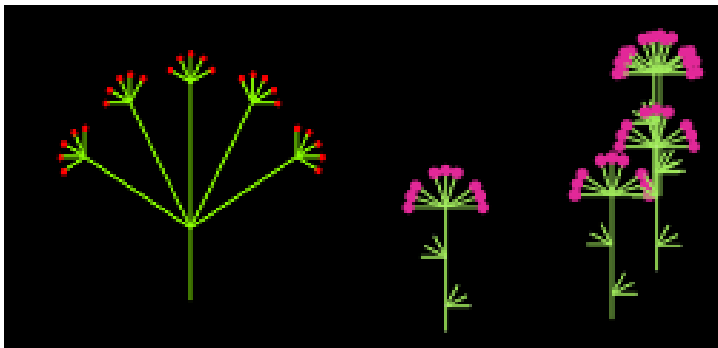
We designed teaching of modeling of plants in secondary education in the intention of obtaining of motivation in science education and modeling

knowledge and skills. We connect subject mathematics, computer science, and biology. The aim of lessons is that students using information technology tools have to create a simple model of the real world (Kelemenová, 2005). We have examined its conjunction with learning algorithms and programming.

We realized the experimental teaching through the lessons of algorithms and programming at the first grade of a high school (Majherová, 2009). Pupils created a simple model of a flower (see Majherová & Gunčaga, 2011). By the example of a plant's model, the pupils have understood the concept of the model and principle of its creation in computer - visualization. By the creation of the model, pupils applied also knowledge from geometry and biology (mutual relationships of geometric shapes, morphology of plants, etc.).

Pupils used a turtle graphics in programming environment Baltie 4 C#. Plant's model was created in the coordinate system with the help of procedures for the simple orders of movement forward, left and right. As a pattern of the originals, we have used the pictures of various types of flowers (fig. 4).

Figure 4: Models of flowers



By the creation of the plant's model we have determined following educational goals, which were assigned the code based on their location in hierarchy customized by revised Bloom's taxonomy by Anderson et al. (2001). (see tab.1).

The Knowledge Dimension	The Cognitive Process Dimension					
	1. Remembering	2. Understanding	3. Applying	4. Analyzing	5. Evaluating	6. Creating
A. Factual knowledge		X	X			
B. Conceptual knowledge		X	X			
C. Procedural knowledge		X	X	X	X	X
D. Metacognitive knowledge		X	X	X		

Table 1: Dimensions of the education goals in the creation of the plant's model

During the education, the students have obtained the following knowledge and skills:

- To design graphic model of the plant based on original – that means in customized Bloom's taxonomy to understand and apply real, conceptual, and procedural knowledge (code **A2, A3, B2, B3, C3**), and also metacognitive aspect of the connection of knowledge from several subjects (**D2**)
- To use the instruction of the turtle graphics for realization of the plant's model – to apply conceptual and procedural knowledge (**B3, C3**)
- To use the element of the casualness by the modeling – to apply conceptual and procedural knowledge (**B3, C3**)
- To realize graphical model of the plant on the computer – to create (**C6**)
- To change the properties of the model – to apply and analyze the knowledge (**C4, C5**)
- To use variables, cycles, methods in the program – to apply procedural knowledge (**C3, C4**)

- To create the project Modeling in informatics – to create, apply, and analyze relationships among subjects (math–biology–informatics) **(C6, D3, D4)**

Within the frame of cognitive process, a student should obtain competences in all areas from memorizing up to valuation and creation of the new products. By qualitative analysis of pupil's programs and projects, we have found that all students have reached the levels of memorizing, understanding, application. Part of them has reached knowledge by analysis and some of them have showed level of independent analyses, evaluation, and creation.

Logic Game in Teaching Computer Science

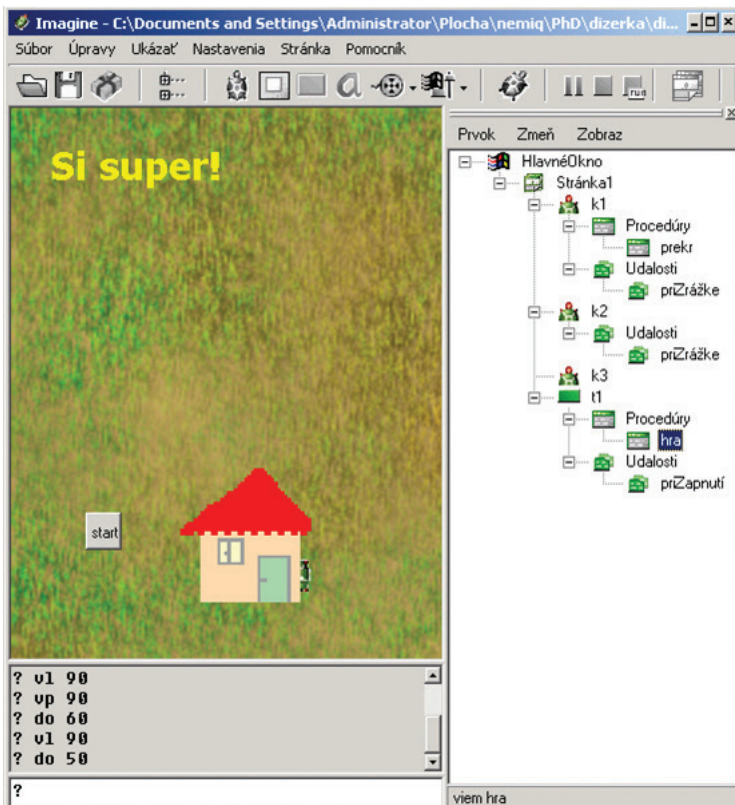
Prensky (2001) compiled several key characteristics of the computer games such as management of certain rules, definition of goals and ideas, results and feedback for the players, responses to conflict / competition / challenge / opponents, interaction with other players or the computer, and the representation of the story.

We often meet with the misconception of parents and sometimes even teachers that the games (so much fun) and learning simply cannot go hand in hand (Círus, 2010). If we learn about something important, which we will need later on written works and in the oral replies, we must not entertain and we must not simply be in a good mood.

Using just the dimension of learning in the computer games is well designed and interesting to enhance motivation from: thanks to that learning becomes fun, because children want to play themselves. This kind of education in general does not feel like a duty. Facer (2004) argues that a key factor in learning through games is developing the skills. Among the most important skills here include communication and work in a team, problem solving, and developing logical thinking and mathematical skills by special kinds of games. The success depends on the correct use of logical reasoning in a logical game. Logic games are based on logical procedures that need to be applied. Such games develop logical thinking, force the player to think over each next step creatively.

We show one logic game which we use in teaching a thematic unit “Algorithms and algorithmization”. It was conducted at the St. Andrew High School in Ružomberok for the first grade students. One part of the experiment was the introduction in the teaching of online games, custom games, and projects, which were programmed in the programming language Imagine, as well in the creation of student’s Imagine projects. The game was used for learning the basic commands in the programming language Imagine. There are two visible turtles on the desktop, one turtle is hidden. The first turtle has the shape of a small house. The task of the player is using basic commands: left, right, forward, or backward to get a second turtle in a small house (fig. 5). Although the principle of the game is simple, it takes the pupils’ attention. The pupils create a simple game themselves.

Figure 5: Example for the Imagine games



The introduction of logical tasks in the teaching process has a positive impact for the pupils, particularly, on the interest of the pupils and their subsequent tasks of joy. When pupils learn, they are more successful in resolving. Tasks do not constitute a stress factor for pupils, but they represent a form of entertainment. The ability to think logically and algorithmically will be gradually developed by pupils.

The Geometrical Tasks in GeoGebra

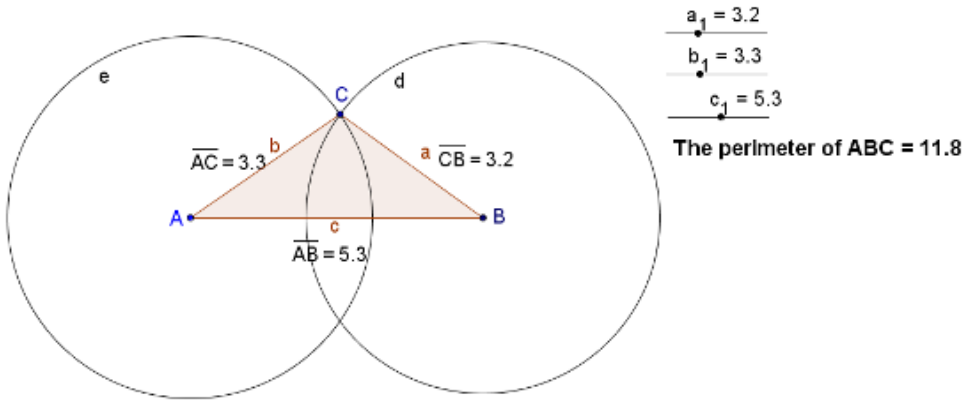
The new Slovak curriculum ISCED 2 for lower secondary level includes multiple educational competencies for teaching of geometry. The pupils should be able to construct and describe the basic geometrical figures or to specify properties of their particular elements (e.g. a relationship of sides, diagonal, triangle inequality and so on). They should know basic geometrical transformations, axial and central symmetry, the relationship between figure and its picture in transformation, and how to analyse and solve application of geometrical tasks with a use of mathematical know-how (see ISCED 2 (2010)).

Since the new curriculum in mathematics in Slovakia has been introduced only recently, textbooks satisfying these new rules are still missing. The materials from Wiki can help teachers to educate pupils in these new conditions. During this process of development, our aim is to cooperate with the teachers at schools, pupils and university students – future teachers. Some examples can be also found in works by Duatepe (2013), Billich (2008), or on the website <http://geogebra.ssgg.sk>.

Now we can present some works, which are applicable in teaching of geometry. These examples have been prepared by students from the training programs for teaching of mathematics at secondary school. The materials are focused to explain new notions with support of interactive GeoGebra applets.

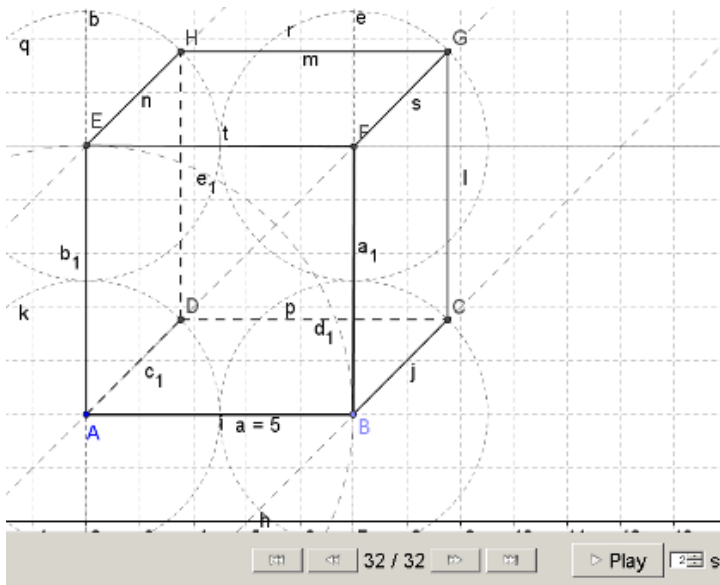
The first example belongs to the framework of teaching the plane geometrical figures (triangles). On the Figure 6 we can see an applet for the construction tasks for a triangle in the case that we know sizes of all sides (Ranostaj, 2010).

Figure 6: The triangle in Geogebra



The second example describes how to draw a cube in the plane using the rule that the side edges have the half length compared to the front edges (fig. 7). Playing the construction is an important advantage in this teaching unit, see Kopáčová (2014).

Figure 7: The cube with the bottom play



The software GeoGebra can be used as an effective tool to motivate pupils as it can visually represent a variety of mathematical notions and their relationships in a dynamic way, see Herendiné-Kónya (2014). Within the interdisciplinary relationships, we can use GeoGebra also in teaching of computer science in secondary education.

Conclusion

In our paper we describe different examples of using of educational software in teaching of mathematics and informatics in secondary level. There are numerous possibilities for visualization and simulation processes using a computer. The relationships between mathematics, informatics, and other subjects, which are supported by educational software, are a very important part of integration of ICT in education.

Visual possibilities of didactic software allow students to work with models of different objects. Students can apply knowledge gained in learning stage while looking for solutions of different problems. Moreover, they can visually observe the result and thus, understand and adopt basic concepts and notions more easily. Creation of the model and its visualization by computer allows pupils to gain specific experiences regarding the use of mathematics, science and informatics in a practical life.

The role of the teacher is strongly changed. He is no more only instructor in the computer aided education of different subjects, but more like a manager and a moderator of pupils or students. He must prepare activities, in which the educational software and its visualization and modeling aspects can support construction of new knowledge by every pupil (see Krech, 2009).

Solving logical problems helps develop a logical and algorithmic thinking by pupils via modeling and educational computer games. The various tasks have various levels of difficulty and so we have to devote much time for choosing the right tasks. They have many advantages: visualization of algorithms, interactivity and higher motivation of students. Our pedagogical experiments have shown that this kind of teaching is appropriate for students and support and develop their creativity.

Activities with educational software as *Baltie*, *GeoGebra*, *Imagine*, and other tools can effectively assist teachers in supporting the pupils' cognitive processes. Pupils can develop their formal and logical reasoning, cooperation and communication. They gain skills that are necessary for the research work, as the ability to implement a simple research project, to formulate a problem, to look for the solution and cause context, and to learn how to use various methods of problem solving.

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References

- Anderson, L., & al. (2011). *A Taxonomy for Learning, Teaching a Assessing of Educational Objectives*. New York, Longman.
- Billich, M. (2008). The use of geometric place in problem solving. In *Teaching Mathematics: Innovation, New Trends, Research* (pp. 7 – 14). Ružomberok, Catholic University.
- Baláková, G. (2011). *The use of program GeoGebra in subject computer science*. Ružomberok, Catholic University.
- Cirus, L. (2010) *Using ICT to support teaching the subject at the 1st Space Grade of primary school*. Usta ad Albim Bohemica, 2010.
- Duatepe, P. A. (2013). *Origami and mathematics*. In *New Challenges in Education*. (pp. 17-28). Ružomberok, Verbum.
- Facer, K. (2004). *Computer Games and Learning*. A discussion paper, FutureLab, UK, 2004. [Online] Available: http://admin.futurelab.org.uk/resources/documents/discussion_papers/Computer_Games_and_Learning_discpaper.pdf
- Gunčaga J., & Fulier J., & Eisenmann P. (2008). *Modernization and innovation of teaching mathematics analysis*. Ružomberok, Catholic University. (Slovak).
- Gunčaga, J., & Majherová, J. (2012). *GeoGebra as a motivational tool for teaching and learning in Slovakia*. In *North American GeoGebra Journal Vol. 1/ 2012*. (pp. 45-48). [Online] Available: <http://www.ggbmidwest.com/ojs-2.3.4/index.php/ggbj/article/view/4>
- Gülseçen, S., & Çelik, S., & Özdemir, S., & Uğraş, T., & Özcan, M. (2013). *Education in smart cities*. In *New Challenges in Education*. (pp. 126-129). Ružomberok, Verbum.
- Herendiné-Kónya, E. (2014). *How can high school students solve problems based on the concept of area measurement?* In Ambrus, A., & Vásárhelyi, É. (Eds.), *Problem*

- Solving in Mathematics Education, Proceedings of the 15th ProMath Conference, Mathematics Teaching and Education Center (pp. 95-107). Budapest, ELTE.
- Hohenwarter, M., & Lavicza, Z. (2010). Gaining momentum: GeoGebra inspires educators and students around the world. *GeoGebra the New Language for the Third Millennium*. Zigotto Printing & Publishing House Galati-Romania, Vol. 1 No.1. pp. 1-6.
- ISCED 2 – new Slovak curriculum Mathematics (2010). [Online] Available: http://www.statpedu.sk/files/documents/svp/2stzs/isced2/vzdelavacie_oblasti/matematika_isced2.pdf
- Kelemenová, A. (2005). Lindenmayer's systems and their creator. In Kelemen, J., & Kvasnička, V. (Eds.), *Cognition and artificial life V*. (pp. 235-250). Opava, Silesian University in Opava.
- Kopáčová, J. & al. (2014). *Mathematical thinking of children*. Ružomberok, Verbum. (slovak)
- Krech, G., & Krech I. (2009). On some non-transitive relation. In *Proceedings of ICPM'09*. Liberec.
- Louca, L. (2005). Creating games or developing programs? Documenting the use of StageCast Creator as modeling tool in elementary science. In Zacharia, Z., & Constantinou, C. (eds.), *Computer Based Learning in Science*. (pp. 556-569). Žilina, University of Žilina.
- Majherová, J. (2009). Cognitive aspects of L systems based models utilization. In Kelemen, J., & Kvasnička, V., & Rybár, J. (Eds.), *Cognition and artificial life*. (pp. 185 – 192). Opava, Slezská univerzita v Opavě. (slovak)
- Majherová, J., & Gunčaga, J. (2011). Geometry and modeling of plants in secondary education. In Plocki, A., & Krech, I. (eds.) *Matematyka w przyrodzie – matematyka i przyroda w kształceniu powszechnym* (pp. 39-46). Nowy Sacz, Wydawnictwo naukowe Państwowej Wyższej szkoły Zawodowej w Nowym Saczu.
- Mei-Chuen Lin, J. & Long-Yuen Yen & Mei-Ching Yang & Chiao-Fun Chen. (n.d.) *Teaching Computer Programming in Elementary Schools: A Pilot Study*. [Online] Available: <http://handbook5.com/t/teaching-computer-programming-in-elementary-schools-a-pilot-study-w605.html>
- Musa S., & Ziatdinov, R., & Griffiths, C. (2013). Introduction to computer animation and its possible educational applications. In *New Challenges in Education*. (pp. 177-204). Ružomberok, Verbum.
- Prensky, M. (2001) *Digital Game-based Learning*. New York: McGraw-Hill.
- Ranostaj, V. (2010). Applets in Goeogebra. [Online]. Available at <http://www.geogebra.org/en/upload/files/Slovak/Ranostaj/Prezentacia.html>
- Whatisbaltie? [Online] Available: <http://www.sgpsys.com/en/whatisbaltie.asp>
- Slovak Geogebra Institute. [Online] Available: <http://geogebra.ssgg.sk>