PhD Thesis Abstract
Doctoral School of Earth Sciences

GIS in the public and higher education – based on applied examples

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1. Introduction

The importance of GIS increases in our daily lives. Geographical Information Systems are used in more and more areas to solve difficult problems. Although it is quite widespread this is a new scientific field, so its evaluation is still not uniform. According to some experts it is an independent branch of science (DETREKŐI Á. – SZABÓ GY. 2002, MÁRKUS B. 1995), others consider it as an applied science (CSEMEZ A. 1996, ZENTAI L. 2003, HARKÁNYINÉ SZÉKELY ZS. 2008). As time passes the first view will be the dominant, but we are closer to the latter approach, if such systems are treated as tools, as in the case of information technology and mathematics. Based on such considerations the two types of visions harmonize together, if we define the goal of the GIS as its vocation is to be the assistance of other sciences.

'Mathematics is the maid of physics', my physics teacher used to say to the mathematics teacher about the rivalry of sciences. If we think of the importance of the maid, we realize that most systems are dysfunctional without the server, so the faithful and hardworking servant can be proud of his role as a servant. In my dissertation I demonstrate the usability of the GIS as a servant based on applied examples. If we want to give human characteristics for GIS, we may say, it does not want to be a goal; he is contented to be able to help as a tool. The only exceptions are system development and education, where the goal is the extension and the development of the system, as well as the theoretical and practical knowledge transfer (ARADI L. 2000, BROWN, M. J. 2001).

Journals deal with a lot of GIS education, most of them present examples from higher education (BARTHA, G. 2006; BIAN, F. – WANG S. 2008). Although more projects have been written about secondary education since the Hungarian issue of the NCGIA Core Curriculum in 1994 (SHARPE, B. – BEST, A. C. 2001, JOHANSSON, T. 2006), the ATOM project as an experiment in the Elementary School in Erdőkertes is a rare exception (KAPUVÁRI B. 1999).

The map using and map reading research among 14-year-old students represents the problems in the graphical and text information understanding (KÉZDI É. – PÉRCSICH R. 1999; NUNEZ, J. R. et al. 2005). Based on the above facts it should be considered what possibilities of the GIS education are in the different ages.

The technical processes show a specific trend, which in the rapidly developing field of information technology is particularly striking. A newly developed technical tool or technology is used initially by specialists, later also the less skilled users learn it as well, and finally children simply 'grow into' this new technology. Later it is obvious that children are using this 'serious' tool. The idea of banning becomes necessary only in case of dangerous or valuable tools. The real dangers of using the computer should not be ignored. However, this paper will not deal with this issue. Examining values in different articles and reference books, we can find a number of references to the difference in scale between the individual components (Table 1) (CZIMBER K. 2001; DETREKŐI Á. – SZABÓ GY. 2002).

Table 1. The value ratio of the components of GIS
(Source: CZIMBER K. 2001)

hardware	:	software	:	data	:	user
1	:	10	:	100	:	∞

2. Objective

After the introduction more questions have been raised. Is GIS already a public domain? Is geoinformatics an adult theme? Is it possible to talk to children about GIS? Has GIS already reached the level of being an everyday instrument for ordinary people, even for children? The dissertation is looking for answers to these questions.

Considering Table 1 above it is appropriate to set the software, the data, and in particular the user into focus of the research.

How can the software and the data be treated as cost effective? We should use free software and free data source (TIMÁR G. 2007). How can we ‘spare’ with the users? We should not waste their time and energy, but teach them the appropriate work. The education gets a key role in this effort.

On the bases of the ideas described above, the purposes of the dissertation are the following:

a) it gives an overview of the GIS teaching methodology literature, especially with regard to the concerned age;
b) it searches simple tools, that can support the introduction of GIS in public education;
c) it shows an own developed and freely formable tool to the students, which helps to learn the most important geospatial concepts and features (coordinates, scale, orientation, processing, classification, reproduction, retrieval etc.);
d) it introduces the students into the application of free software and the geospatial scripting language;
e) it brings real life examples from the research into the education;
f) it analyzes the geospatial tasks made together with students of the University of Pécs, highlighting the differences between students with or without teacher training;
g) it supports a teacher’s job with a detailed description and samples as well as ready-made study aid;
h) it provides the teacher with a survey which measures knowledge and the result of transferring this knowledge;
i) as result it proves that it is possible and worth dealing with GIS in primary and secondary education.

3. Materials and methods

3.1 Methods

Regarding that GIS is a fairly new scientific field, in education it is useful to show the path searching characteristic of it, besides the fundamentals. According to experiences if students recognise the possibilities of developing and creating something new, they will search for solutions to problems with greater enthusiasm. All projects detailed in this study could be suitable to be worked out in practice. Described cases, methods and tools are different, depending on the type of task or the targeted age. Although free software gain important roles in education, it is worth introducing commercial software as well.

- We have applied ArcGIS to demonstrate the possibilities of wide-spread commercial software. Data of plant permeation and of different settlement information (names, coordinates) are collected in MS Excel chart, and then imported into MS Access database, which can be opened by ArcMap. For visualization the borderline of Hungary is available in DXF format. The outlook of the maps can be considered as a minimum for the later used tools. In higher education the use of the system can also be part of the curriculum, but in primary and in secondary education the aim should be only the demonstration of the possible goal.
- According to the principle of ‘simple tool for simple task’ we drew the data points with OpenOffice.org Calc, XY chart. This case can be solved by secondary school students.
- Creating maps we used Logo program language and its dialects: Comenius Logo, Imagine Logo and Elica. Comenius and Imagine Logo are known already in elementary education. Elica is less wide-spread in Hungary. Nevertheless, it should be dealt with in higher education as well, because of its 3D editing.
- In spatial analysis of vertical surface moving FOSS (Free and Open Source Software) tools were applied. Data of mining activity were processes under GNU/Linux, with OpenOffice.org, and the visualization tool was the module *nviz* in GRASS. Theoretically the above methods can be demonstrated in secondary schools, although the lack of principles of shell script the execution is rather recommended in higher education.
- It is a frequent solution in map making that the final result is made with graphical software. It is mostly used when the system is unable to place textual information (e.g. place names) legibly. In these cases we used PDF file format with Adobe Illustrator.

3.2 Materials

The applied tools according to the previous grouping (hardware, software, data):

3.2.1 Hardware tools

For the written projects we mostly used IBM compatible PCs. In some semesters we worked on Sun Blade 100 Workstations, with SPARC processor.

3.2.2 Software tools

In the projects most of the software were run locally, but the GRASS was sometimes on remote server, because of the weaker power of workstations. The applied software in alphabetic order:

- Adobe Illustrator CS
- ArcGIS 8
- AutoCAD Map 2000
- Comenius Logo 3.0.046
- Elica 5.6
- ET-GeoWizard Free ArcGIS Extension
- GIMP 2.2.17 Portable
- GNU/Linux, more distribution
- GRASS GIS 6.3
- Imagine Logo 2.0
- MS SQL-Server 2000
- MS Office 2003
- MS Windows XP
- OCAD 6.1
- OpenOffice.org 1.0.3
- QCAD 2

In education it is an important attempt to use free software, so the schools do not need to expense for software and the students do not need to use cracked software at home. Debian GNU/Linux 4.0 and GRASS GIS 6.3 used during the work run without problems on a Pentium-II, too.

3.2.3 Data sources

The data sources are the most expensive category, so this topic needs some sentences. During the acquiring and importing we have two important questions to answer (NIKLASZ L. 2005):

a) From where do we get the data? We are in a difficult situation, when we use not own measured data, we do not have financial resources, and the data is not available on the Internet, too. In education it is a good possibility to contract with a data provider or to use fictitious data.
b) What is the most effective method, the data to prepare and to import? It is often a big challenge, but sometimes we can make it easier with scripts, macros or functions.

3.3 Age groups in GIS teaching

The projects of the dissertation aim different age groups. Table 2 summarizes the time points where each project joins to the primary and secondary education. The indicated age always shows the recommended minimum.

In case of the age and subject the presentation of the map or the system, which needs only passive knowledge, should be separated from the development of the system, which needs always active contribution, creative work. However, the presentation may also include analysis; the professional requirements during the developing are higher in all cases.

Table 2. The recommended age groups of the projects
The indicated activity categories: present (p), construct (c), analyze (a), develop (d)

Knowledge ***(Project)***	**Recommended school year**	**Subject** ***(Curriculum)***
Dot map *(Plant permeation)*	p: Class 7 c: Higher educ.	p: Geography *(Different types of maps)* c: GIS
Classed dot map *(Forest school)*	p: Class 7 c: Higher educ.	p: Geography *(Different types of maps)* c: GIS
Diagram map *(GDF time series analyze)*	p: Class 11-12 c: Higher educ.	p: Geography *(Social geography of Hungary)* c: GIS
Dot map *(Spreadsheet diagram)*	c: Class 9 a: Class 11-12	c: Informatics *(Diagram types)* *a:* Geography *(Different types of maps)*
Area class map *(Office software)*	c: Class 9 a: Class 11-12	c: Informatics *(Data visualizing)* a: Geography *(Different types of maps)*
Relief Map *(Comenius Logo)*	d: Class 8	d: Informatics *(Algorithms and data)*
Interactive map *(Imagine Logo)*	p: Class 7 d: Class 10	p: Geography *(Different types of maps)* d: Informatics *(Algorithms and data)*
3D visualizing *(Elica)*	p: Class 11-12 d: Higher educ.	p: Geography *(Surface modelling)* d: Computer graphics, OOP
Complex GIS system *(Vertical movements)*	p: Class 11-12 d: Higher educ.	p: Informatics *(GIS fundamentals)* d: GIS development

4. Projects

4.1 Visualization of geometrical data with professional tools

As the first step of the education we should emphasize the vision. Before the beginning of the real work it should be demonstrated, how the leading commercial software (e.g. ArcGIS) visualizes data. Later the students try for similar result, with free or open source software.

4.1.1 Dot map – Analysis of plant permeation

As our first map, we should look for a real task, which goal was to visualize biotical data. The spread of the six most aggressive invasive plants in Hungary was studied: *Ambrosia artemisiifolia, Elaeagnus angustifolia, Phytolacca americana, Reynoutria japonica, Robinia pseudo-acacia, Solidago gigantea.* The monitored plants were assorted by different parameters and their spatial distributions were recorded and presented on maps with ArcGIS. This work was supported by the Hungarian Research Fund (NKFP-3/050/2001) (PAL R. et al. 2003).

Figure 1 shows the permeation of different plants in the strip mine Karolina, Pécs. According to Table 2 the presentation of these maps is recommended in Class 7, the map making should begin in higher education.

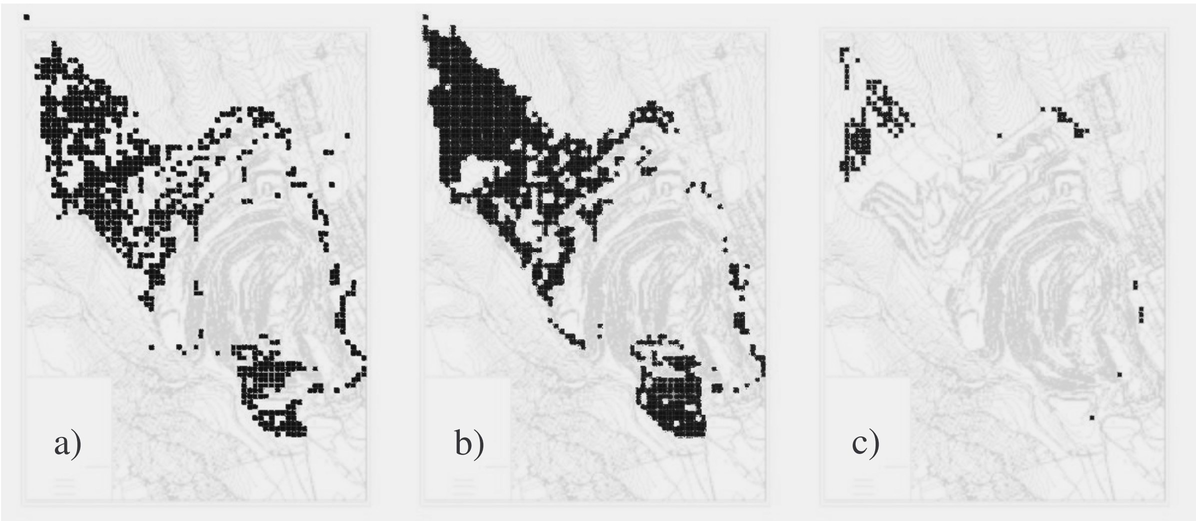

Figure 1. Spread of three plants is strip mine Karolina
a) Robinia pseudo-acacia, b) Calamagrostis epigeios, c) Elaeagnus angustifolia

By the presentation in the primary school we settle for visualizing, we should allude to more geospatial analysis possibilities, e.g. area calculation, puffer zone building etc.

4.1.2 Classed Dot Map – Forest school research

To improve the map above, we look at an example, where we will present more data, beyond the coordinates, e.g. headcount, too. We can draw the additional information with the size of the circles. This example presents a research of forest schools in

Hungary. The presentation of the results is recommended in Class 7, the data processing, database managing, map making should be in higher education (Table 2).

The settlements sending or receiving students in forest schools are drawn with circles, with size proportional with headcount. The map shows the preferred areas in Hungary (Figure 2) (BORNEMISZA I. – KOPÁRI L. 2007).

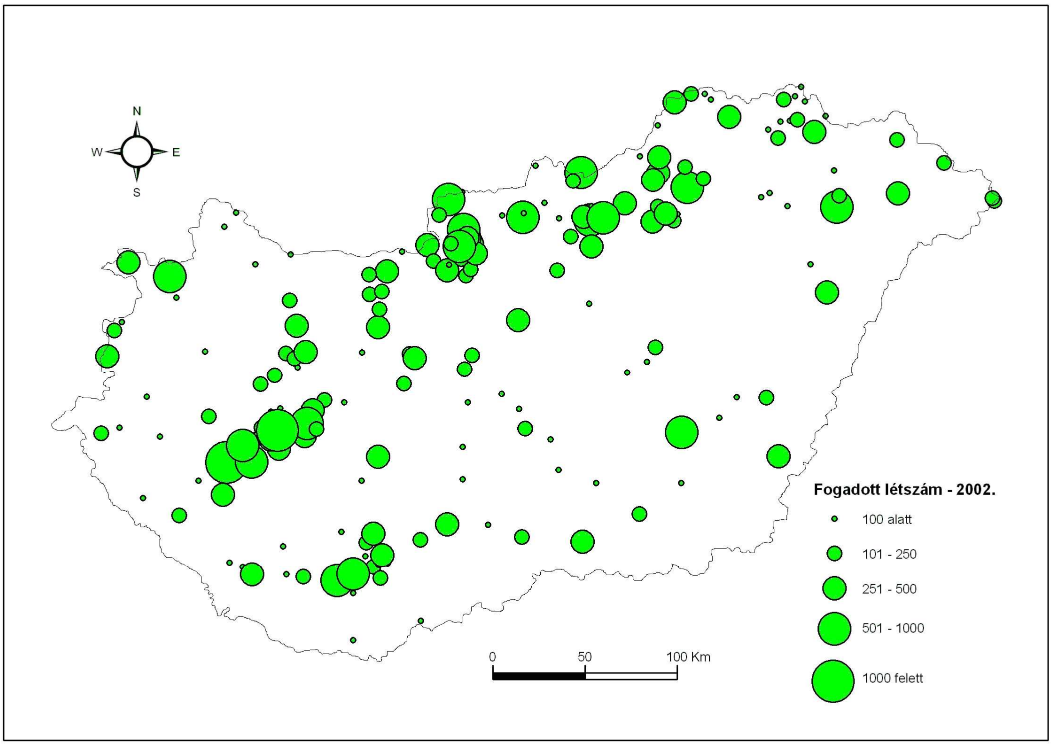

Figure 2. Territorial location and significance of forest schools in Hungary
(Received headcount in school year 2002/2003)

The presented GIS methods give us possibilities in research to reach new goals, to quick verify hypotheses. In this case the goal was now only the presentation again, but here we may allude to possibilities of further quantitative analysis, too. If we have adequate database, we can examine for example the count of forest schools near national parks or big cities.

4.1.3 Diagram map – analysis of time series

The next station of the map making is a database, with more metadata for each point. This example represents a time series with a diagram on each settlement. With so many data there is a risk of illegible maps.

The presentation of this project is recommended in Classes 11-12 but the real geospatial work should be in the higher education (Table 2).

Twelve years ago the Consultation Centre in Kecskemét of the Dennis Gabor Applied University (Gábor Dénes Főiskola Kecskeméti Konzultációs Központja – GDF-KKK) was founded. The demand for a spatial time series analyze was arisen by the big variation of the headcount. The first step was the data import from MS Excel. The typical problems of the representation of all the data was the unreadable place names, the unsatisfactory automatic text location and too small diagrams. Finally three types of maps were useable:

- representation of all settlements, with proportional circle, without place names;
- representation of significant settlements (more than 10 students), with proportional circle, codes instead of place names;
- representation of significant settlements (more than 10 students), with column diagram, with identifier code and sent headcount (Figure 3); the codes are here not displayed, because of privacy.

The displayed map includes all relevant information, the diagrams are difficult to analyze. Other ideas for visualization (colours, arrows, animation) can make the map clearer.

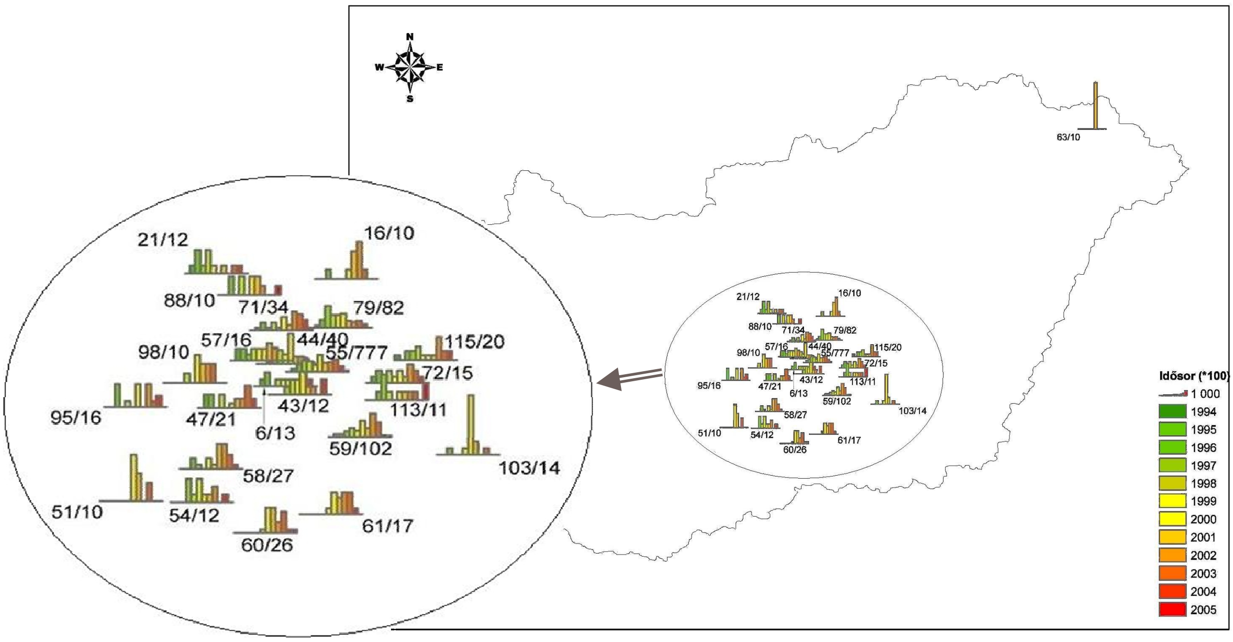

Figure 3. Time series diagram about the student headcount of the GDF-KKK
Near of the diagram are the identifiers of the settlements
and the headcounts of the sent students.
(Edited by I. BORNEMISZA, based on data of É. PÓSFAINÉ BAKOTA)

4.2 The use of simple tools

Now the question is, whether the previously presented (or similar) maps can be achieved with simpler tools available in the education. It is useful to investigate, what software are suitable for mapping based on the close relationship between GIS and cartography. ZENTAI, L. (2004a) rates these tools into next five categories.

1. CAD software
2. GIS software
3. General graphical software
4. Specially cartographer software
5. Other software

General graphical software are only used usually for the final editing of maps, categories 1., 2. and 4. are not suitable for the teaching of theoretical fundamentals, because of its complexity. So, we will use 'Other software' for teaching GIS fundamentals.

When students learn GIS fundamentals, they learn the theoretical components; however, they must use simultaneously both theory and practice. The clear understanding of the simplest functions is especially important. But working with complex software without any real understanding of the steps can be confusing. In this case a simpler tool may be of much help to learn the fundamentals easily.

4.2.1 Point map with spreadsheet

Most office software have some functions for visualization like maps, charts, etc. These functions are helpful but restricted.

For plotting simple data points we do not need special software. Figure 4 shows measured points with two different methods. The type of permeation can be drawn by a spreadsheet – here by the OpenOffice.org (OOo) Calc – Point (X,Y) chart. The feature of the two figures does not differ.

According to Table 2 it is recommended to teach the editing of this chart in Class 9 on Informatics lessons, and the detailed analysis a bit later, in Class 11-12, on Geography lessons (Table 2).

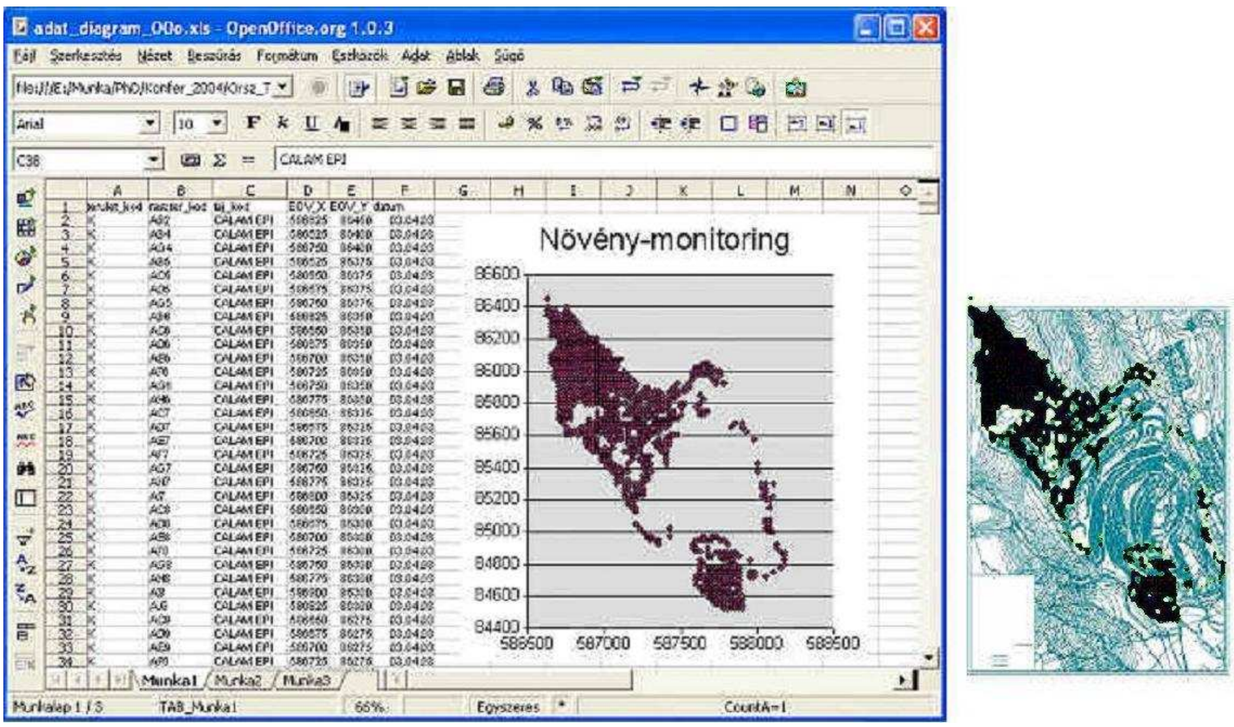

Figure 4. Presentation of measured points – OOo (left) and ArcGIS (right)

4.2.2 Area class map with office tools

The older versions of MS Excel (before version 2002) can draw simple area class maps. Figure 5 shows this capability of the Excel. Unfortunately this Microsoft Map function is missing from the newer MS Office (http://office.microsoft.com).

Although this function with the MS Excel version before 2002 is quite simple, it is recommended in the secondary school, because of the new version and of the other commercial software (Table 2).

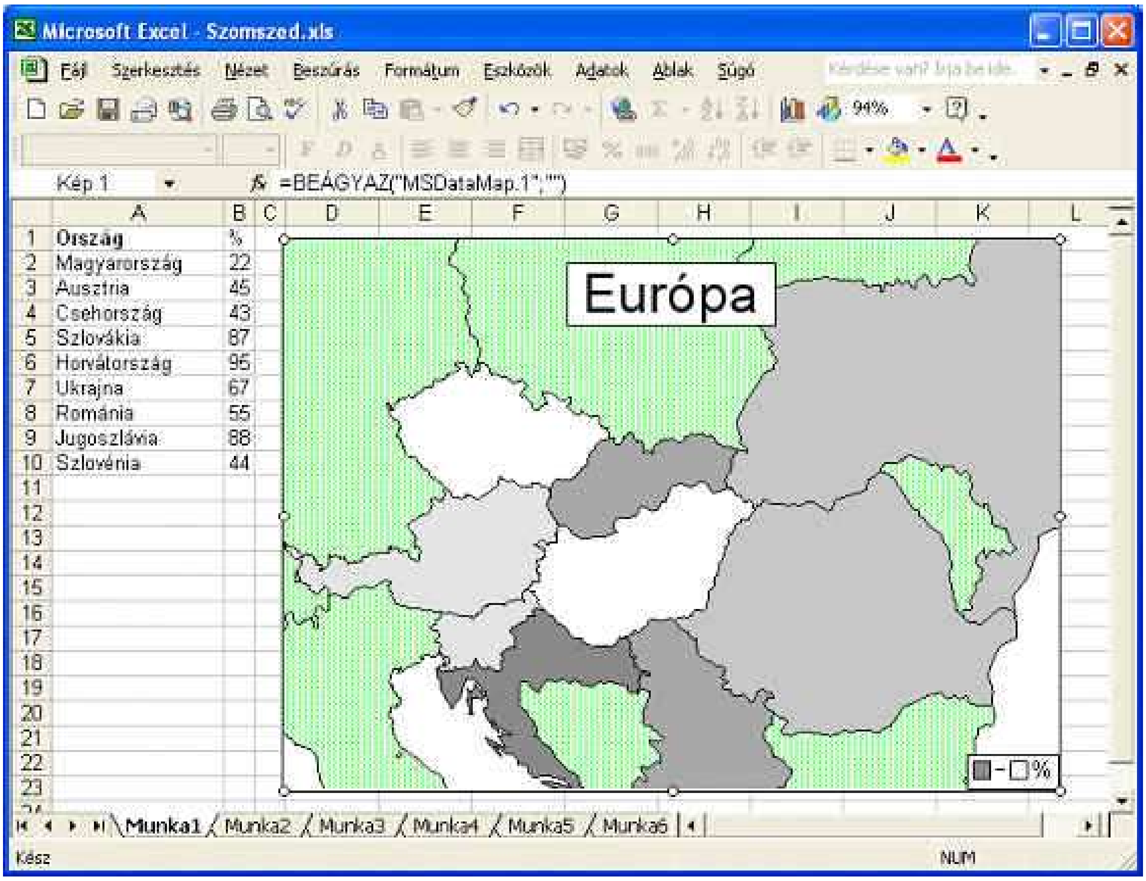

Figure 5. Data visualizing in MS Excel 2000

4.2.3 Relief map – Logo

For the demonstration of data import, data management, reclassification, displaying and querying a more flexible tool is needed. The most flexible one is a programming language, usable for all problems.

Selecting a programming language is not a key issue, since quite a few are used by geographers: Visual Basic (SLOCUM, T. & YODER, S., 1996), Python (KARSSENBERG, D. et al, 2007), shell script (NETELER, M., 2003) etc. The most important aspect of choosing the language is that students should be familiar with it.

Logo is very adapted for our goal, it is easy to use, and most students learned it at primary school (TURCSÁNYI-SZABÓ, M., 1995). In most schools in Hungary Logo is the first learned programming language at the age of 10-12. Students, who later do not specialize in informatics or programming, will be familiar only with this language.

The recommended time table is detailed in Table 2.

The Logo program opens the text file containing data, and searches the maximum and minimum values of X and Y coordinates, and then calculates the scaling parameters. It classifies the altitude values into 16 colours of Logo according to Z coordinates (BORNEMISZA I. 2008). The Logo-turtle copes with the problem (Figure 6).

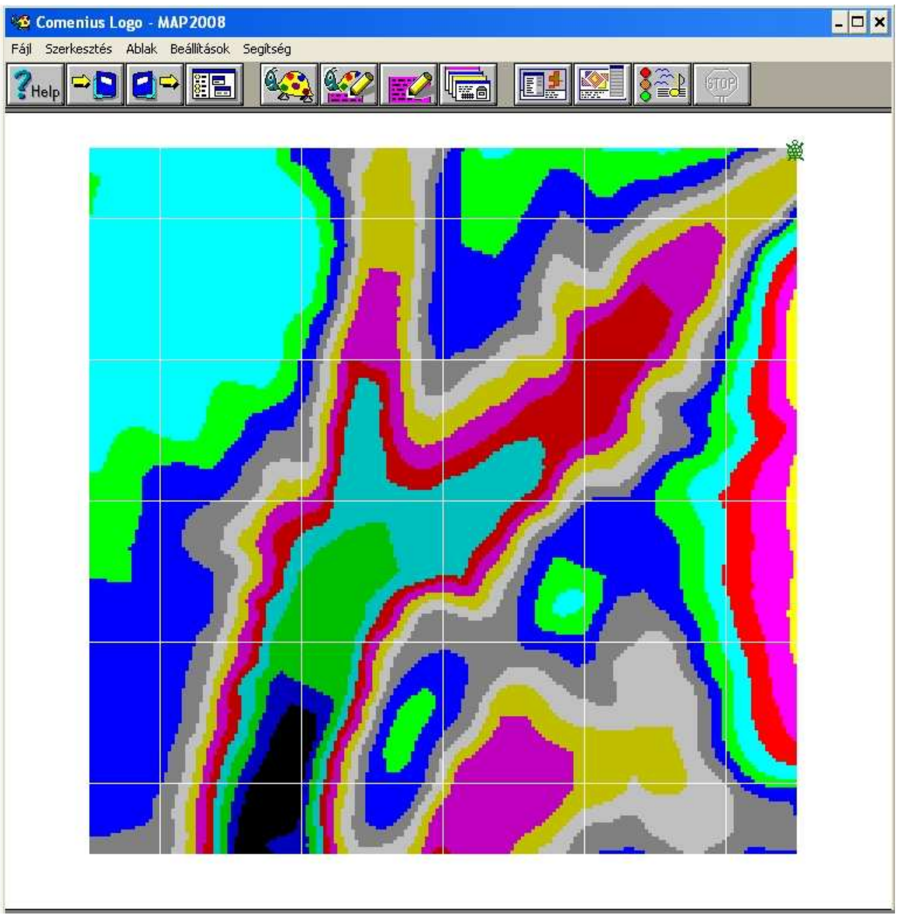

Figure 6. Relief map drawn by Comenius Logo turtle

With some syntactical modification we can rewrite the project into Imagine Logo. The improved project also has a search function. Figure 7 shows the screenshot of the interactive program. The colouring of the map is similar to the original relief maps. We can realize this feature with the RGB coding.

The program writes the coordinates of the mouse in real time, transforms the mouse coordinates in Logo into real coordinates on the map, and writes it into a textbox. After each mouse click the program searches for the Z value, and also writes it into the textbox (BORNEMISZA, I. – BOYTCHEV, P. 2009a).

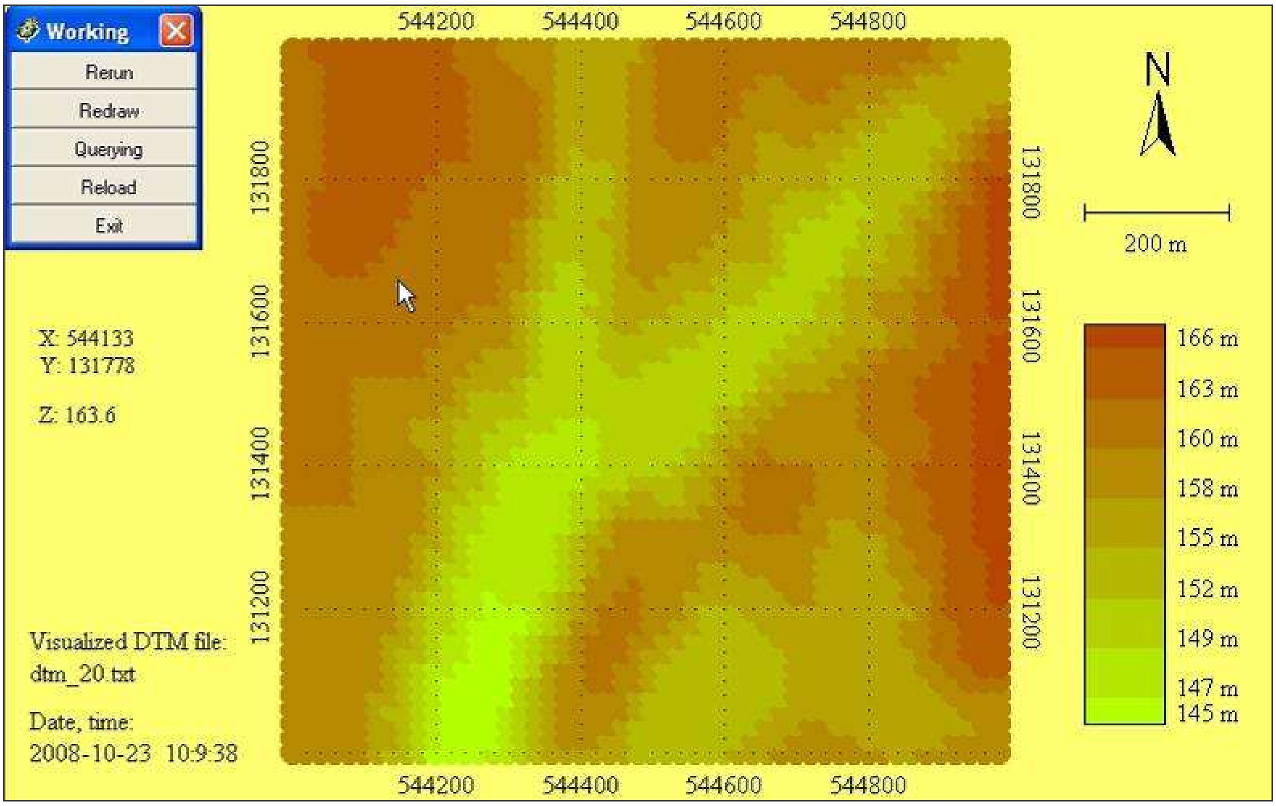

Figure 7. Map of Imagine Logo, with the query function
(Source code is available for download here: http://born.try.hu/imagimap/)

During the study of the feedback from users working with Logo-based GIS-related software, one of the most important issues was to have three-dimensional maps including some landmarks. There are at least three Logo versions which support some kinds of 3D scene, where Elica (Boytchev, P., http://www.elica.net) and aUCBLogo (Micheler, A., http://www.aucblogo.org) are the most advanced ones.

Figure 8 and Figure 9 show the 3D possibilities of Elica (BORNEMISZA, I. – BOYTCHEV, P. 2009b).

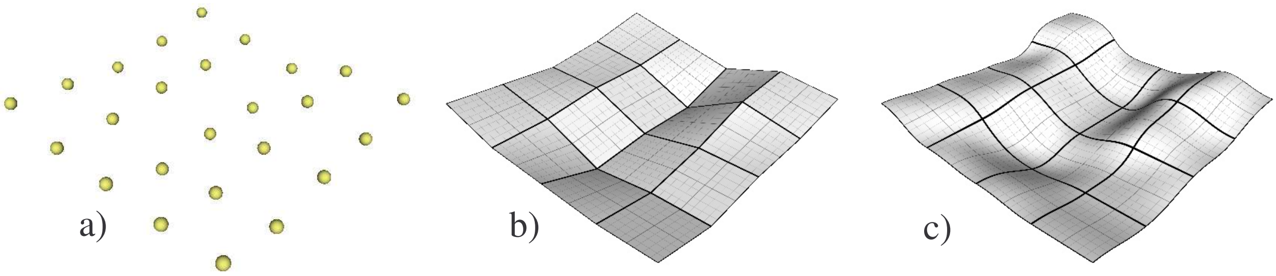

Figure 8. Grid of dots (a), quadrilaterals (b) and NURBS surfaces (c)
(Edited by P. BOYTCHEV)

Figure 9. A satellite photo mapped as a texture onto the NURBS surface
(Edited by P. BOYTCHEV)

4.3 Complex system – GRASS GIS open source software

After the use of simple tools the teaching of geoinformatics culminates in a real GIS tool. The samples in the dissertation are written for GRASS GIS, which 'favourite' operation system is GNU/Linux. The demonstration of this system should be in secondary school, the development is recommended in higher education (Table 2).

The area of this project is the Mecsek region. The data sources are the old uranium mines, measuring surface altitude values at the covering of slurry reservoirs. We processed data with GRASS GIS. We made import, pre-processing and visualization in some steps with the functions of GRASS: *v.in.ascii, v.surf.rst, r.mapcalculator, d.mon, d.text, d.legend, d.barscale.* The *nviz* module can visualize the surface in 2.5D (BORNEMISZA I. 2006A; GRASS DOCUMENTATION 2006).

A shell script and its loop make unique screenshots, so it is possible to compare more pictures. In Figure 10 we can see the thickness of the top-soil (a) and its result, the sinking of the area (b). Figure 11 shows the thickness of the burden, with the module nviz. The last 3D (2.5D) figure exemplifies the process well.

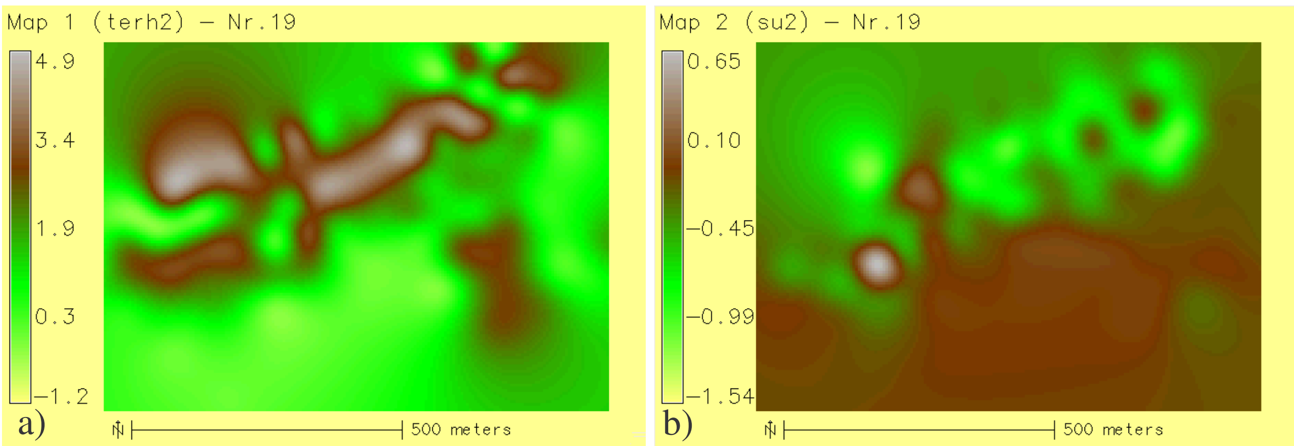

Figure 10. Two-dimensional picture of burden (a) and sinking (b)
(Values of legend mean meter.)

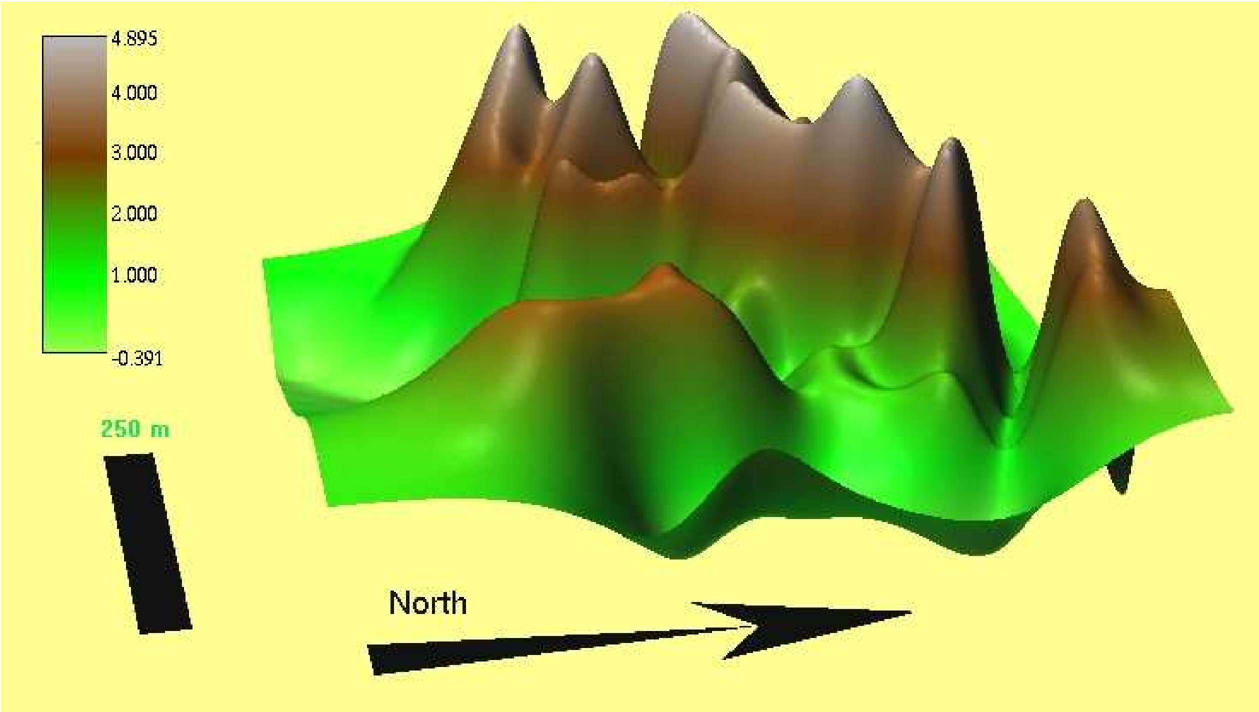

Figure 11. Thickness of burden in 3D
(Values of legend mean meter.)

5. Results

The research is closed. The results of the projects and the answers to the questions are the following:

a) after the methodological overview of the literature we can establish that the question is very timely, whether it is possible to teach GIS in primary and secondary education;
b) we gave new, useable, simple tools in the hand of teachers;
c) we developed a tool for the students, using Logo language;
d) we introduced the students into the application of free software and the geospatial scripting language;
e) with the detailed descriptions we brought real life examples into the education;
f) through the analyzes the geospatial tasks we described the differences between students;
g) supported teachers' job with a detailed description and samples as well as ready-made study aid;
h) we provided the teachers with worksheets to measure knowledge;
i) as result it is proven: it is possible and worth dealing with GIS in primary and secondary education.

6. Further development

Each written projects call for further development. The planned GIS education in primary and secondary education and its evaluation will be the jobs for the following years.

The edited maps have more functions on computer than on paper. Online maps are more useful, expandable. They have more advantages: platform-independence, mobile accessibility, flexibility, free and open source software (ZENTAI L. 1997; ZENTAI L. 2002; ZENTAI L. 2003).

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b.) Conference presentations related to PhD topic

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