Model of Higher GIS Education

Imrich Jakab, Michal Ševčík and Henrich Grežo
Department of Ecology and Environmental Sciences, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Slovak Republic
ijakab@ukf.sk
michal.sevcik@ukf.sk
hgrezo@ukf.sk

Abstract: The methods of geospatial data processing are being continually innovated, and universities that are focused on educating experts in Environmental Science should reflect this reality with an elaborate and purpose-built modernization of the education process, education content, as well as learning conditions. Geographic Information Systems (GIS) have the dominant role in geospatial data processing.

GIS education of students in Environmental Science (ES) in master´s degree can be divided into two main approaches - to teach about GIS and to teach with GIS. Approach "to teach with GIS" is mainly focused on teaching of Landscape Spatial Analysis with use of concrete GIS analytical tools. Students use the tools for solving of concrete problems. They work with real data and methods. The spatial analysis learned can help to manage conflicts of interest within the country, and to assess the impact of human activity on the environment. On the other hand students learn about GIS via tools and methods in concrete GIS software. To achieve higher efficiency in teaching Landscape Spatial Analysis we have created a model of GIS education based on the idea of inquiry-based learning (IBL). In an effort to get closer to the approach used for real problematic task solving, it is essential to include several interconnected systems into the education. While the Global Positioning System (GPS) Web Map Service (WMS) and Database management systems (DBMS) present the work with geospatial data similarly as GIS, Learning Management System (LMS) represents a valuable information source for students as well as an instrument for communication between teacher and students and among the students themselves during work on student projects. The proposed model can offer support of student´s motivation to learn, increased efficiency of education process and improvement preparation of students for their profession.

Keywords: Inquiry Based Learning, GIS education, spatial analysis, Blended Learning

1. Introduction

Methods of acquisition, processing and visualization of data are constantly being streamlined and updated. Every university must keep up with these developments by maintaining an innovative approach to the content and form of their educational offerings. Adapting to the needs of professional practice can be challenging. Science graduates are also expected to have a level of skills in information and communications technology (ICT). (Jakab, Grežo and Ševčík, 2016).

ICT is an umbrella term that includes any communication device or application including radio, television, cellular phones, computer and network hardware and software, satellite systems etc, as well as the various services and applications associated with them, such as video-conferencing and distance learning (Rouse, 2005). Correct usage of ICT in education can improve the quality of teaching and learning, and management in schools, build knowledge across all areas of the curriculum and help to build higher-order cognitive and life skills (Livingstone, 2012; Gaible et al, 2011).

Generally, three objectives are identified for the use of ICT in education: the use of ICT as an object, usually within a specific course, the use of ICT as an aspect, of industry and profession; and the use of ICT as a medium for teaching and learning (Plomp, Brummelhuis and Rapmund, 1996; Drent and Meelissen, 2008).

We apply the above-mentioned three objectives for the use of ICT in GIS education within the study program Environmental Science (ES) at the Faculty of Natural Sciences, Constantine the Philosopher University in Nitra.
ES is an interdisciplinary academic field, which influences the study and practical training of students in the ES study program. In practice, graduates of the study program are expected to manage conflicts of interest in the country and assess the impact of human activity on individual environmental components. Both of these tasks require data analysis and synthesis from various scientific fields. We have to adapt the content and method of our teaching to equip our graduates with the necessary skills to solve these problems. They need to know all

Reference this paper as: Jakab I, Ševčík M and Grežo H, "Model of Higher GIS Education" *The Electronic Journal of e-Learning Volume 15 Issue 3 2017*, (pp220-234) available online at www.ejel.org

relevant input factors and phenomena, acquire and process them efficiently, overlap them logically, subject them to spatial analysis and synthesis and evaluate and interpret the results accurately.

Use of several close-knitted systems, the main one being Geographic Information Systems (GIS), provides a comprehensive solution to this problem. GIS is a system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth (Dueker and Kjerne, 1989).

Geographic information systems are applied in land-use planning, ecosystems modelling, landscape planning and assessment, transportation and infrastructure modelling, market analysis, visual impact analysis, watershed analysis, facility management, real estate analysis, and many other areas. The use of GIS tools has also become standard in scientific activities and it is an essential part of research methodologies for the study of phenomena that can be localized in space (Jakab, Grežo and Ševčík, 2016).

2. Teaching about GIS and teaching with GIS

GIS education at Department of Ecology and Environmental Science is realized within the three courses (Table 1). Passing the courses prepares students to use GIS for spatial data acquisition, its editing and transformation into the required data types, formats and coordinate systems. They should know how to use spatial analysis purposefully and visualize the result properly with use of cartographic techniques. They should also deal with several manners how to publish their data.

Table 1: Geographic information systems – courses in the curriculum of Environmental Science study programme

Course Title	Degree Level	Number of teaching hours per week	Description of Course
GIS for environmental scientists	BSc	4	Direct and indirect methods of data acquisition and its visualization, cartographic presentation and publishing
Landscape Spatial Analysis	MSc.	2	Basic spatial analysis aimed at vector data model in GIS
Advanced analysis in Geographic Information Systems	MSc.	2	Spatial analysis aimed at raster data model in GIS

Conception in GIS education at master´s degree level that uses various systems was published in the article Inquiry Based and Blended Learning Using Geographical Information System (Jakab, Grežo and Ševčík, 2016). The mentioned article presented GIS education model in general, with use of several information systems. In this work we focus on application, completion and specification of the model existed on the base of concrete course teaching (Landscape Spatial Analysis – see table 1). The attention is aimed at content and process point of view of education in relation to the used systems. As an added value are new experiences acquired from the course teaching in academic year 2017/2018.

According to Sui (1995) GIS education can be divided into two main approaches - to teach about GIS and to teach with GIS (Figure 1). To teach about GIS concentrates on GIS technology itself with an instructional focus on training. To teach with GIS focuses applications of GIS with an instructional focus on content education.

In our case, education in Landscape Spatial Analysis combines both approaches. The first approach - Teach with GIS – is focused on education of spatial analysis with use of concrete analytical GIS tools. Using the tools allow students to familiarize the individual spatial analysis directly for concrete possible problems with use of real data, thus analysis is directly connected with practice.

Theoretical outcomes are essential, therefore students have to be prepared in the topic: what is individual spatial analysis used for; which data is it used for; what is the principle of it; what results can be expected; and what are the possibilities for the landscape research for ecologists and environmental scientists?

The approach "teach about GIS" is focused not only on selected GIS analytical tools but also on a number of operations which are necessary for successful solving of spatial analysis in GIS. The operations include tools and processes connected with spatial data acquisition, its modification and visualisation. Students become familiar with concrete GIS software environment (desktop applications), its possibilities, tools, functions and specifications. Likewise in this approach it is essential to combine practical work in GIS with relevant theory which leads to learn about the whole GIS area, not only about one software.

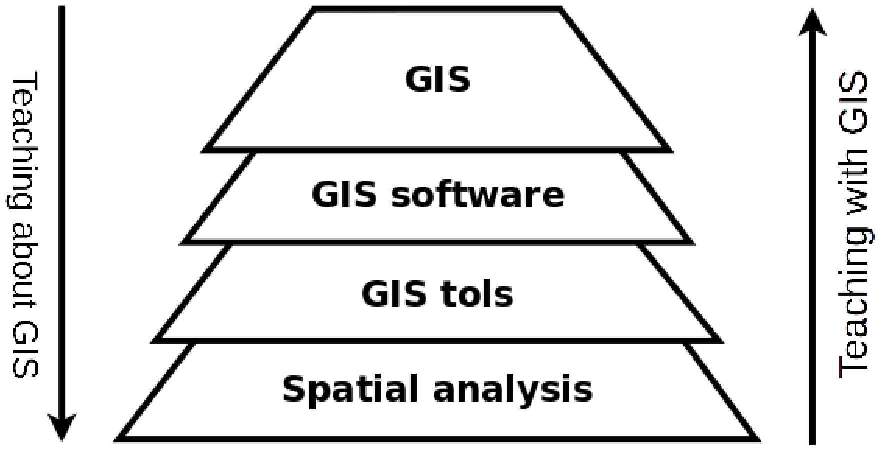

Figure 1: Combination of the approaches Teach about GIS and Teach with GIS

3. Methods

The aim of this contribution is to introduce model of blended learning in GIS education which uses an approach of IBL and other purposefully bounded systems.

In our experience, the content of GIS teaching is focused on three main interrelated steps: data collection, data manipulation and data dissemination. Within the curriculum each step is subdivided. Links on the left and right side of diagram in Figure 2 refer to various systems within the education process. These are used to increase efficiency in work with GIS, as well as to increase efficiency within the educational process in the spatial landscape analysis course:

- **Global Positioning System (GPS)** - is an earth-orbiting satellite-based navigation system providing users worldwide with twenty-four hour access to precise positioning in three dimensions (latitude, longitude, elevation) and precise time traceable to global time standards (Dana, 1997). Students learned how to collect data by GPS at the bachelor degree, therefore it was a subject matter in the course GIS for Environmental Scientists. Teaching in the course Landscape Spatial Analysis is focused on processing of raw data acquired by GPS and their appropriate use for spatial analysis.
- **Learning Management System (LMS)** - is a framework which controls all aspects of the learning process (Forouzesh and Darvish, 2012). In our case, LMS represents a valuable information source for students as well as an instrument for communication between teacher and students and among the students themselves during work on student projects. LMS is used by students to enhance their skills and knowledge about systems (Desktop and Web GIS, GPS, DBMS, etc.) and individual steps mentioned in our diagram (Figure 2).
- **GIS server** - provides the platform for GIS resource-sharing (maps, geodatabases, etc) and provides access to the GIS functionality that the resource contains. Geoserver is a software server that meets our requirement to view and edit geospatial data. It is an open source server for sharing geospatial data, which provides a number of OGC compliant implementations of open standards such as Web Feature Service (WFS) and Web Map Service (WMS).
- **Database management systems (DBMS)** - are computer programs designed to manage the storage, maintenance, and retrieval of information from a computer system. Their use in many different

kinds of computing environments is widespread because they perform the essential functions that almost every data processing application requires (Cooper, 1985). Despite the many advantages of DBMS, like data independence or security, one of the most important aspect of database management systems, for users of the data, is the powerful query language facilities that are available on almost all the systems (Cooper, 1985). Besides SQL students learn basics about functional dependencies, relational algebra and/or calculus, query optimization, and how various (spatial) indexing schemes work. DBMS also have statistical summary commands available to the user (for example, mean, standard deviation), as well as commands that allow results to be tabularly, graphically and spatially displayed.

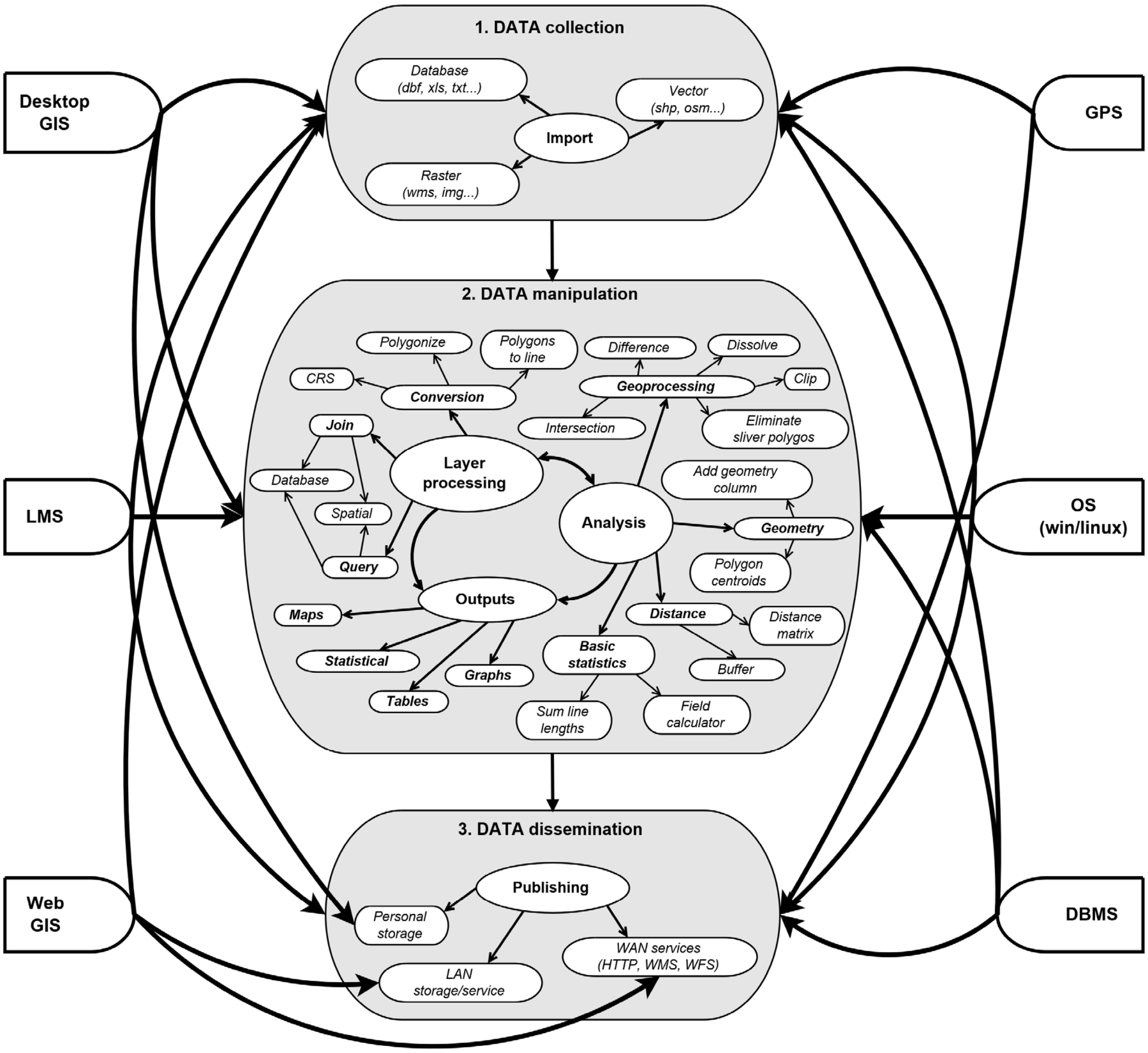

Figure 2: A logical sequence of steps, procedures and systems which students use to solve projects

- While the GPS, and WMS systems present the work with geospatial data similarly as GIS, LMS represents a valuable information source for students as well as an instrument for communication between teacher and students and among the students themselves during work on student projects. Incorporation of DBMS system into education reflects the course Landscape Spatial Analysis. Educational content comprises mainly of vector spatial analysis which use spatial data for definition of attributes in DBMS relation model. In relational model, the collection of inter-related tables represent data and their relationships. Each table is a group of column and row, where column represents attribute of an entity and rows represents records of features.

All of the software listed above belongs to the open source software group - software that is made freely available to all (Hippel and Krogh, 2003), so programmers or users can read, modify and redistribute the source code of a piece of software (Gacek and Arief, 2004). The above-mentioned storage service that we use is free of charge and data can easily be transferred elsewhere if the Terms of Service change. We agree with Coppola and Neelley (2004) that the open source model promotes freedom of choice, increases user access and control, encourages collaboration within the global community, promotes quality, and enhances innovation in teaching and learning.

In the educational process within the afore-mentioned courses, we use Quantum GIS as the professional GIS software. The LMS system is represented by the Learning Platform Moodle. Students have to choose which operating system suits them best; they can use various Linux distributions as well as MS Windows or Mac OS X (Figure 2).

The course curricula for Spatial Landscape Analysis are based on problem solving for real scenarios that students will encounter in professional practice and which require the use of professional technologies, and a scientific approach. Therefore, we propose an educational model that uses an Inquiry-based learning (IBL) approach, which is, according to Dewey (1964) based on the idea that science education should be authentic to science practice. Participation in inquiry can provide students with the opportunity to achieve three interrelated learning objectives: the development of general inquiry abilities, the acquisition of specific investigation skills, and the understanding of scientific concepts and principles (Edelson, Gordin and Pea, 1999; Hmelo-Silver, Duncan and Chinn, 2007).

IBL is student-centered, active learning approach focused on questioning, critical thinking, and problem solving. IBL is frequently used in science education and encourages a hands-on approach where students practice the scientific method on authentic problems Ertmer (2015).

4. Results

Based on the principles of IBL (Dewey, 1964; Feletti, 1993; Hmelo-Silver, Duncan and Chinn, 2007; Ertmer, 2015) we have created an innovated model of GIS education for 1st year students of our master degree study program in ES. The model is designed for the course of Spatial Landscape Analysis focused on vector data representation.

In academic year 2017/2018 we started education with use of the above mentioned model. 18 students of full-time study in ES attended course Landscape Spatial Analysis.
Education is realized via Blended learning, based on a concept of integrating the strengths of synchronous (face-to-face) and asynchronous (text-based Internet) learning activities. At the same time, there is considerable complexity in its implementation with the challenge of virtually limitless design possibilities and applicability to many contexts (Garrison and Kanuka, 2004).

Influenced by IBL, the carrying part of Face-To-Face education in the course Landscape spatial analysis became practices (Fig. 2). They led into active obtaining of knowledge and skills. The content of education was proportionally divided into eight practices (Fig. 2).

The first practice was focused on revision of knowledge learned in previous course, other practices gradually mediated the knowledge in spatial analysis focused on vector data models. Practices bring practical tasks from ecology, landscape ecology and environmental science regarding to priority of the study program. The topics of practices are heterogeneous:

- Area proportion of mapped elements of present secondary landscape structure (revision)
- Population density – socioeconomic indicator of spatial distribution of population in selected region
- Spatial activity of small terrestrial mammals
- Habitat composition of Long-eared owl
- Management arrangements to prevent spreading of invasive species
- Spatial distribution of human activities planned in relation with landscape characteristics
- Relief Analysis of certain city parts, for evaluation of microclimatic conditions, in relation with climate change adaptation in cities
- Difference analysis of time-spatial development of landscape elements in model area

Solution of the practical tasks during the education process requires, that students use already known analytical tools in GIS and each practice brings a need to learn some new tool. From practice to practice increases difficulty of its solution and simultaneously rises a number of tools learned and each practice brings revision of formerly learned tools.

Solution of the problem situations runs through the same phases (Figure 2). Education process of each practice was followed by one basic question:

What procedure is used to solve the problem task?

Solution of the problem situation requires considering approach from two points of view: approach of environmental scientist and approach of geoinformatics. The first theoretical approach of environmental scientist requires definition of the problem, theoretical background and possible methods for solving the problem. In this phase we respected the instructions of Feletti (1993); Hmelo-Silver, Duncan and Chinn (2007); Ertmer (2015). We start IBL with an introduction into the concrete authentic problem situation, which will be solved using various research methods. Introduction of the situation is closely linked with discussion Edelson, Gordin and Pea (1999), Feletti (1993). The situation is analyzed in detail from the point of view of the problem solved as well as from the point of view of potential solutions. Searching for the correct and an optimal solution is a part of education process supported by IBL.

The second geoinformatics approach rests in looking for the individual methodical steps of problem solving – concrete technical solution of the task. It means that students look for the appropriate geographic tools as well as tools from other information systems to fulfil individual methodical steps of problem solution, they define input data and setting of tools chosen, create their own outputs of various form and verify accuracy of the results. For each problem task offer geographic information systems several possibilities of solution. It means that correct result can be obtained by several procedures and it is possible to use several alternative tools, several settings and various outputs.

Students prepare outputs containing calculated and created map layers which are visualized in original maps or exactly expressed values of phenomena and object properties. The results they get are unknown for them. Thus the problem solution became opened as describe Colburn (2000) and Staver and Bay (1987) who entitled the education approach as *Guided inquiry.* Within the approach the teacher provides only the materials and problem to investigate. Students devise their own procedure to solve the problem.
Students are put in the role of geoinformatics and during the problem solving they search for answers for the following questions:

Which input data are needed for problem solving? Where can we take the data from and what kind of modification does it need?

Usually the work on the project which uses GIS begins with data collection and importing the necessary data to the GIS database or GIS project.

Students can use data with various content depending on data accessibility or the possibility to create it. They can also use existing data, which are available at the Department of Ecology and Environmental Sciences. Other possibilities of data: data available via WMS, data obtained by students with the use various direct or indirect methods of geospatial data acquisition according to Jackson and Woodsford (1991).
Whereas the content of the course is focused especially on spatial analysis, there is not so much space for learning a wide range of methods for geospatial data acquisition. This was content of the course GIS for environmental scientists that is incorporated into curriculum of bachelor degree level in ES. In the Landscape spatial analysis we focus especially on basic, selected and often used methods in the depth which is necessary for solution of the problem tasks.

Often used indirect method for geospatial data acquisition is the digitalization of map sources and creation of new map layers via spatial analysis within the frame of derived mapping. Direct methods of geospatial data acquisition present localization of objects and phenomena with GPS. When the input data, essential for the solving of inducing situation and problems, are defined, it is important to closely specify the attributes of the environment where the geospatial data will rise and where the spatial analysis will be done. This step is closely related to data modification, necessary for the further data processing.

Collection of input data from various sources produces various problem situations. The most important are as followed:

- ***Difference in coordinate systems -*** Majority of the inquiry based problems solved uses geospatial data georeferenced in local or global coordinate systems. Transformation of coordinate systems is sometimes required. Global coordinate system is specific for the data obtained by GPS localization as well as for geospatial data available via WMS, and for larger areas (e.g. Europe, world). Geospatial data on a national level use Local coordinate system (Slovakia has Coordinate system S-JTSK). Local coordinate systems should be accepted and promoted either to calculate the position more precisely or to synchronize happenings (Munoz et al, 2009). Therefore, due to the unification of coordinate systems, we will transform all layers into the S-JTSK coordinate system.
- ***Various level of generalization and various scales of map layers -*** Selection of scale and the level of generalisation of map layers are very important steps. Map generalization is the name of the process that simplifies the representation of geographical data, to produce a map at a certain scale with a defined and readable legend (Ruas, 2008). Students have to be prepared for the fact that various degree of generalisation of map layers and various scales, in which the data were created, can cause incompatibility of map layers for overlapping and therefore they cannot be used for solution of the problem situation.
- ***Some data is out of time and problems with comprehension of time –*** One of the most common problems during the solution of problem situation is lack of appropriate actual data. Availability of appropriate and actual input map layers strongly influences process of solution and exactness of the results. Another problem of present geographic information systems is that time information given on map layers is often incomplete and inaccurate. The most commonly it says when phenomenon or situation was recorded in GIS. But we do not know anything about time when phenomenon arose or when the situation appeared for the first time, as well as we do not know whether the time data is actual for geometric and for attribute part of geo-element.

Which spatial analysis we are going to use for problem solution and which modification is required for the analysis?

The true power of GIS lies in spatial analysis. GIS makes spatial analysis (geographic and location analysis) easier, so the number of users of GIS application increases and the scope expands (Audet and Ludwig, 2000). GIS analysis shows patterns, relationships, and trends in geographical data that help one understand how the world works, make the best choice from among options, or plans for the future (Mitchel, 1999). Spatial analysis presents the basic educational content of courses in which the IBL model is implemented, and therefore, the analysis needs enough attention.

There are two basic forms of representation of geospatial data in GIS: vector and raster form (Couclelis, 1992). Each form offers different possibilities and means of data processing as well as different possibilities of spatial data use. In the course Landscape spatial analysis students meet both forms of spatial data representation, but priority is given to vectors and vector analysis.

Conceptually, geographic data can be divided into two elements: observation or entity (spatial component) and attribute or variable (thematic component). GIS have to be able to manage both elements, and this defines the overall requirements to the database technology behind (Hansen et al, 2008).

Spatial analysis which students learn during the course are focused on the both together linked components. It means that properties of geospatial data can be studied considering the thematic aspect (statistics), the locational aspect (spatial analysis) or both, what is specific character of GIS according to Parker (1988).
The knowledge in spatial analysis is divided equally into the 8 prepared problem situations. The first practice is revision and systematization of background knowledge in GIS. Other practices gradually enlarge knowledge from spatial analysis and every new situation (lecture) requires knowledge of the former situations, but also learning of the new one spatial analysis (Figure 3).

This type of learning allows multiple revisions of the analysis, and students obtain not only necessary knowledge and skills to use concrete analytical tool, but also experience with the adequate use of the tools. The learning system makes easier selection of convenient analytical tools in the next problem situation.

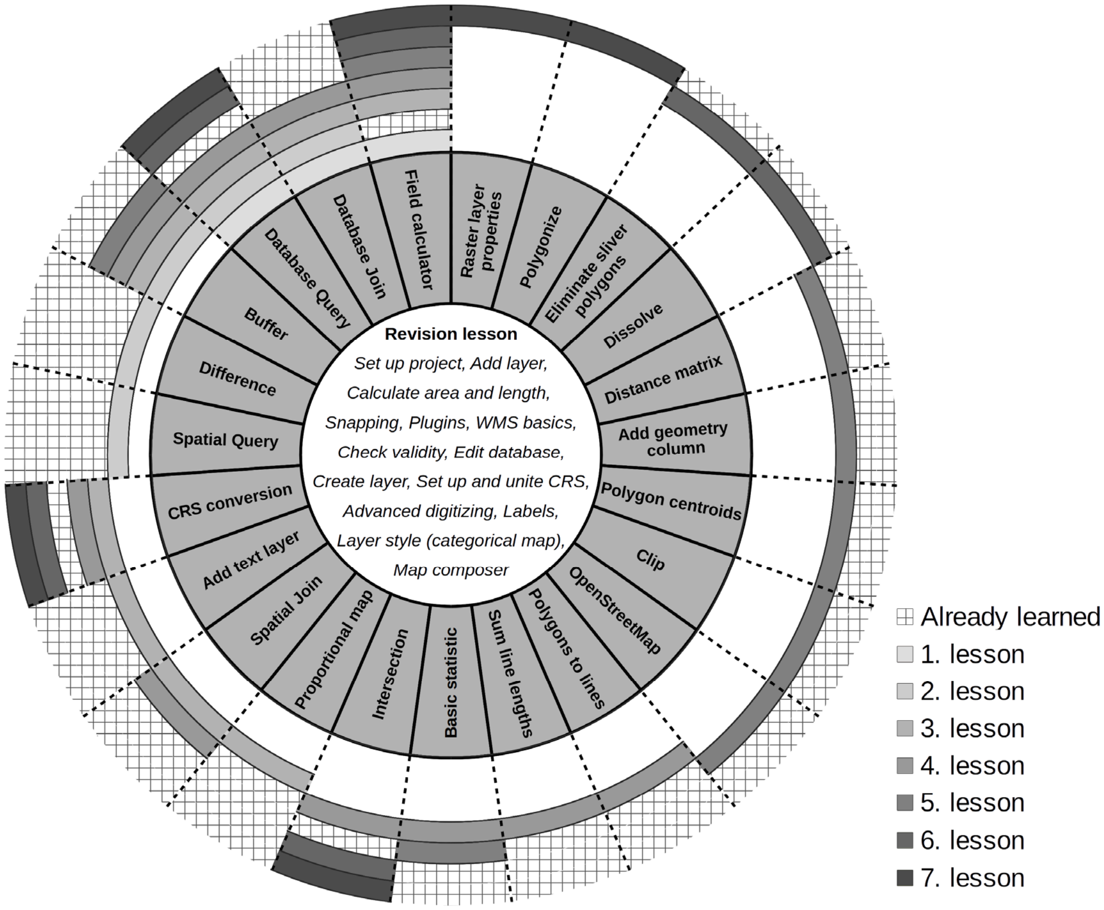

Figure 3: Process of knowledge acquisition useful for spatial analysis during the course

Besides the tools for spatial analysis students learn other tools for map layers modification. Modification of data is often essential before spatial analysis itself is realized. Basic modification of map vector layer is filtration and questioning resulted in the concrete features, which fulfil our spatial or attribute conditions. The other modifications can be map layers overlapping (e.g. join, difference, intersection), and conversion from raster to vector format or contrariwise.

What kind of outputs we expect and in which form?

After answering the basic questions, we can start mapping layer processing, spatial analysis and creation of map outputs. All these three operations are not always present in problem solving, therefore some solutions require just analysis without modifications of map layers. Other cases require only modifications of map layers without spatial analysis or several following modifications of analysis. Outputs creation can bring valuable outputs from every step in this phase (modification of layers or analysis) and therefore it is not possible to integrate output creation only into the final phase.

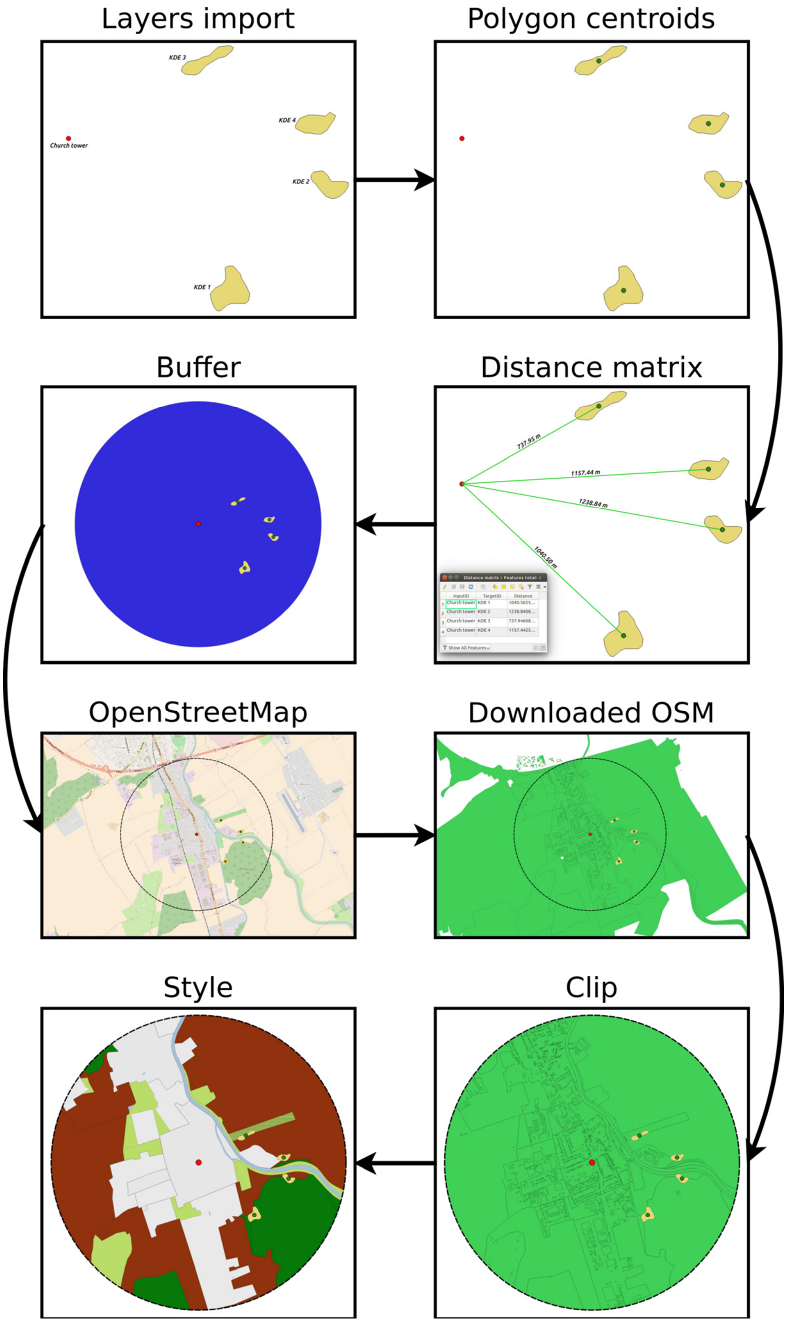

Figure 4: Examples of problem tasks solved by students

The solution results can be in a form of map outputs (Figure 4), tables or graphs. Students usually work individually on the results, but in some cases the map layer results can be connected into one common result, depending on the requirements of the problem situation. If the result is a common output, students have to communicate as a group (verbal communication, LMS Moodle chat) from the first steps of problem solving, because of the unification of scale, generalization degree, and unification of procedural steps. The last phase of dealing with problem situation is dissemination.

Large part of the data that students use to solve their tasks, are usually stored in their own repository (personal cloud or any other personal storage). As the evaluation process is finished, layers created by students (Figure 2) can be shared through the department geodatabase. Fulfilled tasks can be uploaded for evaluation by lecturer via SFTP client. Part of the results is only accessible within the university LAN and finished data, ready for publication, are available through HTTP, WMS or WFS to the general public. Layers created by students are mostly vectors, created by direct methods (application of GPS, digitalization) and by derived mapping (results of spatial analysis). Data dissemination is provided through GeoServer, which is serving as information hub linking different data sources (vector files, database, raster data) and make them accessible through Web services.

E-learning course was created as a support of the course teaching in academic year 2017/2018. It brings to students theoretical outcomes and offers methodical process for revision of practices which were already realized.

Students can revise already completed practices and spatial analysis available for individual practice. As it is showed in Figure 5, content of e-learning course corresponds with actual face-to-face education with exception of methodical processes for each practice, which are made available after corresponding face-to-face practice is over. Reason is realisation of practices applying IBL approach where methodical processes are incorporated into education content which is inquired by students. When face-to-face practice is evaluated and finished methodical processes are added into e-learning course. Students can use them for comparison of their own processes and for revision.

Besides the methodical processes linked with each practice, corresponding theoretical outcomes are present directly on the sites where concrete analytical tools are used. These outcomes are marked in the text. Students learn about individual analytical tools in the sites where the tools are used practically what directly mirrors the possibilities and ways of their use.

Another particularity of e-learning course is use of dictionary that is also used as a source of information on tools for spatial analysis. As the theory is implemented only when the analysis is used for the first time, another use of the same analysis (its next use, use in next practice) is not linked with previous theory but the Dictionary can be used to get basic information on the analytical tool, its function, inputs, settings, outputs and use. This manner of obtaining basic theory can students appreciate when one click is needed to get the appropriate information from the practical part of e-learning.

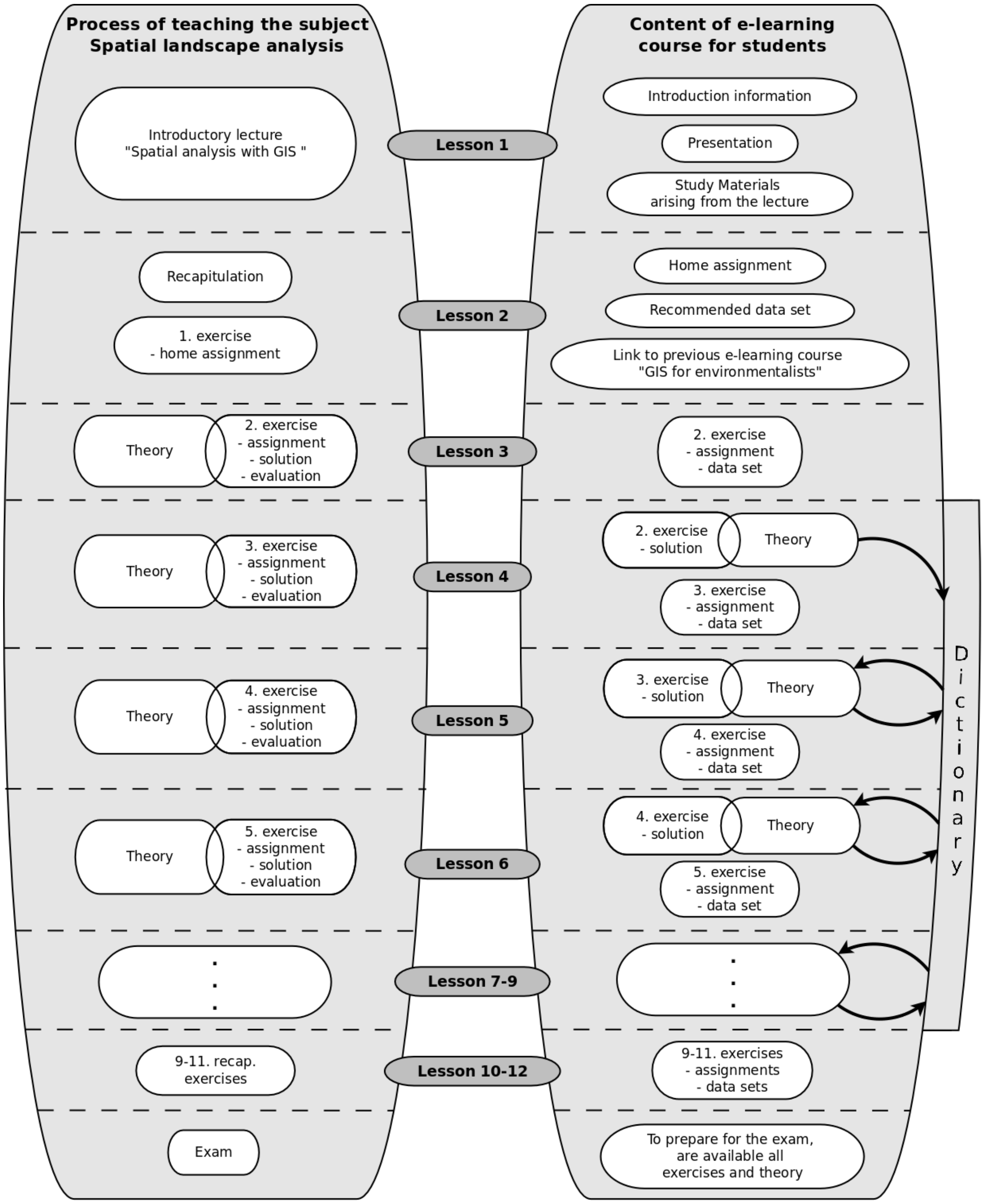

Figure 5: Carrying content of e-learning course Landscape Spatial Analysis.

E-learning course brings a great advantage especially for home preparation of students for examination practical tasks from the course. The examination also has practical nature, students are working using computers on their practical tasks.

5. Discussion

Fundamental object of research and education of students at the Department of Ecology and Environmental Science is landscape, its structure, attributes, changes in space and time, study of mechanisms which run the changes and study of its influence on spreading the plant and animal species. From this reason all the data which students meet during the study has spatial character.

The course Landscape Spatial Analysis is aimed at teaching the students in selected spatial analysis via solving the practical problem situations with use of real data. A science, a technology, and a discipline, allow involving the integration of spatially referenced data in a problem-solving environment is GIS (Cowen, 1988; Longley, Goodchild and Maguire, 2005).

Education in GIS at our department started in 2004. From that time we tried to apply several different technologies, education forms and pedagogical approaches. Based on our present experiences with education in GIS allow us to suggest some ideas and recommendations for teaching them:

5.1 Scientific solutions for authentic problem scenarios

Several of scientific studies were devoted to GIS education with use of practical problems solution (e.g. Chen, 1998; Demirici, Karaburun and Ünlü, 2013; Bowlick, Bednarz and Goldberg, 2016). Mentioned studies use an integrated problem-solving approach to teaching GIS by applying the Project-based learning.

Our approach uses IBL whereby gives students the opportunity to solve real-life problems using scientific methods. Moreover, IBL brings another practical dimension to these practical oriented courses - from a „Research-oriented“ to a „Research-based“ education, where according to Griffiths (2004) students learn as researchers, the curriculum is largely designed around inquiry-based activities, and the division of roles between teacher and student is minimised.

The analytical tools and processes used in our course are selected with the learning objectives of the curriculum in mind and from real problems, which graduates will encounter in professional practice.

5.2 Use of IBL in GIS education for increase students motivation to learn

GIS education via IBL showed us two motivating facts. The first is the Solving authentic problems using professional systems and real data. Students have to find solutions for the problems posed by solving individual tasks, using real data and professional systems (such as GIS, GPS, WMS, DBMS) (Figure 2). These modern methods of processing and analysing data are highly sought after in practice, so graduates acquire disciplinary subject knowledge and skills that enhance their attractiveness on the job market. The second is the Student-driven solution of problem situations. According to Thomas (2000) problem-solving in IBL should be predominantly student-driven. IBL problems (question, situation) are not, in the main, teacher-led, scripted, or packaged. Within our model, projects do not end with a predetermined outcome or take predetermined paths. IBL incorporates a good deal more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction and traditional projects. Figure 2 contains a diagram describing the logical sequence of the project implementation steps, but at every step the student has the opportunity to choose from a variety of GIS tools and settings to use for solving the problem.

5.3 GIS education is not only about the GIS

The proposed model combines IBL and ICT toward a common unified goal - to make teaching of spatial analysis more efficient and modern. In our model, IBL represents a student-centred, active learning approach, according to Ertmer (2015) and ICT covers several heterogeneous technologies and information systems. While the GIS GPS, and WMS systems present the work with geospatial data, LMS represents a valuable information source for students as well as an instrument for communication between teacher and students and among the students themselves during work on student projects.

According to Gaible et al (2011) students are frequently ready to benefit from instructional methods, therefore use of ICT in the educational process does not present any problem for them. We agree with Rose (2009) and Livingstone (2012) that ICT skills are becoming accepted as a third life skill alongside literacy and numeracy.

Students' orientation towards ICT is therefore best viewed in relation not only to their needs for social networking and leisure use of technologies, but also in relation to the way in which ICT is used in relevant areas of employment (Edmunds, Thorpe and Conole, 2012). So ICT becomes an efficient medium (LMS Moodle in our case) for dissemination of educational content and a convenient way to increase student motivation to learn. Besides enhancing interest and motivation Blumenfeld et al (1991) identified further 5 contributions that technology can make to the learning process and that we approved positively: Providing access to information; allowing active, manipulable representations; Structuring the process with tactical and strategic support; Diagnosing and correcting errors, managing complexity and aiding production.

Combination of IBL and e-learning for increasing efficiency of education – teaching of the course Landscape Spatial Analysis is organised as blended learning which combines Online and Face-To-Face Education (Watson, 2008). Face-To-Face education means in our case practices of the course via IBL and is focused on receiving of new knowledge and skills as well as its application. Online education presents e-learning course with the main function to revise acquired knowledge and skills and to prepare students for the examination.

5.4 Interdisciplinary character of education does not have only positive effect

On one hand cross-disciplinary character of GIS causes development of wide range of key competences (Jakab, Grežo and Ševčík, 2016). On the other hand GIS require certain basic knowledge and skills from various scientific disciplines, at least from geography, computer science and mathematics. Moreover they require logic and spatial orientation.

This means that GIS education can cause problems in study programs, which are far from geoinfomatics.
We meet this reality at our department as well. Students often choose study program Environmental Science with expectations that they do not battle with mathematics, computer science, logic etc. Therefore they can consider courses in GIS to be demanding and thus unattractive. Permanent low number of students who chose optional courses focused on GIS supports this fact. However optional courses in GIS are taught with the same education model as well as they are taught by the same teachers, the main reason why only small number of students chose the courses is their demandingness coming from their cross-disciplinary character.

6. Conclusion

GIS education in general comes down to just 4 simple ideas: create your own geospatial data, manage it, analyse it and display it on a map.

These ideas show possibilities of GIS application everywhere where the spatial data linked with earth surface is used. GIS can be used efficiently not only in education in geography (e.g. Kemp, Goodchild and Dodson, 1992; Yap et al, 2008; Singh, Kleeman and Van Bergen, 2012) but also in other disciplines: environmental science (Ayuga et al, 2007; Ozbay et al, 2014), history (Zainol and Yacob, 2014; Ribeiro and Bragadacosta Monteiro, 2014), mathematics (Furner and Ramirez, 1999; Čeretková, 2016), chemistry (Reed et al, 2008) and others.
Each implementation of GIS into the science, art disciplines and mathematics meets with two approaches of GIS teaching according to Sui (1995). On one hand students learn via GIS subject matter arising from the discipline. On the other hand use of tools, methods and concrete software environment familiarize with GIS themselves.

The course Landscape Spatial Analysis within the Environmental science study program applies the approach mentioned above. Students familiarize with GIS via spatial analysis that can be used for evaluation of landscape data.

For increasing the efficiency of the Landscape Spatial Analysis course we have created the model of GIS education based on the idea of IBL according to Dewey (1964) that science education should be authentic to science practice. The model connects:

1. face-to face education and distance learning,
2. practical work with real problem solving (real methods, real data),
3. use of professional systems (used for work with geospatial data) with applying the *learning management systems.*

Based on our long-term experiences with GIS teaching, this new and actual education model appears to be useful for the course Landscape Spatial Analysis within the ES study program as well. It could be used as an idea how to increase efficiency of higher education in GIS in the study programs which work intensively with geospatial data.

Acknowledgements

The work was supported by the projects VEGA 1/0608/16 and KEGA 025UKF-4/2015.

References

Audet, R.H. and Ludwig, G.S. (2000). *GIS in schools*, Environmental Systems Research Institute, Redlands, CA.

Ayuga, T., Gonzalez, G., Velazquez et al (2007) "Internet and ArcGis resources, tools for the supervized teaching of Geographic Information Systems (GIS) in Environmental Sciences", *6th Spanish American Conference on Systems, Cybernetics and Informatics*, Vol II, pp 1–5.

Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J., Guzdial, M. and Palincsar, A. (1991) "Motivating project-based learning: Sustaining the doing, supporting the learning", *Educational Psychologist*, Vol 26, No. 3, pp 369–398. doi: 10.1207/s15326985ep2603and4_8

Bowlick, F.J., Bednarz, S.W. and Goldberg, D.W. (2015) "Student learning in an introductory GIS course: Using a project-based approach", *Transactions in GIS*, Vol 20, No. 2, pp 182–202. doi: 10.1111/tgis.12146

Colburn, A. (2000) An inquiry primer, *Science scope*, Vol 23, No. 6, pp 42–44.

Cooper, M.D. (1985) "Teaching database management system use in a library school curriculum", *Journal of the American Society for Information Science*, Vol 36, No. 5, pp 330–338. doi: 10.1002/asi.4630360508

Coppola, Ch. and Neelley, E. (2004) *Open source - opens learning: Why open source makes sense for education*, [online], http://arizona.openrepository.com/arizona/bitstream/10150/106028/1/OpenSourceOpensLearningJuly2004.pdf. [Accessed 25 May 2016].

Couclelis, H. (1992) "People manipulate objects (but cultivate fields): beyond the raster-vector debate in GIS", *Theories and methods of spatio-temporal reasoning in geographic space,* pp 65–77), Springer, Berlin Heidelberg.

Cowen, D. J. (1988) "GIS versus CAD versus DBMS: What are the differences?", *Photogramm. Eng. Remote Sens.*, Vol 54, No. 11, pp 1551–1555.

Čeretková, S. (2016) *Materials for Teaching Together: Science and Mathematics Teachers collaborating for better results*, p 133, Palacký University Olomouc, Olomouc.

Dana, P. H. (1997) Global Positioning System (GPS) time dissemination for real-time applications, *Real-Time Systems*, Vol 12, No. 1, pp 9–40.

Demirci, A., Karaburun, A. and Ünlü, M. (2013) "Implementation and effectiveness of GIS-Based projects in secondary schools", *Journal of Geography*, Vol 112, No. 5, pp 214–228. doi: 10.1080/00221341.2013.770545

Dewey, J. (1964) Progressive organization of subject matter, *John Dewey on Education*, pp 373–387.

Drent, M. and Meelissen, M. (2008) "Which factors obstruct or stimulate teacher educators to use ICT innovatively?", *Computers and Education*, Vol 51, No. 1, pp 187–199. doi: 10.1016/j.compedu.2007.05.001

Dueker, K. J. and Kjerne, D. (1989) "Multipurpose Cadastre: Terms and Definitions", *ASPRS/ACSM Annual Convention Technical Papers*, Vol 5, pp 94–103.

Edelson, D., Gordin, D. and Pea, R. (1999) "Addressing the challenges of inquiry-based learning through technology and curriculum design", *Journal of the Learning Sciences*, Vol 8, No. 3, pp 391–450. doi: 10.1207/s15327809jls0803and4_3

Edmunds, R., Thorpe, M. and Conole, G. (2012) "Student attitudes towards and use of ICT in course study, work and social activity: A technology acceptance model approach", *British Journal of Educational Technology*, Vol 43, No. 1, pp 71–84. doi: 10.1111/j.1467-8535.2010.01142.x

Ertmer, P.A. (2015) *Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows*, Edited by Andrew Walker and Heather Leary, Purdue University Press, United States.

Feletti, G. (1993) "Inquiry based and problem based learning: How similar are these approaches to nursing and medical education?", *Higher Education Research and Development*, Vol 12, No. 2, pp 143–156. doi: 10.1080/0729436930120203

Forouzesh, M., and Darvish, M. (2012) "Characteristics of Learning Management System (LMS) and Its Role in Education of Electronics. In Conference proceedings of» eLearning and Software for Education", *eLSE*, No. 01, pp 495–500, Universitatea Nationala de Aparare Carol I.

Furner, J.M. and Ramirez, M. (1999) "Making connections", *TechTrends*, Vol 43, No. 4, pp 34–39. doi: 10.1007/bf02763232

Gacek, C. and Arief, B. (2004) "The many meanings of open source", *IEEE Software*, Vol 21, No. 1, pp 34–40. doi: 10.1109/ms.2004.1259206

Gaible, E et al, (2011) *First Principles: Designing Effective Education Programs Using Information and Communication Technology (ICT)*, [online], http://www.equip123.net/docs/E1-FP_ICT_Compendium.pdf. [Accessed 25 May 2016].

Garrison, D.R. and Kanuka, H. (2004) "Blended learning: Uncovering its transformative potential in higher education", *The Internet and Higher Education*, Vol 7, No. 2, pp 95–105. doi: 10.1016/j.iheduc.2004.02.001

Griffiths, R. (2004) "Knowledge production and the research–teaching nexus: The case of the built environment disciplines", *Studies in Higher Education*, Vol 29, No. 6, pp 709–726. doi: 10.1080/0307507042000287212

Hansen, H. S., Viuf, P., Loibl, W., Peters-Anders, J., Zudin, S., and Vogt, J. (2008) "Requirements for data management and maintenance to support regional land use research", *Sustainability Impact Assessment of Land Use Changes*, pp 269–290, Springer, Berlin Heidelberg.

Hippel, E. von and Krogh, G. von (2003) "Open source software and the "Private-Collective" innovation model: Issues for organization science", *Organization Science*, Vol 14, No. 2, pp 209–223. doi: 10.1287/orsc.14.2.209.14992

Hmelo-Silver, C.E., Duncan, R.G. and Chinn, C.A. (2007) "Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006)", *Educational Psychologist*, Vol 42, No. 2, pp 99–107. doi: 10.1080/00461520701263368

Chen, X.M. (1998) "Integrating GIS education with training: A project-oriented approach", *Journal of Geography*, Vol 97, No. 6, pp 261–268. doi: 10.1080/00221349808978843

Jackson, M. J., and Woodsford, P. A. (1991) GIS data capture hardware and software, *Geographical Information Systems: Principles and Applications*, Vol 1, pp 239–249.

Jakab, I., Grezo, H., and Sevcík, M. (2016) "Inquiry Based and Blended Learning Using Geographical Information System", *ECEL 2016-Proceedings of the 15th European Conference on e-Learning*, pp 287–295.

Kemp, K. K., Goodchild, M. F., and Dodson, R. F. (1992) "Teaching GIS in Geography", *The Professional Geographer*, Vol 44, No. 2, pp 181–191.

Livingstone, S. (2012) "Critical reflections on the benefits of ICT in education", *Oxford Review of Education*, Vol 38, No. 1, pp 9–24. doi: 10.1080/03054985.2011.577938

Longley, P.A., Goodchild, M.F. and Maguire, D.J. (2005) *Geographic information systems and science*, John Wiley and Sons, New York.

Mitchell, A. (1999) *The Esri guide to GIS analysis: Volume 1: Geographic patterns and relationships*, Environmental Systems Research Institute Inc., U.S., Redlands, CA.

Munoz, D., Lara, F.B., Vargas, C. and Enriquez-Caldera, R. (2009) *Position location techniques and applications,* Elsevier Science, Amsterdam.

Ozbay, G., Sriharan, S., Fan, C., Prakash, A. and San Juan, F. (2014) "Application of geographic information system (gis) in environmental science and sustainable agriculture education", *EDULEARN14 Proceedings*, pp 415–424, IATED.

Parker, H. D. (1988) "The unique qualities of a geographic information system: a commentary", *Photogrammetric engineering and remote sensing (USA)*.

Plomp, T., Brummelhuis, A. and Rapmund, R. (1996) *Teaching and learning for the future. Committee on Multimedia in Teacher Training, Final Report.*

Reed, S. M., Ayres, B. R., Kulkarni, A., Sanghvi, N. and Garrick, W. (2008, April) "CHED 136-Using geographic information systems (GIS) tools in chemical education: Chem map web site", *Abstracts of papers of the american chemical society,* Vol 235, AMER CHEMICAL SOC., 1155 16TH ST, NW, WASHINGTON, DC 20036 USA.

Ribeiro, V. and Bragadacosta Monteiro, I. (2014) "Enhancing the teaching and learning of history and geography through gis: the case of routes and battles of peninsular war (1807-1814) DIGITAL MAP", *ICERI2014 Proceedings*, p. 3016–3024.

Rose, J. (2009) *Identifying and teaching children and young people with dyslexia and literacy difficulties: an independent report*.

Rouse (2005) *What is ICT* (*information and communications technology - or technologies*), [online], http://searchcio.techtarget.com/definition/ICT-information-and-communications-technology-or-technologies [Accessed 25 May 2016].

Ruas A. (2008) *Encyclopedia of GIS: Map generalization*, pp 631–632, Springer, New York.

Singh, S.S.B., Kleeman, G. and Van Bergen, P. (2012) "Opportunities to implement GIS in teaching and learning geography: A survey among smart schools in Sabah, Malaysia", *Procedia - Social and Behavioral Sciences*, Vol 69, pp 884–889. doi: 10.1016/j.sbspro.2012.12.012

Staver, J.R. and Bay, M. (1987) "Analysis of the project synthesis goal cluster orientation and inquiry emphasis of elementary science textbooks", *Journal of Research in Science Teaching*, Vol 24, No. 7, pp 629–643. doi: 10.1002/tea.3660240704

Sui, D.Z. (1995) "A Pedagogic framework to link GIS to the intellectual core of geography", *Journal of Geography*, Vol 94, No. 6, pp 578–591. doi: 10.1080/00221349508979371

Thomas J. W. (2000) *A review of research on project-based learning*, [online], http://bobpearlman.org/BestPractices/PBL_Research.pdf [Accessed 25 May 2016].

Watson, J. (2008) *Blended Learning: The Convergence of Online and Face-to-Face Education. Promising Practices in Online Learning*, North American Council for Online Learning.

Yap, L.Y., Ivy Tan, G.C., Zhu, X. and Wettasinghe, M.C. (2008) "An assessment of the use of geographical information systems (GIS) in teaching geography in Singapore schools", *Journal of Geography*, Vol 107, No. 2, pp 52–60. doi: 10.1080/00221340802202047

Zainol, R. and Yacob, S. P. (2014) "Embedding web-based geographic information system (web-based gis) in teaching and learning of history", *Proceedings of EDULEARN14 Conference,* [online], http://eprints.um.edu.my/13411/1/1262.pdf.