Cartographic Education in Geomatics Curriculum

Otakar Čerba, Václav Čada, Martina Vichrová, Karel Jedlička, Karel Janečka, Jakub Šilhavý, Jan Ježek

ABSTRACT: Geomatics is a multidisciplinary science branch connected with many different subjects such as surveying, geoinformatics or remote sensing. Also cartography and spatial data visualisation represent a important part of geomatics. What is the current position of cartography among above mentioned sciences in geomatics curriculum? It is necessary to realize that cartography transforms complicated spatial data products to clear, intelligible and attractive outputs (maps and similar products). Cartography summarizes and presents all results of other parts of geomatics. Also cartography influences all disciplines focused on spatial data capturing and processing as well as it is influenced by them. This paper describes the role of cartography (as the tool to spatial data visualization and presentation) in geomatics curriculum in general, including relation to change of paradigm of university education. The following part shows the state-of-the-art of cartographic courses (e.g. Thematic Cartography or History of Maps and Mapping) and related subjects (e.g. Introduction to GIS or Social-economic Geography for Geomatics) at the University of West Bohemia in Pilsen (Czech Republic), where the strong connection between cartography and geomatics has a long tradition (more than fifteen years). The last part introduces the new activities focused on cartography. It means research projects (VisualHealth), networking projects (NeoCartoLink), educational projects (Multimedia Geomatics) and implementation of results of bachelor and master thesis. The new activities are also connected to application of new knowledge (domain knowledge as well as common pedagogical knowledge) and cartographic trends (web cartography, real-time mapping or server solution for historic and old maps).

KEYWORDS: geomatics, education, cartography, course, teaching

Introduction

At first we would like to mention the information published by U.S. Department of Labor – it has designated Geotechnology as one of the three "mega-technologies" of the 21st century – right up there with Nanotechnology and Biotechnology (in Berry, 2006). Previous sentence emphasizes the importance and key role of geotechnological activities, including an education of geomatics and cartography now as well as in the future.

Considering the multidisciplinary substance of geomatics experts are discussing various components of geomatics curricula at universities, their extents and interconnections. There are two extreme approaches – tending to traditional disciplines (e.g. surveying) or focus on modern technologies (e.g. geographic information systems /GIS/).

Regardless of the representation and interaction between those two extreme approaches creators of geomatics study programmes incorporate the study and cartography and their

various disciplines. The cartography is found in study programmes as particular single courses (see selected courses at the University of West Bohemia /Czech Republic/ in following sections). Cartography is also connected with other geomatics courses such as GIS or geography. In these courses some cartographic rules and principles are taught as well.

Why are cartography and spatial data visualization so important? It is necessary to realize that cartography is able to transform very complicated spatial data products to clear, intelligible and attractive outputs (maps, plans, globes and similar products such as digital 3D browsers). These cartographic products are very important and understandable above all for many non-expert users. Because other forms of spatial data presentation (e.g. tables, graph, texts...) are not able to transfer an information in such easy way. Cartography summarizes and presents all results of other parts of geomatics that are focused on data capturing (e.g. surveying, photogrammetry) and processing (e.g. GIS, databases).

Cartography influences all disciplines focused on spatial data capturing and processing as well as it is influenced by them. The theoretical principals of these sciences are quite stable, because all disciplines have strong and comprehensive background. But the technologies are changing very fast. Therefore a cartographic education is also very important, because geomatics experts need to be in touch with modern methodologies, technologies and tools.

The technological evolution plays one of the main roles in the incorporation of cartography into geomatic curriculum, but it does not just depend on technologies. It is necessary to mention importance and influence of globalization or development of pedagogical methodologies, techniques and technologies.

This paper describes the role of cartography (as a science as well as the tool to spatial data visualization and presentation) in geomatics curriculum in general, including relation to change of paradigm of university education. The following part shows the state-of-the-art of cartographic courses (e.g. Thematic Cartography or History of Maps and Mapping) and related subjects (e.g. Introduction to GIS or Social-economic Geography for Geomatics) in Section of Geomatics (gis.zcu.cz) at the University of West Bohemia (Czech Republic), where the strong connection between cartography and geomatics has a long tradition (more than fifteen years). The next parts introduces the new activities focused on cartography. It means research projects (VisualHealth, research of old maps), networking projects (NeoCartoLink), educational projects (Multimedia Geomatics) and implementation of results of bachelor and master thesis. The new activities are also connected to application of new knowledge (domain knowledge as well as common pedagogical knowledge) and cartographic trends (web cartography, 3D cartography, real-time mapping or server solution for historic and old maps).

This paper continues in previous articles focused on education activities in the Geomatics section in the University of West Bohemia, Plzen (Czech Republic). These articles were published during last years in various international conferences such as 24th International Cartographic Conference (Čerba et al., 2009), 23th International Cartographic

Conference (Baranová and Čerba, 2007), Joint ICA Symposium (Čada et al., 2011), New Perspective in Science Education (Čerba et al., 2012a), 19. kartografická konference (Vichrová et al., 2011), 4nd International Conference on Cartography and GIS (Čerba et al., 2012b), 2nd International Conference on Cartography and GIS (Baranová et al., 2008), V1 Magazine (Čerba et al., 2010). They opened a discussion on cartographic and geomatic education as well as they provided an important feedback to improve our cartographic and other courses.

Cartography in the Geomatics Curriculum – Overview

Description of Courses Connected with Cartography

Upcoming paragraphs are focused on description of particular subjects. We provide a brief description here as well as our opinion why we see these subjects to be important for our graduates.

One of the courses that are focused on mathematical b aground of cartographic are called Mathematical Cartography 1 and Mathematical Cartography 2. These courses are focused on introduction to following themes: Form of the Earth, reference surfaces, coordinate systems, curves on the reference surfaces, principles of deformations, basic map projections, spherical trigonometry and some calculations on the sphere, cylindrical, azimuthal and orthographic projections. We see the importance of this courses as cartographic projections and related theory is essential part of every GIS system. Even such simple task as measuring of distance or area is hardly influence by cartographic projection and its mathematical aspects. Even if we are not using the ruler and paper map to measure distance from the map nowadays (most people probably use web maps like Google maps or GIS), we have to educate students in the theory how such information is calculated. Such subject is essential for the GIS experts as they should know not just how to work with particular software but also what algorithms and precision can be expected by particular calculation. We also focus on practical issues related to coordinate reference systems and their transformations. Topics like EPSG (European Petroleum Survey Group) database, coordinate transformation methods and related OGC (Open Geospatial Consortium) standards are also taught within these subjects.

Course Thematic Cartography is a part of bachelor study program. Therefore it is more practically focused than following courses. The target is to teach students to create thematic maps and use cartographic methods (dasymetric maps, isoline maps, choropleth maps, diagram maps, cartograms etc.). Students have to know and keep essential cartographic rules such visual variables, basic of map composition or using of colors. This course represents the final phase of geomaticts framework – data capturing, data processing and data publishing. Except above-mentioned lessons students meet the fundamental theory of cartography, overview of thematic maps produced by army and state administrative of the Czech Republic and basic overview of history of cartography. The big part of course focused on history of cartography was shifted to the new course History of Maps and Mappings. Therefore this course is more concentrated on practical construction of various types of thematic maps. After absolving students should be able to analyze input data, to select suitable cartographic technique (based on data analyze, user

requirements and specifics of output map) and create the thematic map or similar cartographic product. The choice of useful tools is not solved in this course (it is a part of previous course such as Introduction to GIS). In the near future we plan another changes above all total reconstruction of syllabus. It should not be based on classification of techniques of thematic cartography. The new version should be focused on character of visualized spatial data and transferred information.

The target of course History of Maps and Mapping is a summary of information on the development of the field of cartography and mapping, and especially the creation of connections and relationships between the old maps, plans and technical methods and current products of cartographic visualization of spatial data. There is very important to embed cartography and mapping in a broader historical context. Cartography is an integral part of the course. The students in this course get new information about the importance of the history of cartography and old maps, about the first mapping's initiatives, cartography and mapping in the 18th, 19th and 20th century, personalities of cartography and mapping, history of cartographic projections, about the history of international cooperation of cartographers, old and historical, archives and map collections, about technical and technological development of equipment for mapping and interdisciplinary applications of old maps and map sets. Thanks advanced digital techniques there are used the accesses to map portals with old maps, digital accesses to map collections of archives and museums at the course.

The goal of the course Introduction to Geographic Information Systems is to present to students following topics: Definition and basic terminology in GIS. Fundamentals of GIS. Data structure of GIS - simple and hierarchy data structure, raster data structure. Fundamentals of vector data structure - points, lines and polygons. Data getting and organization. The course focuses on theoretical principles and technical background of GIS. There of course are several interconnections to cartography, namely cartographic projections and basics cartographic techniques used mainly for simple symbolization of GIS outputs. But there is no cartography teaching, because there exists cartographic specific courses in the Geomatic Curricullum - see Mathematical Cartography, Thematic Cartography or Computer Cartography. There is no plan of involving more cartography in the course - there is just continuing communication with teachers of cartographic courses - to keep above mentioned interconnections up to date.

Course Social-economic Geography for Geomatics is focused on spatial data sets and their processing in various disciplines of social-economic geography. The course is divided into zhe two parts. The first part is designated for spatial data, ways of spatial data description (metadata, ontologies) and spatial data harmonization (including harmonization of visualization rules). The second part covers basics of socio-economic geographical disciplines (e.g. geography of votes, geography of transport etc.) and geodemography. Cartography is not a special subject of course. But student need to have cartographic knowledge to process and present geographical data. Students use various techniques of thematic cartography (e.g. choropleth maps, diagram maps, isolines) in their final works that consist in a solution of particular spatial data harmonization or geographic problem. Therefore a completion of course Thematic Cartography is necessary. In the near future we would like to extend the cartographic portfolio of the

course of two main sections – Style Layer Descriptor (as a "cartographic standard" of web services) and modern methods of spatial data visualization (e.g. animations, 3D Earth browsers, visualization web services and non-cartographic methods /graphs, infographics/).

Course Computer Cartography represents the most advanced cartographic course in geomatics study programm. The contemporary version of course is focused on Internet cartography. The main part of course covers an overview of markup languages connected with cartography. Students meet various formats and languages based on Extensible Markup Language (XML) that represent an universal exchange format in the world of information technologies. They are educated in basic spatial formats (Geography Markup Language, Keyhole Markup Language), transformation styles and languages (Extensible Stylesheet Language – Transformation, Cascading Style Sheets) and formats coding common vector data (Scalable Vector Graphics). The fundamental concept of this course could be described as complete process of transformation of spatial data to thematic maps with using open markup language standards. Except this essential idea there are another topics such theory of digital maps, trends and news in cartography. In the future we would like to deepen a cooperation with other similar courses that occupy with digital maps, web services and spatial data visualization. We want also to extend a theoretical part of course (specifics of digital and Internet maps, user issues) and to mention another possibilities how to create a thematic map on the Internet.

The goal of the course Algorithms of Spatial Analyses is to present to students following topics: Symbolizing spatial analyses. Algorithms of digital elevation model creation. Computing continuous surfaces directly from vector data. Spatial statistics methods. Selected spatial analyses. Spatial modeling. The course is focused on the analytical part of GIS. During a typical geographic analysis in a layer based GIS, there come many intermediate layers which the symbology is not much important. Therefore symbolization does not play any crucial role. But projection parameters has to be taken into account when the analysis is realized in large areas/small scales or when source datasets are in different coordinate systems. Again, there is no cartography teaching, because there exist cartographic specific courses in the Geomatic Curricullum.

The course Spatial Databases aims to give a basic introduction on spatial databases, data structures, spatial indexes and spatial data modeling and analysis. Some part of the course is devoted to practical examples using the most commonly used spatial data engines like Oracle Spatial, PostGIS and ESRI Geodatabase. As the spatial databases play more and more important role in cartography, the content of selected lessons is going to reflect this fact. Nowadays the data that serve as a base for final maps are stored in spatial databases and therefore the course provides basic principles how to store the multidimensional data effectively. To produce a cartographic product of a good quality the data stored inside the spatial database must be also valid and if possible without huge amount of duplicities. That is the reason why is a part of the course oriented on the topic how to ensure spatial data consistency. The content of lessons is updated on a regular base to provide students with up-to-date information. In the near future it is supposed to cover new cartographic topics dealing with spatial databases like cartographic and data model generalization. In particular the technological information about how the National Mapping Agencies are

creating the map series from the spatial databases point of view could be potentially very interesting and useful. This topic also covers the problem of how to deal with Digital Cartographic Model against the Digital Landscape Model in one spatial database.

The course Applications of GIS is focused on the possibility of extending the standard functionality of the user interface of geographic information systems using programming techniques. Students will learn the application programming interface (API) in particular geographic software. Students learns how to develop an event-driven extension of GIS using their knowledge of the principles of object-oriented programming. Furthermore, the course aims to introduce students to current trends in the field of geographic information systems: geoinformation software, GIS implementations, distributed GIS and 3D GIS. According to modern trends, whose include 3D visualization to cartography (see e.g. True 3D cartography), it is possible to say that 3D cartography is being teached in this course. Due to the increasing emphasis on 3D visualization in geosciences these days, the course curriculum will be extended to 3D techniques in GIS and related disciplines, including 3D cartography.

Cartography in the Geomatics Curriculum – Students' Point of View

The goal of short voluntary survey among students of Geomatics was to find out the influence of cartography to students in their personal and professional life as well as evaluate the teaching of cartography at the University of West Bohemia.

The students of cartographic courses and related subjects were asked using questionnaire. There were 13 responses collected form addressed students (approximately 45 %). Their responses are presented in a graph and table form in the following paragraphs.

The students were asked to evaluate overall quality of cartography education at our university. As shown in figure 1, the most frequent answer was above-average level of quality. This very good rating could be influenced by results of project Multimedia Geomatics (mentioned in Čerba et al., 2012a), the educational project which improved study materials of many subject in the previous year.

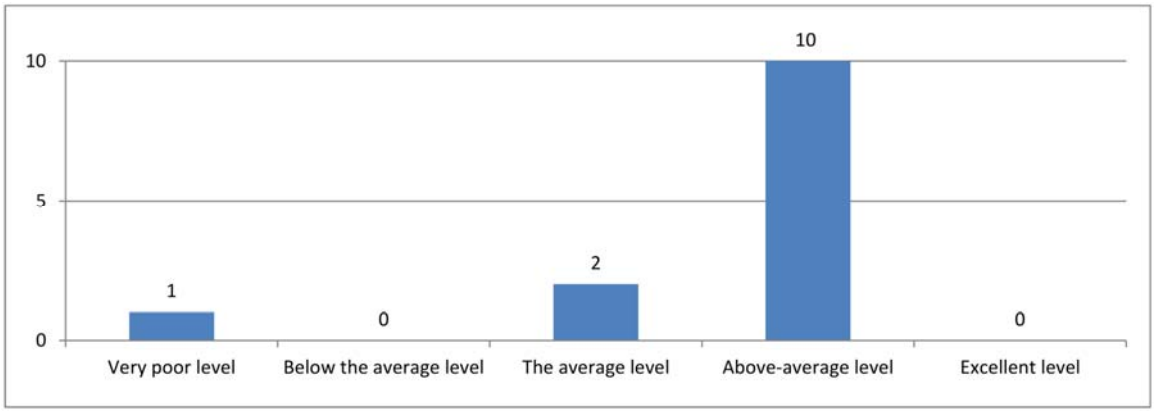

Figure 1. How do you rate the overall quality of cartography education in your study?

In the main part of the questionnaire, the specific cartography disciplines were evaluated. The significance of the different disciplines and their outputs were rated according to use

in professional or personal life. The scale form 1 (essential) to 5 (no significance) was used. The average results are shown in the Table 1.

Table 1. The rating of specific cartographic disciplines related to professional or personal life.

Cartographic disciplines evaluated by students	Professional life		Personal life	
	Average	Description	Average	Description
Large-scale mapping	**2,2**	above-average	**2,5**	above-average
Computer (Digital) Cartography	**2,2**	above-average	**2,4**	above-average
Topographical mapping	**2,3**	above-average	**2,2**	above-average
Internet (Web) Cartography	**2,3**	above-average	**1,9**	above-average
Cartographic production	**2,5**	above-average	**2,7**	average
Thematic Cartography	**2,6**	average	**2,3**	above-average
3D Cartography	**2,7**	average	**2,9**	average
Mathematical Cartography	**2,7**	average	**2,8**	average
Geographical Cartography	**2,8**	average	**2,4**	above-average
Cartographic reproduction a printing	**3,0**	average	**3,1**	average
Cartometry	**3,0**	average	**3,1**	average
Atlas Cartography	**3,4**	average	**2,7**	average

Based on the results of the questionnaire (all respondents work or want to work in the field of geomatics) some interesting relations can be seen, e.g.:

- Comparing the influence of the cartography on a personal and professional life, the results are quite similar.
- The best rate in professional life got two disciplines – Computer cartography and Large-scale mapping. It is caused by two major focus of our students and their employees – surveying and GIS.
- The leading discipline in students' personal life is Internet cartography.

These points indicate that cartography has its important place for example in leisure time activities (maps for orienteering, planning of trips on web portals, etc.). This also probably deals with the fact that the number of web portals is rapidly increasing and portals offer more and more maps and useful functions for various kinds of activities.

In conclusion of this questionnaire we could state that work from educational projects like Multimedia Geomatics has positive impact to students rating. To achieve the excellent level of quality is good idea to continue doing similar kinds of projects.

Cartographic Research Project

Database of Settlements

At section of Geomatics at University of West Bohemia a map server for publishing of old maps is built. The maps that are published there (e.g. Müller's map) are a

cartographic jewel and belong to the cultural heritage. The map server also gives graphic information about the settlements. Some out of them already does not exist and so Database of Settlements (DBS) can be used for exploring of the historical development. These settlements are stored in the DBS containing the definition points and settlements' geographical names. The DBS serves for the old maps localization, query functions and displaying functions of web services.

This database is based on the Territorial Identification Register of Basic Settlement Units (TIR-BSU) which has been created in 1992-2004. The fundamental part of DBS is the SETTLEMENTS table. This table contains information about basic settlement units including definition points and Czech geographical names. The coordinates of centroids of settlements which are stored inside the DBS are considered as a base for localization of map collection into Datum of Uniform Trigonometric Cadastral Network (S-JTSK) coordinate system with accuracy of Czech Basic Map 1:10 000 (ZM10). Next important entity of DBS data model is the table for storing of definition points of settlements located in the Müller's manuscript map series of regions including German geographical names, a type of settlement and other related information (Hajek 2009).

Upon DBS it is possible to make various analyses. There were several students' projects or diploma work (Kralickova 2011) that used and investigated DBS. The DBS data model is normalized in order to ensure efficient processing of attribute and spatial queries. It is possible to analyse an accuracy of localization of the settlements inside and outside the region. Furthermore it is possible to obtain information about disappearance of some settlements or reversely about origin of new settlements. It is also possible to analyze the growing of particular settlements. As stated in (Cada 2011) comparing the name of the settlement in the Müller's map with actual name taken from TIR-BSU (e.g. Radomißchl – Radomyšl) or investigation whether actual name from TIR-BSU is a translation of the German equivalent (e.g. Schweineßchlag – Sviňovice) can be realized and the information about using of both of German and Czech (completed by letter B) names, e.g. Bohemice and .Böemisch respectively. Another important and interesting issue is a possibility to analyze the extent of German environment in the territory of Bohemia at the beginning of 18th century.

Historical Town's Atlas of Plzen

"Historical Town's Atlas of the Czech Republic", is a part of the European project for publishing historical atlases of towns. The Atlas is a valuable contribution to the comparative study of urban areas on the international scale and a remarkable publication achievement since a great number of old maps and plans. Each volume of the atlas contains a textual part, whit summarization of the history of the town from the point of view of archeology. The second part is the cartographic part. Each volume contains a bibliography, a list of sources and graphic documentation.

The cartographic part includes reproductions of old maps and plans of the towns and their environs as well as thematic historical maps of the towns. Among these cartographic sources belong Müller's map of Bohemia from 1720 and Moravia from 1716, the first military maps from the times of the reign of Emperor Joseph II (the 1760's and 1780 s), the stable-cadastre from the 1820's to the 1840's, Kreibich's maps of the Czech regions

from the 1820's and 1830's, Schenkl's maps of the Moravia regions from the middle of the 19th century and the air photographs of the towns with the situation in the 1930's and 1940 s. Maps and plans, which in the past were not parts of extensive cartographic works, document the individuality of each town, (Historický ústav 2012).

The employees of department of Geomatics at the Faculty of applied sciences at the University of West Bohemia participated at the creation of Historical Atlas of the city Pilsen in the years 2008 and 2009. This is the 21st volume of edition - Historical Town's Atlas of the Czech Republic. The Historical Town's Atlas of Pilsen contains 67 maps and plans and about hundred images - reproductions of photographs, drawings and paintings. The text includes an overview of the history of Pilsen to the present. The digital version is available at: http://www.plzen.eu/o-meste/multimedia/ebook/knihy/ebook-historicky-atlas.aspx. The eBook is an important source for studying the history and development of the city Pilsen and comprehensive information about cartographic documents which are available for the area of city Pilsen.

Project VisualHealth

The two-year project VisualHealth (The Visualization of Health Data for the Support of Interdisciplinary Education and Relation with Public) tried to explore abilities of digital cartography to present health data from the Czech republic both to experts and public. In this project there were cooperating three partners from the Czech Republic

1. The University of West Bohemia in Pilsen (Faculty of Applied Sciences, Department of Mathematics, Section of Geomatics),

2. Masaryk University in Brno (the leader of the project),

3. Faculty Hospital Brno.

The project VisualHealth was focused mostly on cartographic visualization, on creating of different types of thematic maps of public health data for education, their presentation and popularization. Simple insight through easy comprehensible maps to this very complicated data could lead to a higher level of prevention and protection of health. The results of VisualHealth project are published on the web portal (http://zdravi.geogr.muni.cz), only a part of this portal is in English, because the maps and other outputs are mainly destined for Czech users. The portal is divided into two parts – for patients and for experts. Both parts contain different types of thematic maps and other components like vocabulary or list of sources. Within the framework of this project there are processed different cartographic methods of spatial data visualization on the Internet. There are four types of maps:

1. Static maps in PDF (Portable Document Format) format.

2. Dynamic maps based on XML source data, XSLT (Extensible Stylesheet Language – Transformation) templates and SVG graphics.

3. Interactive maps – Java tool designed for cartographic publication of time series of health data.

4. "Google" maps – thematic maps for Google Earth or Google Earth plugins generated from database in real-time. (Čerba, 2010)

New activities & changes

Following paragraphs discuss several new activities and trends in cartography that are connected with future of cartographic education and research in the University of West Bohemia.

The future of cartography as well as spatial databases are in a database driven cartography. The functionality and processing possibilities of spatial data engines are still growing up. The challenge that is standing before the cartography, especially before the web cartography, is development of new data structures that will allow transfer progressive data from a spatial database into the web environment. This deals also with the question how to store the spatial data and their cartographic representation in the most effective way.Very important question is still the spatial data generalization of data that are captured in real time. Typical example of such data are moving objects that provides their positions through Internet. In this case we have to deal with cartographic generalization of on data stream, samples zooming, scalability and with data simplification in time and space. In such case data are stored only once (with the highest level of detail) and then it is possible to generate data with the less level of detail on request. There are still many open questions regarding this topic and an extensive research must be done to bring the current results into practice.

Beside classic two dimensional maps, there always were projects focused on creating material three dimensional maps or landscape models. Rapid development of computer graphics has allowed also the production of maps in 3D virtual environments. Third dimension represents one of the opportunities of contemporary cartography. The importance of an interconnection of traditional cartographic methods and modern visualization in 3D is emphasized also in the part Geovisualization and visual analytics of document ICA Research Agenda (Virrantaus et al., 2009), that declares the directions and trends of research activities in cartography.

Without any doubt, it is the photorealistic approach to 3D cartographic vizualization, which is the main cartographic trend nowadays. Authors of this article continuously work on large 3D visualization of detailed geographic data for purposes of documenting Cultural Heritage (Case Study at the castle Kozel)., see e.g. Geocart 2012 or DCH 2012.

Conclusion

This paper describes the role of cartography in geomatics curriculum in general, including relation to change of paradigm of university education. The close connection between cartography and geomatics has a long tradition (more than fifteen years) at the University of West Bohemia in Pilsen.

Cartography and spatial data visualisation represent an important part of geomatics. Cartography is able to transform complicated spatial data products to clear, intelligible and attractive outputs (e.g. maps, plans, globes, products of 3D cartography and similar products such as digital 3D browsers…), which are more important and understandable for many non-expert users than spatial data presentation (e.g. tables, graphs, texts...).

Cartography influences all disciplines focused on spatial data capturing and processing as well as it is influenced by them. The theoretical principals of these sciences are quite stable, but the technologies are changing very fast. Therefore a cartographic education is also very important, because geomatics experts need to be in touch with modern methodologies, technologies and tools.

The students of geomatics were asked to evaluate overall quality of cartography education at our university. The most frequent answer was above-average level of quality.

The three interesting relations can be seen:

1. Comparing the influence of the cartography on a personal and professional life, the results were quite similar.

2. The best rate in professional life got two disciplines – Computer cartography and Large-scale mapping.

3. The leading discipline in students' personal life is the Internet cartography. This also probably deals with the fact that the number of web portals is rapidly increasing and portals offer more and more maps and useful functions for various kinds of activities.

This very good rating could be influenced by results of educational project Multimedia Geomatics, which improved study materials of many subject in the previous year. To achieve the excellent level of quality is good idea to continue doing similar kinds of projects.

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Otakar Čerba, Researcher, Geomatics Section, Department of Mathematics, University of West Bohemia, Plzeň (Czech Republic). Email <cerba@kma.zcu.cz>

Václav Čada, Associated Professor, Geomatics Section, Department of Mathematics, University of West Bohemia, Plzeň (Czech Republic). Email <cada@kma.zcu.cz>

Martina Vichrová, Researcher, Geomatics Section, Department of Mathematics, University of West Bohemia, Plzeň (Czech Republic). Email <vichrova@kma.zcu.cz>

Karel Jedlička, Researcher, Geomatics Section, Department of Mathematics, University of West Bohemia, Plzeň (Czech Republic). Email <smrcek@kma.zcu.cz>

Karel Janečka, Researcher, Geomatics Section, Department of Mathematics, University of West Bohemia, Plzeň (Czech Republic). Email <kjanecka@kma.zcu.cz>

Jakub Šilhavý, Researcher, Geomatics Section, Department of Mathematics, University of West Bohemia, Plzeň (Czech Republic). Email <jsilhavy@kma.zcu.cz>

Jan Ježek, Researcher, Geomatics Section, Department of Mathematics, University of West Bohemia, Plzeň (Czech Republic). Email <jezekjan@kma.zcu.cz>

Martina Vichrová and Karel Jedlička were supported by the European Regional Development Fund (ERDF), project “NTIS - New Technologies for Information Society”, European Centre of Excellence, CZ.1.05/1.1.00/02.0090.