EDUCATION AND TRAINING IN PHOTOGRAMMETRY AND RELATED FIELDS – REMARKS ON THE PRESENCE AND THE FUTURE

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ABSTRACT:

Changes in technology and social-economic conditions have influence on the education and training in photogrammetry and related fields. From a European point of view the present situation is analyzed and possible future developments are discussed. E-learning will play an important role in the continuing professional development as well as in the education at universities. The education at universities has to change if the available resources are reduced and if the number of students becomes smaller. Then cooperation between educational institutions is necessary, nationally and internationally. The quality of education will become a decisive factor in the international competition of products and services in the mapping and geo-data field. Quality management and quality control of the education are important tasks and international organizations like the ISPRS should engage themselves and give guidelines.

1. INTRODUCTION

Photogrammetry is an old science but has changed drastically in the last 30 years. These changes are not only technical ones, but the social and economic conditions are also different today. The changes and the new conditions have consequences for education and training in this subject that now also includes remote sensing and some other fields. It is the goal of this paper to analyze the present situation and to formulate next steps for education in Photogrammetry and its related fields. The education in Photogrammetry is no longer restricted to a few years of study at universities, it must be lifelong. The Internet and e-learning will play a bigger role in the future education and training. The methodologies in teaching and training have to be adapted to the new conditions. International cooperation has to be organized and organizations like ISPRS have a mission to accomplish this.

2. CHANGES IN TECHNOLOGY AND SOCIAL-ECONOMIC CONDITIONS

The changes in technology **and** in social-economic conditions are numerous. Only the important ones can be named here. They influence each other, but they will be handled separately.

2.1 Changes in technology

Today airborne photogrammetry is digitally. Large format digital cameras take imagery, and position and attitude sensors in the airplane are used for georeferencing of the taken imagery. All processing to digital elevation models and to orthoimages is carried out in computers and is to a large extend automatically. Topographic mapping of large areas from images is still carried out manually, but very economically and superior to any other technology. The automatic extraction of roads, houses and trees is still in a research phase, but results with automated and semi-automated methods are very promising. Close-range photogrammetry uses multiple images and self-calibrating techniques. There is no need to use stereo viewing, which has always been a big hurtle for students and newcomers to the field. The matching of conjugate points and areas is carried out by the computer, but now more accurately and more quickly. Blunders may occur and detection and removal of blunders becomes an important subject in modern photogrammetry. Many new sensors were developed. Laserscanning from the airplane and from the ground are competing with the photogrammetric method when surfaces have to be mapped. The way how a computer can recognize objects in the images developed to its own discipline: Computer vision. It is applied in robots and used in scanners in medicine. Hyperspectral scanners are applied in order to map automatically and more reliably by means of object-based classification methods. Various sensors are combined to a system and data of different sensors are used to identify changes and to map them. Various sensors are installed in unmanned vehicles and imagery can be taken from low altitudes. Remote sensing is regularly carried out from satellites and space vehicles. Ground sampling distances at civil application is down to 0.6 m, but large coverage is achieved from a 450 km altitude. Radar systems can be used day and night for mapping of areas in all weather conditions. Photogrammetry and remote sening are closely connected and form one discipline today. Efficient methods for data compression make the transfer of the data to remote places at high data rates possible. The Internet can be used as a tool for communication, computing, learning, and delivery of products. Improvements in the computer technology and software tools contribute to the possibility to obtain results automatically, in real time and with high accuracy. All these achievements are gained at the costs of considerable sophistication in the methods and tools. Knowledge of many different disciplines is necessary in order to use sensors and processing systems properly. On the other hand knowledge about digital photography and digital image processing has become general knowledge in recent years due to the fact that digital cameras became cheap and handy and amateur photography is carried out by means of digital cameras. They are nowadays even part of cell phones.

2.2 Social and economic conditions

Today we live in the time of globalization. Fortunately it is a peaceful world and with great freedom for an individual. He or she can visit, study or work in many places. Mapping tasks are carried out around the globe and in cooperation with other groups. The access to imagery and other sensor data is no longer so much restricte as it was 17 years ago in some parts of the world. Mobility, flexibility and readiness for learning new things are the requirements of the workforce in mapping and production of geo-products. Lack of resources and unemployment are still severe problems to be solved and this can be tough for some individuals. The rapidly changing technology requires high update rates and high maintenance costs for the computer systems and software packages.

3. EDUCATION AND TRAINING IN PHOTOGRAMMETRY AND REMOTE SENSING

The education and training in photogrammetry and remote sensing takes normally place at universities. But the necessary lifelong education requires also education and training outside the universities. This continuing professional development needs other approaches and will therefore be discussed separately.

3.1 Education and training in photogrammetry and Remote Sensing at universities

3.1.1 Study programmes

Photogrammetry and remote sensing is usually not a study programme itself. Education and training in these subjects are embedded in various curricula. In Central Europe and Canada has been part of Surveying Engineering or Geodesy. In recent years, with the upcoming of Global Positioning and Geographic Information Science, the study programme has been named Geomatics or Geoinformatics. Table 1 gives some examples of curricula with Photogrammetry and Remote Sensing. The content of the study programme, however, can be very different; even if it has the same name. Many European countries recently structured their five year diploma programmes in a three year Bachelor and a two year Master Degree programmes after Anglo-American example and according to the recommendations of the “Bologna Declaration” of the European Union. In Germany, for example, 41 Bachelor Programmes and 48 Master Degree programmes were created where Photogrammetry and Remote Sensing are a part of (Schiewe, 2005). The change to a two level study programme was connected with the wish for more mobility and comparability. Some of the German degree programmes are now taught in English in order to attract more foreign students and to bring the native students and teachers to higher skills in the English language. The new Master degree programme of the TU Berlin includes also Computer Vision. The many new sensors for imaging and georeferencing, and their integration into a data acquisition system require knowledge about sensors and measuring techniques. The specialization in “Measuring Science” within a study programme of Geomatics was therefore created, for example at Aalborg University. A list of all academic institutions and its programmes in Geomatics (Geodesy, Surveying, Photogrammetry, Cartography, GIS) is published in (TU Munich 2006).

3.1.2 Equipment and personnel

Beside the changes in the curriculum many new tools and systems have to be procured in order to create practical exercises for the students. Table 2 shows some of the investments at the research group of Geoinformatics at Aalborg University. Not all of the educational institutions have the resources to invest in the latest developments. The number of personnel is the other prerequisite for carrying out good education; especially if the number of students is high it may be a problem. But the number of students in engineering subjects like Geomatics currently decreases in many European universities. The reasons are different. Students at high schools seem to neglect mathematics, physics and computer science and prefer ‘soft’ subjects or subjects where high salaries or estimation can be achieved after graduation. The education at universities should be based on research. Active participation of the teachers in research projects is therefore required. Their research work has to be documented by publications in refereed journals. Supervision of PhD-students is another task of teachers at universities. Special research schools have been created in some countries. For PhD-students they organize special courses, visits of conferences and short stays at other universities.

3.1.3 Forms of education

With all the changes in technology and social-economic conditions the form of education has to be discussed. Various pedagogic models are used at universities today. The ‘problem-based and project-organized learning’, which is practised at some younger universities, is one approach. Other approaches are the ‘progressive inquiry’ and ‘integrated micro learning’. These methods will be explained in more detail. The traditional model, which is based on lectures, small exercises and a lot of examinations, needs no further explanation.

Study Programme	University	Country	Degree
Geomatics Engineering	Ohio State University The University of Melbourne Stuttgart University	USA (E) Australia (E) Germany (E)	MSc MSc MSc
Geodesy & Geoinformatics	University of Hannover	Germany	MSc
Geoinformatics	ITC	The Netherlands (E)	M, MSc
Geomatics	Aalborg University Helsinki University of Technology	Denmark Finland	MSc MSc
Remote sensing	University College London	UK (E)	MSc
Civil Engineering	Aristotle University of Thessaloniki	Greece	BSc
Photogrammetry and Geoinformatics	Stuttgart University of Applied Sciences	Germany (E)	M
Airborne Photogrammetry and Remote Sensing	Institute of Geomatics	Spain (E)	Msc
Geodesy and Geoinformation Science	TU Berlin	Germany (E)	MSc
Geodesy and Cartography	CVUT Praha	Czech Republic	MSc
Geographical Information Systems	Lund University	Sweden (E)	MSc

Table 1. Examples of curricula where Photogrammetry and Remote Sensing is taught.
MSc… Master of Science Programme, BSc…Bachelor of Science Programme, M…Master Programme, (E)… in English

The **problem-based and project-organized learning** is best characterized by means of an old Chinese proverb.

Tell me, and I will forget.
Show me, and I may remember.
Involve me, and I will understand.

Problem-based and project-organized learning (PBL) means that projects are carried out by a group of students. A problem has to be defined and solved, and the solution to the problem or the search for a solution has to be documented, presented and defended. A problem is the starting point for acquiring and integration of new knowledge.

Teachers have a different role in this type of learning; they are advisors and facilitators for the group. The evaluation of the project involves also external or internal examiners. The problem to be solved is part of a theme, and courses are given for introducing the theme and for providing an overview on the theories, methods, tools and applications. The project has to be carried out within one semester. The semester includes also some study courses which are not related to the project. At Aalborg University (AAU), for example, the students use about 50 % of their time (corresponding to 15 Credit Points in ECTS[1]) for projects (compare Figure 1).

Projects are carried out in each semester of the BSc and MSc study. Another university which uses PBL as their educational model in the Geomatics curriculum is the University of Aveiro, Portugal. (Gomes Pereira 2004). More detailed information on project-based learning is published in (Höhle, 2005).

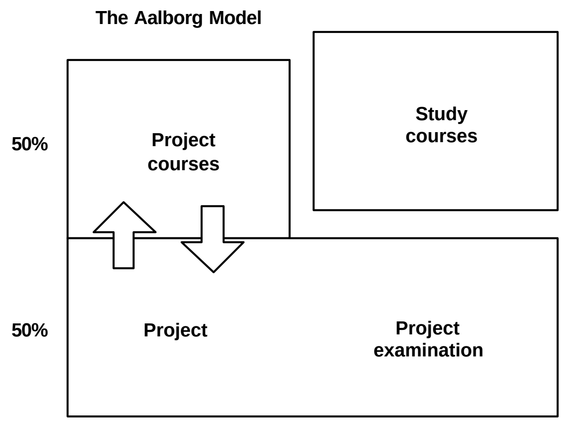

Figure 1. Problem-based and project-organized learning

At **progressive inquiry** the students take part in a research process. The students learn to inquire and investigate by means of relevant methods. The figure 2 depicts the essential elements of progressive inquiry. More detailed information can be found at (Muukkonen, H. et al.,1999).

Another approach is **Integrated Micro Learning** (IML). IML works on the basis of subdividing the learning process into small activities embedded in everyday life. Learning takes place along with professional and domestic activities and as such it is in strong contrast to “artificial” learning found in conventional course-settings. More information on this approach can be found at (Hug, 2005).

[1] One credit point in European Credit Transfer System (ECTS) is the equivalent to 30 hours of student's work.

The selection of the pedagogical model depends on the attitude of the teachers, the available resources and the maturity of the students. In the Aalborg Model, for example, the students have a very active role in their studies. There is a short distance between teacher and student – both physically and concerning the power. New knowledge and information flow both ways. The teacher is forced to update his knowledge continuously. The system is, however, vulnerable when the number of students increases. Group rooms and equipment might then be lacking.

3.1.4 Core knowledge

Due to the big changes in technology the number of subjects is substantially increased. This is also the case in many other subject of the curriculum. It is, therefore, necessary to reduce obsolete knowledge and to concentrate on core knowledge and on specialized up-to-date knowledge. At Aalborg University, for example, the education in photogrammetry starts with the 5th semester as part of the BSc Programme in Geomatics. It consists of a course and exercises which are followed by a project. The content of this basic course is summarized in Table 3 The project is carried out in groups consisting of two students each. The photogrammetric task comprises the selection of ground control, orientation of a stereopair, photogrammetric mapping, and derivation of a DEM and of an orthoimage. Furthermore, these photogrammetric products have to be compared with the map and the DEM derived by terrestrial methods **and** with the products of the mapping agencies which are stored in the geodata library of the study programme 'Geomatics'. The knowledge in photogrammetry, map projection, surveying, and adjustment theory is examined together with the report of the project. An external censor gives marks in cooperation with two teachers. The project work has 25 CP in ECTS, the basic course in photogrammetry (lectures, small tasks and exercises) amounts to 4 CP.

Equipment	Name	Number
Stereo workstation incl. SW for mapping, DEM & Aerotriangulation	Z/I Imaging Image Station	4
Digital terrestrial camera	Kodak 14N	1
Software for calibration and mapping	Photomodeller	1
Terrestrial laser scanner incl. SW	Leica HDS 2500/3000	2
Global Positioning Systems	Leica 530, Trimble R8	4, 2
Inertia Measuring Unit	Crossbow IMU400	1
Robot total station	Trimble S6	1
Software for aerotriangulation	Bingo	3
Software for object-based classification	e-cognition	1
Software for editing DEM data	Inpho DTMaseter	1

Data (GSD [cm], m_b, number of channels)	Name	Number
Digital aerial images (6, 6700, 3)	Vexcel UltraCAM	22
Satellit imagery (61, ~67 000, 4)	Quickbird	2

Table 2. Recent investments in equipment and data for exercises and project work at AAU's research group for GeoInformatics

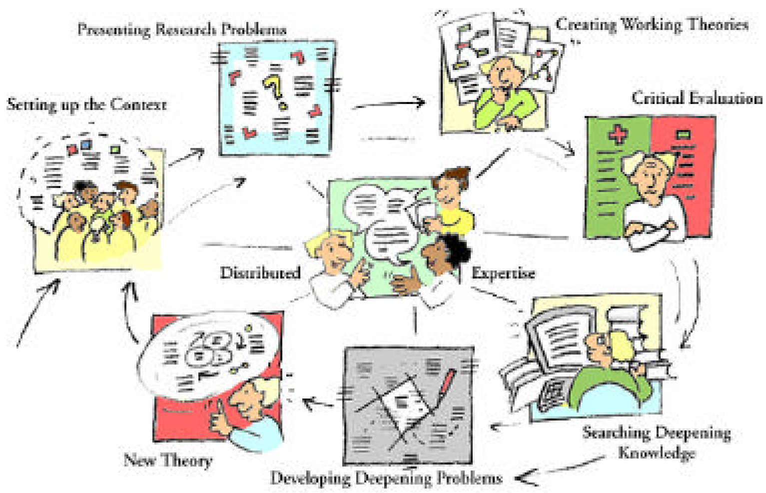

Figure 2. Elements in the learning model of 'progressive inquiry'. Source: Muukkonen, H. et al., 1999

Lectures and small assignments
Image geometry and orientation
Stereoscopy
Rectification
Photography and scanning
Project planning, flight planning, navigation
Mathematic concepts in photogrammetry
Orthoimaging and monoplotting
Introduction into digital photogrammetry
Stereomethods and stereo workstations
Selection of control points
Introduction into aerotriangulation
Topographic mapping
DEM generation
Exercises
Measurement of parallaxes
Rectification
Relative and absolute orientation
Stereocompilation
Orthophoto production
Automatic measurement in images
Image processing
DEM generation

Table 3. Content of the course "Basic Photogrammetry" at AAU's Bachelor's Programme in Geomatics (Status autumn 2005).

With this core knowledge the students specialize at the MSc programme.

3.1.5 Specialization in the MSc Programme

Table 1 gives some examples of MSc Programmes which contain courses in Photogrammetry and Remote Sensing. The content differs considerably and there are also differences in the pedagogical approach. Aalborg University and the TU Berlin are used as examples.

Currently there are three specializations at AAU: Measurement Science, Spatial Information Management, and Land Management. The **specialization 'Measurement Science' at AAU** has two themes: 'Positioning' and 'Sensor- and Data Integration'. The courses under the theme 'Positioning' (7th semester) are Advanced Photogrammetry, Terrestrial Laserscanning, Data Libraries & Data Quality, and free study activities ('mini-projects') about point determination by means of terrestrial digital photogrammetry, and data collection and modelling by means of terrestrial laserscanning. Courses on Sensor Integration in Photogrammetry and Remote Sensing, Data Integration & Image Analysis, and a free study activity ('mini project') about Automated DTM Derivation including Quality Control are part of the education under the theme 'Sensor- and Data Integration' and take place in the 8th semester. Table 4 shows all subjects regarding Photogrammetry and Remote Sensing of AAU's MSc programme 'Measurng Science'. Altogether, the students can obtain 15 ECTS credit points from courses and free study activities in the 7th and 8th semester in the subjects Photogrammetry, Remote Sensing and Laserscanning. The lectures are complimented by a few guest lectures, excursions, and presentations of companies.

In the 9th semester the focus is on professional development where a specific individual learning process is possible. For example, students can choose to have an internship in a company or a public institution; to study abroad at a foreign university; or to stay at Aalborg University to continue their studies. During this semester all students are connected to a virtual network, which means that they stay in contact with their fellow students and the lecturers from Aalborg University. The final semester of the MSc programme is dedicated to the production of the thesis, which takes 30 CPs.

Advanced Photogrammetry
Analytical photogrammetry
Aerotriangulation techniques
Terrestrial photogrammetry
Calibration of non-metric cameras
Industrial photogrammetry
Automation of photogrammetric processes
Terrestrial Laserscanning
Principles, instruments, methods & applications
Data Libraries and Quality of Data
Image libraries and their characteristics
Quality of DTMs and orthoimages
Sensor Integration in Photogrammetry& Remote Sensing
Imaging sensors in Photogrammetry and Remote Sensing
Platforms of sensors
Additional sensors
Direct georeferencing
Mapping from space imagery
Airborne laserscanning
Combined restitution of laserscanning and aerial images
Data Integration & Image Analysis
Operations at integrated raster data
Automated georeferencing of images
DTM&DSM production
Production of true orthoimages
Automated extraction of houses, roads, trees, etc.
Automated Quality Control of Orthoimages and DTMs.

Table 4. Photogrammetry and Remote Sensing subjects in the specialization "Measurement Science" of the MSc programme of Aalborg University.

The MSc Programme of the TU Berlin "Geodesy and Geoinformation technique" offers **specialization in "Computer Vision and Remote sensing"** with 42 CPs which are distributed over two semesters. It is supplemented with one semester of basic courses (including one course on sensor orientation and object reconstruction) and one semester for the production of a thesis (each with 30 CPs). More details on this study programme can be found at (TU Berlin 2006).

3.2 Education and training outside universities

Other education and training in Photogrammetry and Remote Sensing is carried out outside universities, for example by means of short courses, summer schools and Master degree programmes for professionals. In this way the continuing professional development (CPD) can be realized. Photogrammetry and Remote Sensing may also be integrated into high school subjects like mathematics and geography. This leads to the concept of 'Progressive learning network' (compare figure 3) and according to (Haggren 2005) the future curricula in Finland will be based on it. It means that the subjects Photogrammetry and Remote sensing are distributed over the whole lifetime of some individuals. The need to have more students in the education in Geomatics calls for marketing efforts at high schools already.

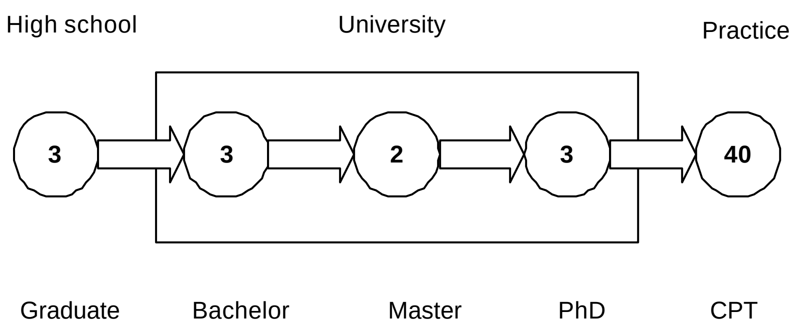

Figure 3. Life long education in Photogrammetry and Remote Sensing. The numbers stand for the number of years the studies normally last.

Organization	Subjects	Type of education
European Organization for Spatial Data Research (EuroSDR)	Photogrammetry, Remote Sensing, GIS	Short courses with introductory seminar
E-Learning Academic Network (ELAN) Niedersachsen, Germany	Photogrammetry Image processing	Short courses
ITC, The Netherlands	Remote Sensing, GIS	Short courses
GITTA, Switzerland	GIS	Short courses
Institute for Advanced Education in Geospatial Sciences, USA	GeoSpatial Information Technology	Short courses, curriculum

Table 5. E-learning courses and e-learning programmes in Photogrammetry, Remote sensing and related fields.

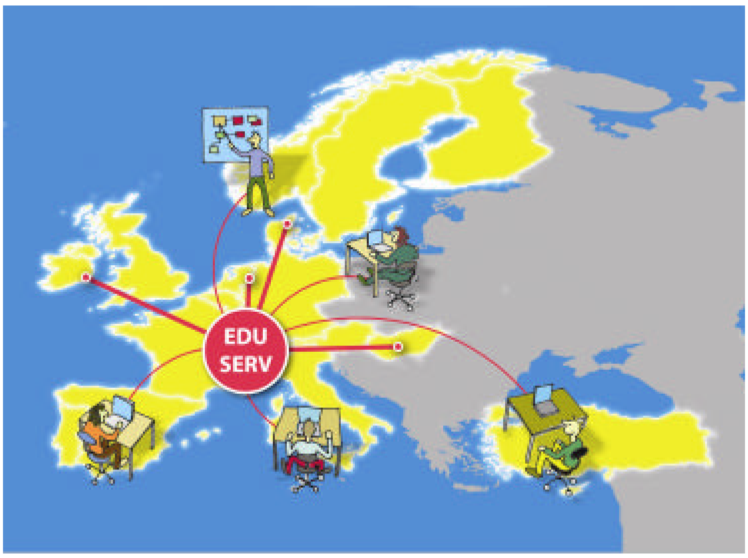

Figure 4. The educational service (Eduserv) of the European Organization for Spatial Data Research. The countries painted in brighter tones are the current member states of EuroSDR.

4. THE ROLE OF E-LEARNING

Education face to face will remain the best education or training. However, there are many reasons to use computers and the Internet in education. Today many courses in photogrammetry and related fields are offered on the Internet. Learners are sitting on remote places and study beside work and communicate with their teachers and fellow-students. At the universities e-learning is also used by the students in their group rooms or at their dormitories. Project work and work for a thesis can now be done outside the university, for example in a mapping organization. Even MSc programmes are offered as a mixture of e-learning at the home town and a few weekend seminars at the university. Companies instruct their clients how to use sophisticated hardware or software properly by means of e-learning. The learning material uses text, images, videos and sound, and a lot of interactivity. Other features for a successful e-learning are a quick feed back from the teacher or a learning system and collaborative exercises. How to design course ware for e-learning in Photogrammetry and Remote Sensing has alreadyy been presented in former ISPRS meetings, for example in (Höhle, 2004). Interactive learning programs with animation, interaction and feedback are used with success. New developments in e-learning are lectures recorded on streamed video, 3D virtual reality, games and micro learning components. The courses may use special conference and communication software packages where the course modules, discussion boards, calendar, and file exchange are integrated. Examples are First Class, Black Board or Web CT.

Many universities have now established research and/or service groups for e-learning. The production of good courseware requires many resources and good teamwork of different specialists. The carrying out of the courses including marketing requires substantial efforts as well. Table 5 shows a list of e-learning courses and e-learning programmes. It is by no means complete. The first example of Table 5 will be explained in more detail.

The **educational service of the European Organization for Spatial Data Research** carries out short courses on the Internet about the results of their research projects. A two day long seminar introduces three or four courses and e-learning of two weeks follows at their home locations (compare Figure 4). During the seminar the participants become acquainted with the teachers and to each other. The teacher can judge the prerequisites of the participants who come from different countries and different educational background. The 'distance' to the teachers is reduced and collaborative work between the participants is eased in this way. This e-learning has been carried out since 2002; four seminars and eight different e-learning courses took place. From the feedback of the participants (by means of questionnaires) it was confirmed that the combination of a short introductory seminar and e-learning at the home environment gives the participants trust, motivation, and thereby ensures good learning success.

5. QUALITY ISSUES IN EDUCATION AND TRAINING

Education at **universities** should be regularly evaluated, by students **and** by teachers. Good education should be up-to-date and based on research. Students should learn by doing. By their example how to do good research the teachers can motivate students. With the increase in knowledge and subjects the curriculum has to be divided into core knowledge and in specialized knowledge. The study should not be overloaded with details and examinations. The student has to have an active role and should be responsible for his or her education. Project work in groups will create the abilities required in practice. Professional development will increase by means of internships in a company, a public institution, or by studies at a foreign university.

Dissemination of knowledge by **e-learning** requires good educational material and communication abilities in writing. A high degree of interactivity is necessary. Short response times to questions of the students are essential. The student should experience a progress in his or her learning.

Quality management and quality control of the education are important tasks. The international organizations like ISPRS should engage themselves and give recommendations and guidelines. The comparison and rating of the specializations "Photogrammetry and Remote Sensing" at MSc programmes or of the many short courses are such tasks.

6. POSSIBLE DEVELOPMENTS IN THE FUTURE

The development in technology and social-economic conditions will go on, very likely at a higher speed. There will be many new sensors, systems and also new applications. Efforts in research and innovation become essential for the competitiveness of a national industry engaged in the production and use of spatial data. The photogrammetric community will become more connected. The resources for education will very likely be reduced due to the shrinking number of students in such technical subjects like Photogrammetry and Remote Sensing. This means that a stronger co-operation between educational institutions has to take place and, therefore, more educational networks have to be formed. The role of e-learning will increase and a global learning space will develop.

7. CONCLUSION

Education and training in Photogrammetry and related fields is changing due to new technologies and due to new social and economic conditions. In the curriculum of Geomatics also other subjects have to cope with changes and enlargements in their fields. Furthermore, the interest of young people in technical subjects and in natural sciences seems to decrease and the number of students declines. Therefore, the resources for the education in Photogrammetry are reduced in several European countries. There is nothing wrong with the subjects of Photogrammetry and Remote Sensing themselves. In this situation the core knowledge and specialization has to be defined and modularized. International cooperation and e-learning have to be organized. The advancements in Photogrammetry, Remote Sensing, Computer Vision, and Image Processing depend on good research activities. The universities should be the place of research **and** education. The governments and also the private industry should support the efforts of the universities to produce good research results and innovations and to carry out research-based education. Candidates of universities will then be able to think in new ways, to search efficiently for knowledge, methods and tools, and to manage projects in a given time frame. Problem-based and project-organized learning is a good approach to cope with such demands. The communication between people, also across borders of language and culture, will play a big role in the future and has, therefore, to be trained. The education in Photogrammetry and related fields has to use the global learning space.

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