Surveying Education for the Future[1]

by Andrew U. Frank, Geoinformation, Technical University Vienna

ABSTRACT. The Third International Think Tank on Surveying Education held in Vienna showed a surprising agreement among experts from 12 different countries in Europe, USA and Canada. In these closing remarks I try to summarize the debate from my personal point of view and to show on which points we have reached agreement and which other points must be debated further.

Surveying Engineering contributes to the common wealth of society and the profession and has to adapt to the changes in social needs and business opportunities. Surveying education must respect these changes and adapt to them. A few guidelines for curriculum development in surveying are given, listing areas to expand but also indicate where cuts might be possible.

A profession means not only the business and the services but also needs a common intellectual core, which is shared by all professions. Measurement theory and geodesy were the cores of the past 50 years, but increasingly spatial information theory provides the intellectual core, the challenging questions for research, which go with the changes in the curriculum.

1. INTRODUCTION

The Third International Think Tank of surveying education brought together experts from America, Canada and Europe to discuss the content and form of future surveying education. The contributions confirmed many trends and showed how far we have already reached agreement. Delegates addressed new and sometimes surprising issues and there were controversial points, which need further debate. In these closing remarks I attempt to summarize the debate from

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my personal point of view and contribute some of the experience I have made in teaching surveying engineering programs both in the U.S. and in Europe.

Two major points of agreement were stressed in nearly all presentations:

- The surveying education program - as any educational program - must serve the needs of society and the students. This raises the question what demands society has and what role surveyors fulfill. Fortunately, the answer to these questions seems relatively clear, despite all differences between the professional practice in different countries.
- Geographic Information Systems (GIS) becomes the new focus around which surveying education must be reorganized. Despite the attention paid to GIS, other areas of surveying have to remain in the curriculum and must be modernized to reflect their particular developments as well.

A profession requires an *intellectual core*, a central moving idea which is served by all professionals, irrespective of their particular position in private business, administration or academia. The debate during the Think Tank was not confined to technical issues of a curriculum reform but also addressed this issue extensively. It would be premature to expect a generally acceptable definition. The answers provided here are a personal contribution to carry on the debate.

To start this report, I will briefly touch on social demands for surveying engineering and discuss the resulting business perspectives. An understanding of the surveying business leads to the abilities surveying professionals must have and thus provides an idea about what the graduates of a surveying program should be taught. I will then describe the problems of surveying curriculum design and some of the main concepts I have used in the past and go into some detail on how they can be realized. This is not sufficient to answer the question of the intellectual core and I turn to the research efforts to find an answer there. I conclude with a plea for more research to maintain a viable, forward looking surveying profession.

2. SOCIAL NEEDS AND BUSINESS OPPORTUNITIES

There is widespread agreement that the society of the late 20th century demands increasing amounts of information for any decision. Our societies follow the path of rational decision making which started with the movement of the enlightenment and led to what can be called the age of information. Decisions with spatial effects are numerous and of vital importance to assure a rational use of the limited space at our disposition. They range from the location of 'locally unwanted land uses' (e.g. waste deposits, prisons) to the analysis of the spatial distribution of health risks or to the planning of public transportation systems. Albaredes estimated that 80% of all decisions made have a spatial component and could consequently benefit from GIS to properly deal with their spatial influences and effects (in his keynote presentation at EGIS Munich 1992).

Everybody agrees that there is an increasing demand for spatial information in all areas. The traditional business of surveyors, namely the surveying of individual properties to assure boundaries of private ownership is thriving; countries which do not have well functioning cadastral systems find out that a functioning cadastre is crucial to a working real estate market and thus fundamental to orderly economic development. They start to invest in legal surveys and property registration. Administrative uses of spatial information for planning, resource management and environmental protection are growing rapidly. Additionally, applications of spatial information for business are emerging rapidly. A booming market exists for the combination of economical and social data from the official statistics together with spatial reference files; these data can be readily used in business to fine tune many marketing decisions, from mailing efforts to the location of new outlets of banks, fast food restaurants or stores.

All this development is fueled by rapid technical development of information technology, primarily the ubiquitous usage of the personal computer. It is clear that development of hardware and software will continue for a few more years with the speed we have become accustomed to over the past years. Currently there are no technical boundaries visible. The *technology push* will continue and - in a time of dwindling resources - the critical assessment of social needs and well founded business opportunities will become more important. Not everything which can be done must or should be done and thus the *social pull* must be considered increasingly.

The technical development has simplified the usage of measurement instruments. Many new instruments are fully automatic and can be used by non-surveyors with little instruction. Precision is so advanced that usage is straightforward and does not often demand a sophisticated set-up and measurement plans. Many domain specialists are thus enabled to do their own measurements and produce their own spatial data. This reduces the surveyor's business in simple measurements (not in the complex situation of engineering surveys) but this loss of business in a not very lucrative area is compensated by an increase of business in assisting these domain specialists to organize, manage and present the results of their measuring efforts.

The surveyor becomes thus what was foreseen in 1981 during the FIG congress in Montreux: the specialist to systematically collect, manage and present spatial information [FIG, 1981]. This can be seen as a secular change from the times where surveyors were specialists to build, set up, and use very delicate instruments to determine the position of objects on the earth [Bauernfeind, 1869]. Over the last 100 years, instruments became more and more self contained and about 50 years ago, surveyors stopped constructing their own instruments and left this business entirely to the specialized companies. About 20 years ago, we also stopped to make adjustments to our instruments - if they do not work properly, we send them in for repair. In the same time frame, surveyors with a university degree ceased to go regularly to the field for measuring and concentrated on the arrangement and management of surveying operations. These changes have been absorbed by the profession at large and we are not worse off economically. Thus, we may expect that the current change will be beneficial and increase our business as well.

The latest business opportunity emerging is the function of the surveyor as a 'spatial data broker'. Data collected by one agency may be valuable for other organizations, thus creating a business opportunity. Unfortunately the technical, organizational, and legal problems are substantial [Frank, 1992]. A direct contact between data producer and potential additional users is not likely to lead to a successful exchange. This creates a business for repackaging and distributing spatial data - similar to other commodities, where middlemen between producers and consumers earn substantial fees [Frank, 1994]. Surveyors have a good chance in this business, as they understand the technical problems and can assess the quality of the data and their fitness for use. Traditionally, surveyors were trained in legal and managerial aspects and are able to address the substantial non-technical problems.

There is also a growing opportunity for surveyors - as specialists of spatial data - to contribute to the development of software for geographic information systems. Job opportunities with the major manufacturers and vendors of general purpose GIS platforms are available. Many smaller companies create and sell inexpensive and more specialized GIS software, creating yet another market. The major consulting companies adapt 'off the shelf' components to particular situations and design codes that connect the available functions.

3. GOALS FOR A SURVEYING CURRICULUM

The development of a curriculum must respond to the needs of society. Graduates who are now in the surveying programs will work typically for over thirty years, till around 2030. We have to educate in response to today's and tomorrow's business needs, but we also have to consider that the design of a curriculum will affect the type of business surveyors are going to have. There is a distinct possibility of creating 'self fulfilling prophecies'. They can predict a positive direction opening up the profession to increase surveying business, or they can take a pessimistic attitude of closing, a 'coral the wagons' reflex, and to retreat to the decreasing business of measurement.

The mix of skills and knowledge a surveying professional should possess are very diverse. Of course, a sound foundation in engineering science (mathematics and physics) is necessary and the graduate must understand the technical base of surveying and geodesy. In addition to these traditional fields, graduates typically should have a very substantive understanding of information technology and computer science. These are the standard demands for good engineering graduates: understanding the technology and know how to apply it. Hardly ever do employers of our graduates complain that they are not sufficiently educated in this direction.

Employers of surveying graduates invariably mention three areas where our education could be improved:

- Graduates lack communication skills. They are not able to present the results of their work convincingly in oral or written form.
- Graduates are not experienced to work in a team with others.
- Graduates do not understand the business aspects of their work.

These seem to be internationally valid observations, heard all over the world. It is imperative that our curricula respond to these justified demands. In addition, we must predispose graduates to the process of life long learning and provide them with the skills to learn on their own whatever they need in the special situations they will encounter.

Demanded is a mix of theoretical knowledge and practical skills. Graduates from academic surveying programs are sometimes compared with graduates from technician programs and it is observed that the latter are more skilled in setting up instruments and, in general, are more readily "usable" and produce a profit for a business quickly. This is a justified differentiation between the goals of the two kinds of programs [Bartsch, 1992]. Surveyors should be capable to work with any instrument, current or future, given the manual and time to prepare. They will not often carry out measurements past the first five years of their professional careers and it is therefore not justified to concentrate extensively on short lived skills of instrument handling. The curriculum cannot prepare them for all future eventualities, but can only provide a foundation for rapid adaptation to particular situations.

4. CURRICULUM DEVELOPMENT

4.1. SITUATION IN NORTH AMERICA VERSUS EUROPE

A curriculum is a balanced list of courses. The most difficult aspect of curriculum development is not the determination what should be added to the education of surveyors. A long list of topics which would enhance the current program is quickly set up and gets longer with every discussion. The more difficult problem is deciding what should be cut. Here, the reasoning becomes much more difficult and delicate.

Academic surveying education in Europe is mostly based on a 4 1/2 to 5 year program of study, leading to an engineering diploma (the German 'Diplom-Ingenieur'); students entering these curricula have completed all requirements of general education and are typically 20 years old. The curriculum is determined in a complex process, mostly with contributions from students and faculty. Courses are scheduled for 1 to 6 hours of teaching or exercises per week for semesters of typically 15 weeks. The total number of hours is 200 (or about 20 per semester week), of which 40 % are exercises.

In North America, the situation is more varied: there are programs lasting 4 years, leading to a Bachelor of Science in Surveying or Surveying Engineering. Students entering these programs are typically less than 20 years old (but there are increasing numbers of 'non-traditional' students, who are older and may have some professional experience). From a total of around 130 credit hours (exclusive exercise hours), more than 40% are 'general education' subjects (English, social sciences etc.). Some of the programs are accredited by the ABET (Accreditation Board of Engineering and Technology) and inspected regularly to fulfill some minimal quality requirements. Students from these B.Sc. programs - but also from others programs - can join Master of Science programs to further advance their professional education. A completed Surveying education counts towards the requirements for the license to practice (legal) land surveying.

The situation in North America and Europe - despite all apparent dissimilarities - is very similar. It can safely be assumed that the quality of graduates of the better North American Master of Science programs and graduates with a European engineering diploma are comparable. An American student covers 130 credit hours for his B.Sc. (of which 52 are for general education subjects) and another 30 credit hours (of which 6 are for the thesis), totaling 160 credit hours, of which 102 are credit hours in the surveying field. A student in Vienna covers 200 hours, of which 80 hours are exercises (which would not count as credits); this yields a comparable 120 credit hours in surveying subjects. In consequence, the problems faced when designing the curriculum are also essentially the same.

The first temptation is to lengthen the curriculum to create more time to include all desirable topics. This temptation seems to be resisted by most schools, sometimes under pressure from a wise legislator, limiting the maximal study duration. It is also observed that surveying degrees should be comparable to other technical academic degrees. Neither should the curriculum be longer than, say, civil engineering degrees; this would disadvantage surveying in the competition for incoming students. Nor should the curriculum be shorter than other comparable degrees, disadvantaging graduates, who would face problems of acceptance in the marketplace and certainly be considered of 'lesser standing' for professional advancement.

This reduces curriculum development to a 'Zero Sum Game' - whatever is added one place must be taken out some other place. To cut hours from a curriculum is often very difficult because it relates directly to the faculty that teaches the subject. It is - under unfortunate circumstances - seen as a reduction of prestige, sometimes even of a reduction in resources which are related to the number of hours taught.

4.2. SIX THESES FOR CURRICULUM DESIGN

Changing a curriculum should be guided by a few firm rules. The process can either be gradual - this is what the University of Maine followed for several years - or it can be a single reform - the model that was mandated to the Technical University of Vienna and to other universities. Details of such reforms are reported but they strongly depend on special situations, in particular on the persons involved and their abilities. I found the rules reported here useful in the discussions in the U.S. and in Austria; they seem to be independent of particularities. Most rules discuss what should be included, but also indicate what can be reduced.

4.2.1. KEEP MATHEMATICS STRONG

Mathematics and related sciences should remain strong in the curriculum. Graduates should have the experience of mathematical rigor and should master abstract thinking as it is used in mathematics. Physics should remain prominent and early in the curriculum to build the foundation for the understanding of measurement processes and instrument design; the teachers of the physics courses should arrive at a compromise to teach a rigorous course based on high school calculus which does not load students more than is appropriate.

Mathematics courses should contain less calculus and more discrete mathematics, linear algebra and other similar subjects related to the formalism needed in Computer Science. Keeping mathematics strong does not automatically imply that the current dominance of calculus and differential equations must be preserved. With computers, most engineering calculations are solved by numerical methods and the ability to differentiate and integrate complex formulae is rarely used. Calculus and differential equations can be reduced by restricting them to the topics of interest to higher geodesy.

On the other hand, discrete mathematics providing the foundation for computer science and information theory is often completely missing in our mathematics courses. The recommendation is to include at least some parts of logic, algebra, predicate calculus, graph theory, topology etc. This can be balanced by judicious cuts in calculus.

4.2.2. KEEP NEIGHBORING DISCIPLINES

Geographic Information System are an integrative technology: data from different sources are combined based on spatial location. Our graduates should be at least literate in the basic ideas and methods of a number of disciplines providing data for a GIS or using GIS. The temptation to cut in the 'related disciplines' when pressed for a sufficient number of hours must be resisted and courses in urban planning, natural sciences (geography, biology), soils, civil engineering should be offered. However, the teaching of neighboring fields which lack an intellectual core or a useful, teachable methodology appears questionable.

4.2.3. KEEP FORMAL SPATIAL DISCIPLINES

Surveyors deal with space in a formal manner. One must therefore maintain all disciplines, which provide formalism to treat space. Among them are higher geodesy and mathematical cartography. However, the topics which were traditionally important, but are not actually needed anymore, should be removed to a 'historical methods' section and treated summarily. This probably means in many curricula that the compulsory number of credits in these subjects can be reduced considerably.

4.2.4. KEEP PRACTICAL SURVEYING TRAINING

Surveyors not only need to know in theory how surveying instruments work, but must see how they are actually used. Certain skills can only be trained by extensive exercises. The practice of careful measurement and clear field notes is as important as the organizational skills necessary for field work.

Teaching content must be carefully assessed and all instruments and methods which are not practically used anymore should be presented in an 'historical methods' section and not extensively trained. The simplification in instrument use should logically result in reducing the required number of hours. This is balanced by the need to include new measurement technologies in the curriculum.

4.2.5. ADD CORE COMPUTER SCIENCE AND INFORMATION SCIENCE

Our graduates must be able to use computers professionally in any aspect of their work. It is best to add an introductory course in the first semester introducing them to personal computers and the regular 'productivity tools' like word processing, spread sheets, symbolic mathematics packages (e.g. Mathematica). The skills achieved are required for later homework, until the use of a computer becomes second nature to the students.

All students also have to have a fair foundation in computer science and it is generally assumed that an introductory course in any programming language should be part of an engineering education. This should be an introduction to programming only without the intention of students becoming professional programmers. The language should be selected for pedagogical reasons (e.g., Pascal or an Object-Oriented teaching language like Scheme) and should rather not be one of the current professional languages (C or C++) which are better taught as a second language.

A discussion about software engineering is judged useful as many issues of work organization in the age of information processing are discussed and formal tools for their treatment are provided. A general course in information systems is also desirable.

4.2.6. ADD A SUBSTANTIVE SET OF GIS COURSES

The introduction of Geographic Information Systems should be evenly spread through the curriculum and not be concentrated in a single theoretical course or a short sequence in the last semesters of the curriculum. A sequence which seems to work well in several institutions is:

- starting in the first semester with a CAD course, essentially replacing the old 'Geodetic Drawing' course.
- in the third semester, an example oriented course "Introduction to GIS" is offered to provide the student with an overview of the ideas and application areas of GIS. This is mostly a set of carefully prepared exercises (e.g. the set of exercises elaborated by NCGIA [Dodson, 1991]) which the student works through at her own pace.
- In the fifth and sixth semester, a sequence of two courses presenting the theory of GIS, using a textbook, e.g., the book by Laurini and Thompson [1991]. We usually treated the database and information system aspects in one course and dealt with the issues of space and the representation of geometry in a second. More specialized topics can then be treated later in advanced courses.

4.3. SPECIALIZATION IN SURVEYING

A curriculum cannot fulfill the needs of all students in Surveying and specialization is necessary. The first principle should be to reduce the number of specialization as much as possible and to stress the common core of the curriculum. Some students will continue with the subject of their specialization, others will not. Students should be capable to take on any work in surveying, irrespective of the specialization they selected during the studies. Specialization only aims for allowing the student to learn one topic in more detail in an exemplary fashion.

A first subdivision takes place for students who want to learn more about surveying and the management of spatial data and others which prefer the more mathematical or engineering aspects of higher geodesy and surveying engineering. At the Technical University in Vienna, this results in the two major specialization's, each with two subdivisions:

Geoinformation:

- Management of spatial information, including the technical, managerial and legal aspects. In this group all traditional topics of cadastral surveying, legal and organizational courses are included. Courses also include business administration issues and economics.
- Spatial information theory. Students from this specialization will be prepared to build GIS software. In this group a substantive amount of computer science courses is integrated (database management, expert systems, computer graphics, image processing) and students are expected to learn at least one professional programming language in order to work on their assignments and diploma theses.

Engineering Surveying and Higher Geodesy:

- Engineering Surveying treats the theory of measurement systems and their application, including measurement robots.
- Higher Geodesy and Geophysics allow students to study advanced topics in satellite geodesy, astronomy etc.

4.4. Other Goals

The list of courses to be covered does not guarantee that other essential educational goals are achieved. Communication skills and similar goals cannot be achieved in a formal course, and other education situations must be created. The Danish experience with project oriented learning is very positive and other schools have used similar methods of project work [Stubkjaer, 1993] (excerpt included in annex).

Communication skills - written and oral - are traditionally improved by asking students to review recent literature and to present the results in a seminar. Unfortunately, the available literature is insufficient for a substantive treatment and the reports turn out shallow. Presentations of work performed in field camps or project oriented work in courses provide better material for presentation and thus more realistic situations. This leads to higher demands on the content of the presentation. Important is an in-depth critique of the presentation organization, visual aids and style.

Project oriented work allows to integrate the contents of several courses and to exercise theoretical knowledge like business calculations in the context of a realistic engineering problem. We are currently finalizing exercise material for a course about the organizational, business and technical issues of the introduction of a GIS. Each student writes a 'feasibility study' for a GIS idea of his choice. This combines technical understanding with business thinking and assessing the practicability of ideas and leads to a formal presentation of results.

Group projects with distributed responsibilities seem to be necessary to break with the unfortunate university tradition of single individuals working on their own in competition to others. Students should achieve an understanding for group dynamics and how to organize work in a group to benefit most from the contributions of each individual.

Our experience indicates - similar to the reports from Denmark - that project oriented work in small groups is most stimulating and motivates students. It seems one of the best methods to go beyond mere teaching and achieve real learning. Confronting students with open ended questions and unfamiliar issues and encouraging them to organize their own approach is a first step towards enabling them to learn on their own accord, which is crucial for a long and successful career in a rapidly moving world.

Looking back introspectively and asking oneself "which university courses provided me with valuable and useful skills and knowledge ?" invariably indicates that the personality of the teacher is the single most important element. Seen from a distance, it is not so much the detailed knowledge - detailed knowledge ages very quickly and detailed expertise becomes obsolete in 5 to 10 years - than the general methods of work in a discipline. As methods cannot be taught in the abstract, courses provide details to exercise and demonstrate general methods.

5. INTELLECTUAL CORE: SPATIAL INFORMATION THEORY

A listing of courses does not really describe what surveying is about. An academic profession must have an *intellectual core,* which is more than the sum of the subjects taught. But the profession is also more than the professional services rendered. And a profession is different from the organization of the professionals to protect their domain from intruders. In order for a profession to be viable, a profession must have an intellectually stimulating idea, which is socially acceptable (often a social ideal, for surveyors for example to 'manage the resource land better'). Unless we have such an intellectual core, it will be very difficult to defend our 'professional territory' against other professions with similar backgrounds.

The intellectual core must be shared by all surveying professionals. It is the glue that connects the practitioners in the trenches with the university teachers and the researchers. The intellectual core points to the ideal goal of surveying and addresses its future agenda. It is thus linked to the research questions that are asked today: the practitioners point to the shortcomings of today's practice. Researchers pick up these questions and transform them into research questions which they can solve. The results are then distributed by the academic teachers and introduced to tomorrow's practice.

"Spatial Information Science" could form this core, as it provides a set of scientific questions intimately related to surveying in this new, broader understanding [Goodchild, 1990]. Spatial Information Science is wider than Surveying Science, which limits itself mostly to the problems of measurement technology. Spatial Information Science deals with Large Scale Space (geographic space) [Frank and Mark, 1991, Kuipers, 1978], it concentrates on the information and it strives for a coherent theory.

Spatial Information Theory is linked to other sciences, but it is independent as each of the contributing or related sciences has a distinctly different point of view.

- It deals with large scale space like Geography, but Geography concentrates on processes in space.
- It uses methods from Computer Science, which concentrates on data processing in general.
- Many of the questions of the representation of spatial information are related to Artificial Intelligence.
- Methods from Cognitive Science and Linguistics must be used, but the interest concentrates on human understanding of large scale space.

In Spatial Information Theory one can also include the legal and economic aspects of surveying. The general discussion of legal methods from an information processing point of view is of interest not only for surveying but the methods are applicable also here [Al-Taha, 1992]. The topic of economic treatment of information is one of the most important questions of this decade and of primary importance to GIS.

Considering spatial information as a broader issue opens the mind for cultural influences and differences between different cultures [Campari, 1993]. Surveying must be centered around a social concept of space and how space is used and cannot be limited to the mere measurement of position in a 'culture-independent' space. This is most visible if the concept of 'property' is considered or if one thinks of urban planning. But the strong cultural influence is also affecting the way how people use a GIS. That must be taken into account when designing the user interface [Campari, 1994].

6. RESEARCH

A discussion of academic curriculum has to include the topic of the intellectual core and research. Academic disciplines are formed around research issues, and the academic profession is linked to the research efforts by a two way communication channel: providing questions to address and applying research results into practice. An intellectual core cannot exist without a complex set of challenging questions and the resources to work on them.

Research is of practical importance in the field of surveying. Technical and professional development is fueled by research. Development slows down without research. Comparing GIS with other information technologies, only slow progress is observed. Much of the software currently in use is based on designs of the late seventies and completely new designs are few. Other areas of information processing have been developed through several generations in the same time. I would attribute this lack of progress to the low level of research caused by insufficient funding.

Fundamental research should be done at university, this is what university staff is good at. The more applied research and development efforts can be shared by industry and universities. Pure development should be done by industry - universities are typically not well organized for this end. Universities have the freedom to address the questions GIS will face in 5 to 10 years. If these questions are not addressed today results will be missed later - and research cannot be done faster (as little as other projects cannot be sped up by adding more manpower when it is too late [Brooks, 1972]).

It might be instructive to consider the current level of research in Spatial Information Theory. There are three regular conferences with peer reviewed papers, all bi-annual:

Spatial Data Handling Conference SDH [Waugh, 1994] (since 1982)

Spatial Databases SSD [Abel, 1993] (since 1985)

Spatial Information Theory COSIT [Frank, 1993] (with a precursor [Frank, 1992]).

All of these conferences are using a careful peer review, asking authors to submit full papers which are then reviewed by three leading scientists in the field. The acceptance rate varies between 30% and 70% of all papers submitted (with a tendency to demand higher quality). There are other important conferences (AutoCarto, GIS/LIS etc.), but they do not have a rigorous method of quality control in place.

Considering these conferences one can assess the seize of the research community in the GIS field, rounding generously upwards to include other researchers not appearing in these proceedings. A figure of 700 researchers world-wide from all related disciplines (Geography, Computer Science, Surveying) shows that the GIS research community could be compared with the community of database researchers (a sub field of Computer Science), but the total amount of available funding is definitely much smaller (probably by more than a factor of 10).

Unfortunately, surveying is only marginally present in the research community. Only a small number of university surveying programs appear regularly in research related publications with a small number of researchers. As in any discipline one should also ask: Who educates the researchers of tomorrow?

7. CONCLUSIONS

Surveying is moving forward. The content of the curriculum has to be reviewed in regular intervals. The International Think Tank on Surveying Education provides a forum to compare the experience made in America and Europe. Despite all differences between the educational systems and the situation of the profession the problems are very similar and the answers proposed resemble each other. Experience of successful programs demonstrate the same trends on both sides of the Atlantic. Nevertheless, the comparison between apparently different solutions help us to identify the fundamental similarities.

Agreement exists that surveying is moving towards a more comprehensive science of spatial information. The pure measurement aspects of surveying business are reduced and increasingly 'value-added' services of organizing spatial data collection, management and presentation of spatial data are taking over. Curricula must follow this trend.

My personal conclusions from the discussions at the Think Tank are summarized in six guidelines for curriculum design:

- Keep mathematics strong,
- Keep neighboring disciplines,
- Keep formal spatial disciplines,
- Keep practical surveying training,
- Add core computer science and information science, and
- Add a substantive set of GIS courses

These guidelines indicate not only what should be added, but also what needs to be preserved in our educational programs. Most importantly, they also indicate what can be reduced. There seems to be agreement that specialization is important but should only be added to a strong common core; the differentiation between a management and organization of a group of topics (including traditional legal survey) and a group addressing the computer science and information processing topics resolves some of the most debated issues of the level of compulsory computer science education.

Quality control has to become a continuous effort in surveying education and we must install methods of control that the education we provide for our students is appropriate and responds to their real needs. Furthermore, with continuous checks we have to assess that the education method is the best possible with the necessary resources made available.

A profession needs an intellectual core, which links practitioners, academic teachers and researchers. The common issue of 'spatial information theory' could provide this focus and stimulate research with resources from different origin. To keep surveying a viable academic discipline a substantive research effort is necessary and surveying programs must include a research component. Surveyors have to participate in an internationally organized research forum and make the contribution others expect from them.

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REFERENCES

Abel, David, and Ooi, Beng Chin, ed. Advances in Spatial Database - Third International Symposium SSD'93 Singapore. Vol. 692. Lecture Notes in Comuter Science. Berlin: Springer Verlag, 1983.

Al-Taha, Khaled. ”Temporal Reasoning in Cadastral Systems.” Ph.D., University of Maine, 1992.

Bartsch, Eckhard. ”A Wishlist of the Public Surveying, Mapping and Cadastre Administration to the Academic Institutions.” In Think Thank II in Campobello, CA, edited by Tyler, David A, and LaCrosse, N. Christie, University of Maine, Dept. of Surveying Engineering, 13 - 17, 1992.

Bauernfeind, Carl Maximilian. Elemente der Vermessungskunde. Stuttgart: J.G. Cotta, 1869.

Brooks, Frederick P. , Jr. The Mythical Man-Month. Essays on Software Engineering. Reprinted 1982 ed., Reading MA: Addison-Wesley Publishing Co., 1972.

Campari, I. ”Cultural Differences in GIS. A Basic Approach.” In EGIS'93 in Genoa, EGIS Foundation, 10-19, 1993.

Campari, Irene. ”GIS Commands as Small Scale Space Terms: Cross-Cultural Conflicts of their Spatial Content.” In Sixth International Symposium on Spatial Data Handling in Edinburgh, Scotland, edited by Waugh, T., and Healey, R., Association for Geographic Information, 554 - 571, 1994.

Dodson, Rustin. GIS Laboratory Exercises. NCGIA, 1991. 91-12.

FIG Federation Internationale des Geometres, XVIe Congres International des Geometres. Montreux, Switzerland: 1981.

Frank, Andrew U. ”Acquiring a digital base map - A theoretical investigation into a form of sharing data.” URISA Journal 4 (1 1992): 10 - 23.

Frank, Andrew U. ”Zielsetzung der Tagung GeoLIS III.” Oesterreichische Zeitschrift fuer Vermessung & Geoinformation 82 (1 + 2 1994): 7 - 8.

Frank, Andrew U., and Mark, David M. ”Language Issues for Geographical Information Systems.” In Geographic Information Systems: Principles and Applications, ed. Maguire, D., Rhind, David, and Goodchild, Michael. London: Longman Co., 1991.

Goodchild, Michael F. “Spatial Information Science.” In 4th International Symposium on Spatial Data Handling in Zurich, Switzerland, edited by Brassel, K., International Geographical Union IGU, Commission on Geographic Information Systems, 12, 1990.

Frank, A., Campari, I., and Formentini, U., ed. Theories and Methods of Spatio-Temporal Reasoning in Geographic Space. Vol. 639. Lecture Notes in Computer Science Vol. 639. Berlin: Springer Verlag, 1992.

Frank, A. U., and Campari, I., ed. Spatial Information Theory - Theoretical Basis for GIS (Proceedings of the

European Conference on Spatial Information Theory COSIT'93). Lecture Notes in Computer Science. Berlin: Springer Verlag, 1993.

Kuipers, B. "Modeling Spatial Knowledge." Cognitive Science 2 (2 1978): 129-154.

Laurini, Robert, and Thompson, Derek. Fundamentals of Spatial Information Systems. APIC Series, Academic Press, 1991.

Stubkjaer, Erik. "The Danish Education of Land Surveyors - The LIS/GIS Components and the Control Instruments." In 2nd Seminar Education in Land Information Systems ELS in London, Faculty of Geodetic Engineering, University of Technology Delft, 5.16 - 5.18, 1993.

Waugh, T. C., and Healey, R. G. Six International Symposium on Spatial Data Handling. Vol. 2. Edinburgh: AGI, 1994.