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Geospatial capacity-building, best applications and practices**

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Geospatial Capacity Building, Best Applications and Practices

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Introduction

Over the years, geo-information has become an increasingly important resource for society at large. Society, in short, requires geo-information for meeting the increasing information demands to manage and solve current global problems related to, for instance, health, environment, climate, and governance (see for instance the millennium goals - http://www.un.org/millenniumgoals/). This is not surprising since of the five fundamental human questions — What? When? Where? Who? How? — the first three trigger the elementary characteristic of geospatial data: location. Location is thus an important component in information for humans. It is claimed that 80 percent of all our decisions involve a spatial component. In this light a constantly increasing information demand by society can be witnessed. How can the data be provided and how can one guarantee access to the necessary information? In our networked global society, Internet plays a prominent role in this process.

The traditional approach of the geospatial data handling process is based on the components of the classical information system: input, storage/processing, and output. This approach has been particularly attractive from a data supplier's perspective, such as that of national mapping agencies. It results in a geo-version of this system in which the real world is being observed with a particular purpose in mind. The observations range from fieldwork to remote sensing. In the ITC context the last technique prevails. Data structures are needed to store the data collected to guarantee that the data can be queried in a particular context. Often this is part of data processing that can result in output such as maps, diagrams, tables or new data to be used in geospatial analysis operations. Traditionally this is the basis of many different geo-production lines, ranging from mass production to ad-hoc solution to solve geo-problems. However, the above typical data supply-driven environment is changing rapidly in a data demand-driven environment. A more flexible approach is required because more data is available from different sources and more non-experts are using the data, while the web will become the predominant working environment and dissemination channel. Many data providers are offering their data via the web and a start has been made to create portals where users can get access to the data in a kind of one-stop-process. This is been facilitated by a so-called Geospatial Data Infrastructure, which can be loosely defined as: *a set of institutional, technical, economical, and legal arrangements.* Because it is not only data that can be obtained through these portals but also more and more services that can solve certain data related problems one could address the GDI as a Geospatial Service Infrastructure.

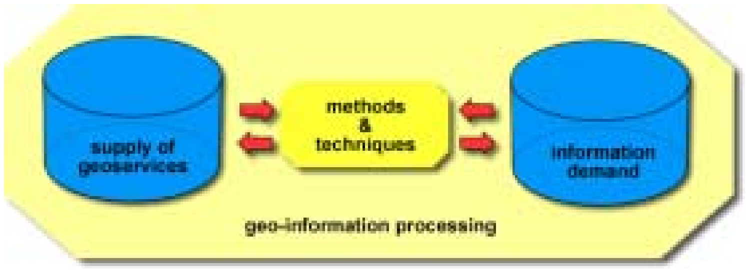

Figure 1.
Geo-Information Processing in between data supply and information demand in the GDI context.

It will be obvious that the above developments have their influence on the training needs, and will also influence curricula development at the institutes that offer education and training. This paper will discuss capacity building in the context of a GDI and illustrates the discussion by how it might effect National Mapping Agencies (NMA's) (those to be educated) and how it effects ITC geoinformatics masters (those educating).

Capacity building
How should for organization providing geospatial data anticipate on their position and role in the world geoinformation in the next ten years, and what kind of staff (capacity and capabilities) do the need? Not an easy question if one considers new and ever changing opportunities offered by the modern technology, the new concepts of the role of government and the evolving new (global) economy that all impact the development of (national) geo-data infrastructures in which NMA and other geospatial data providers have to operate. Still one has to try to find an answer to establish the role of NMA's in the modern evolving information society. Within this society a new business and Geo-ICT environment is emerging which forces GI-providers to develop new business strategies. Consequently they have to adjust their Geo-ICT strategies and develop new Geo-ICT architectures and adjust their organizational structure (see figure 2).

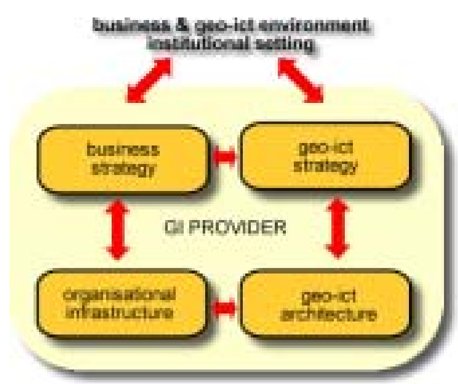

Figure 2: GI-Providers have to adjust their strategies, organizational structure and geo-ict architectures to meet the modern challenges of their business and geo-ict environment (Courtesy of Y. Georgiadou, ITC)

The growing importance of this field for civil society requires involvement of governments to set policies and to make and stimulate large investments to create and develop spatial data infrastructures. The technological and institutional conditions in many regions in the world are far from optimal for the creation of an information infrastructure so that great investments are required. These should be complemented by institutional and organisational arrangements to make sure that these investments will be adequate and effective. This issue is manifest nowadays and appears high on the agendas of the international gi-community, as can be witnessed in the programme of the 8th Regional Cartographic Conference for the Americas in New York and the equivalent of the CODI conferences in Addis Ababa in Africa.

Capacity building is not a trivial issue as we see also a rapid transformation of the professional groups involved in this market. In the (recent) past professional mapmakers had a central role with respect to geospatial information production, and were especially involved in the provision of framework data. They were mainly geodesists, cartographers, surveyors and photogrammetrists, who worked in a mainly data supply driven environment. In the seventies and eighties a new remote sensing and GIS community evolved which consisted in the early days of interested experts from other fields, mainly the various surveying disciplines, and pioneering amateurs who obtained their skills by training and through experience. Nowadays the gi-community consists increasingly of highly educated professionals who more and more work in a data demand driven environment. These professionals can be divided in three major categories which each have their own educational needs:

- Experts in the field of spatial information handling (or specialists in certain aspects of this field)
- Users of geo-information
- Decision makers and policy makers, who are developing the required legislation and institutional arrangements

Their education and training requires carefully designed curricula, programs and courses based on the mature paradigms of geo-information science and its related disciplines. The design should also be based on a proper understanding of the contexts in which geo-information is produced and used and of the role that the three different types of professionals play in this field. It should also be realized that experts from one specific disciplinary background can seldom address all aspects involved; therefore Geo-informatics should always be seen in an interdisciplinary setting.

These observations imply that capacity building in the context geo-information provision should be put high on the agenda of the international GI-community and a dedicated effort is required to identify the needs for education. In this respect we should consider the current and new processes for geo-information provision (geoservices) in relation to the three categories of roles that experts, identified here above, play in this context. One can look at this from two perspectives (see figure 3):

- *The process structure* for geo-information production (looking at the different the stages of the process: data acquisition, storage and retrieval, processing and presentation and dissemination and use.

- *The process contexts.* One could of course easily look at the above stages from a technological perspective and consider aspects of sensor systems or particular web services. But these stages can also be seen in the context of the application domains, such as land registration and administration, natural resources management, disaster mitigation, etc. Other contexts are the information flow management with its organisational aspects and also the institutional and policy issues.

PROCESS / CONTEXT	data acquisition	storage & retrieval	processing & presentation	dissemination & use
application domain				
technology				
information management				
institutional setting & policy				

Figure 3. A dual perspective on the aspects of the geospatial data handling process

Professionals operating in the field of geo-spatial data infrastructure are aware of this fact. On the other hand the fact that the application domains cover a wide variety of fields, such as land registration and administration, natural resources management, disaster mitigation, etc., implies that specialisation (although within an interdisciplinary context) will be required for professionals to keep up to date with the state of the art in their field of expertise. These apparently conflicting criteria for the education of professionals and scientists in geo-informatics require a careful focusing and design of educational programs. Not all requirements can be fulfilled by one single program, one should rather think of a coherent family of education programs to educate the members of the future geo-informatics community

Finally, the rapid technological developments, as well as developments in demand for information, imply the continuous upgrading of professionals as part of the “lifelong learning” principle observed throughout present-day society. This in turn challenges the education and training institutes themselves to keep up to date with scientific and technological developments while simultaneously dealing with the proliferating variety in demand. This requires a strong interaction between education and research

The importance of GDIs for governance has implications for the national (public) organisations responsible for establishing and operating these GDIs. Hence, besides the education of individuals, capacity building of the entire organisation is required (Georgiadou and Groot, 2002). The goal of education is to prepare (young) professionals for their tasks ahead, while the goal of capacity building is to simultaneously shake up the organisation that will employ them. The aim is to strengthen an organisation so that it can assume responsibility for designing, managing and sustaining development. For this, not only are thematic professionals required but also staffs that can formulate, design, manage and negotiate with other organisations and central government in order to address organisational and institutional issues in support of the acceptance of technological solutions. Hence capacity building comprises human resources development, organisational strengthening and institutional strengthening – of which education is part and parcel. We have seen here above that we should think of coherent families of programs that cover the different aspects of the field presented in Figure 3, we see now also that for capacity building the three levels of Figure 4 should be covered.

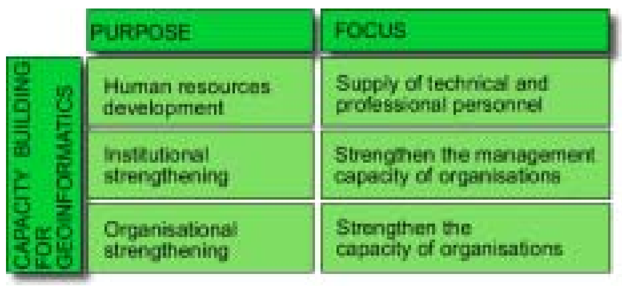

Figure 4. Capacity building for geoinformatics, its purpose and focus.

Example I: impact on National Mapping Agencies

National Mapping Agencies traditionally provide framework data. This includes next to basic topography, the elevation model, geodetic control points, administrative boundaries and geographic names. This type of base data allows linking to other kind of (geo)data and is required for nearly all geo-applications. However, they operate in a changing environment and will have to deal with the methods and techniques recognising the changing balance between geo-services supply and information demand in the framework of the Geospatial Data Infrastructure (GDI). The geo-services can include data as well as computational components to deal with the data.

It will be obvious that this approach is different from the traditional geospatial data handling process and the GIS-based perspective. However, the basic methods and techniques are still required: *storage and plain provision* of (geo-)data, the provision of computational services, such as simple geodata conversions or, more advanced, spatio-analytic functions such as geostatistics or geosimulations, and the simple or advanced techniques for presentation of the serviced goods, whether they are data or computational products. The context has changed.

The basic questions NMA's are used to ask are changing or require a different answer and are very much influenced by the timeframe of the above developments. These questions are:

- *How & where to get data to up-date the databases?*
  This might have been a simple question: the agency would take care of the data collection and have the staff to execute the job.
  However, up-to-date has a different meaning these days, because long revision cycles are no longer accepted. And since related organizations have similar problems it is good to see if one cannot use each others data. It will stop the collect-many-times-use-many-times and change to collect-once–use-many-times. This put constrains on quality and exchange and asks for standards.
- *How to organize this data in an information system?*
  Creating one or multiple databases to support the map production process used to be the policy.
  However, it seems a better policy to have one master database and derive smaller scale data from this database. This approach is still difficult because of the multi-scale problems to doles. Since people may want data (or a map) for a particular range around geographic phenomena or would like to have the full hydrographic data set with geographic names which they would like to combine with their own data the organization have to step away from the map sheet as an organisational unit. In addition user could as for derived data such as a generalized road data set to be used in their application that adds value to the original data for a traffic control application.
- *How to manipulate and analyze the data to satisfy the needs of end users in an optimal way?*
  Paper maps used to be the final product.
  However, today's products might look different. The traditional 2d data have evolved into 3d data while one has also interest in spatio-temporal analysis of changes over time which requires data from different periods.
- *How to present and disseminate the data optimally to end-users?*
  Maps at a particular scale and design are available
  However, the maps are still around, but the environment where people use the data has changed. They need the data in combination with other data in a spatial analysis operation or the data has to be suitable in a web service for tourists using mobile devices. This puts constraints on both the data structure and the design conditions. It could also be that the framework data no longer appears in a map form but as 3d laser-scan of the landscape, or as an orthophoto.
- *How to arrange for an environment that allows a smooth exchange of geospatial data/information?*
  A shop or mail-order system where one can buy maps is the classic distribution system for most NMA's.
  However, the Internet has taken over – not just to order the classic paper map but also to download data according user specifications. Are NMA's ready for the age of the geospatial data infrastructure and its geo-services?

Example II: impact on education: ITC geoinformatics master

Geoinformatics education should be seen in the context of a GDI, and for this purpose one can define GDI as:
A Geospatial Data Infrastructure is an open and continuously network of collaborating systems that have been purposefully designed to provide services to an a priori not always well-defined user community, which are likely to change over time. The services they require demand geospatial data provision and geospatial data handling, though may involve non-spatial data as well.

This definition is pictured in the figure below. Different services are networked together and can communicate using agreed upon protocols and messages via specific interfaces. These services can involve data provision (for instance topographic data at a particular scale), but could also include simple or complex geospatial data handling actions. An example of the first is a request to transform a dataset from one projection into another. An example of the second could be getting available road data, request a for generalization operation and finally visualize it according to a particular design template. Users can request for a particular service via a web portal. The services might involve non-geospatial data as well or could be supporting services such as catalogue or security services.

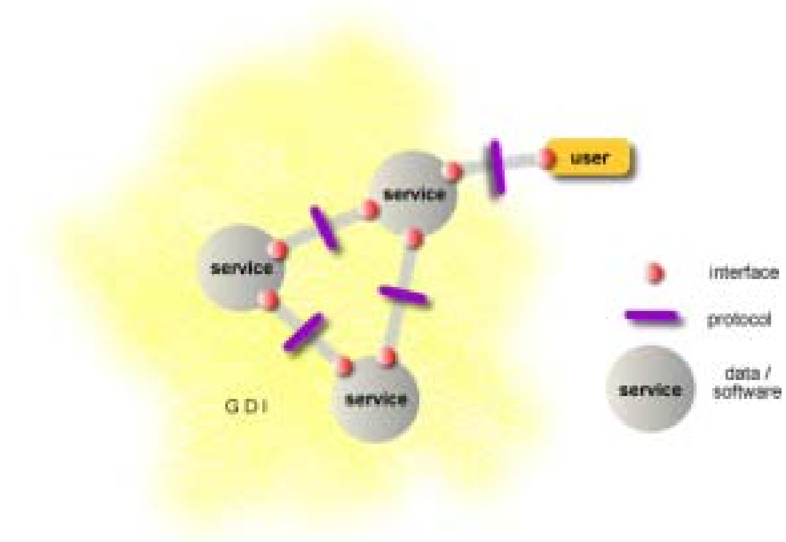

Figure 5. Schematic overview of a Geospatial Data Infrastructure. Services could be data provision (e.g. base data1:10.000) or computational actions (coordinate transformations). Standards and protocols will allow access the services.

To realize the services, standards to guarantee interoperability are important, and the Open Geospatial Consortium (OGC) plays a prominent role to define standards in the context of the GDI. NMA's have to incorporate OGC procedures in their work. This implies their implementation of protocols of communication, and exchanges data and delivers services in standardized ways. A characteristic list of keywords of this dimension is: web services, protocols, interfaces, standards, metadata.

Due to the above developments ITC's geoinformatics programmes are undergoing some interesting and appropriate changes. Todays student can choose between the Master of Science, the Master and the Diploma level. The (Professional) Master programme gets a more engineering like profile. The target students have a position and function to analyze geo-technical problems, design production processes of geospatial data and services, and evaluate performance.

The aim of the course is to "produce" a geoinformatics engineer equipped to operate in one of the fields or aspects outlined above. Different from an MSc s/he will not do academic research with the purpose to develop new technology. Different from a graduate of a technology diploma course s/he will not work on a production execution level. The GFM3 graduate will be able to solve design problems making optimal use of operational technology relevant for providing core geo-spatial data. The course treats modern integrated geoinformation production technology, including methods and techniques of geospatial data acquisition, methods and techniques of geoinformation processing, dissemination and visualization. The course graduate will be able to work at a professional level in geoinformation production including the giving of support to the design and set-up of technological components of a spatial data infrastructure.

On completion of the course, the geoinformatics engineers must be able to analyze geo-technical problems and design production processes of geospatial data and services for different application fields of geoinformation. But they can also give support to the design of and implement technological GDI components in an organization, evaluate (intermediate) information products, which can be used as building blocks for multi-level GDIs. They can evaluate the performance of production and dissemination processes, and are expected to work in multidisciplinary teams engaged in production projects, which involve spatial data collection, database management and data dissemination. And last but not least they are able to transfer the gained knowledge into their own working environment.

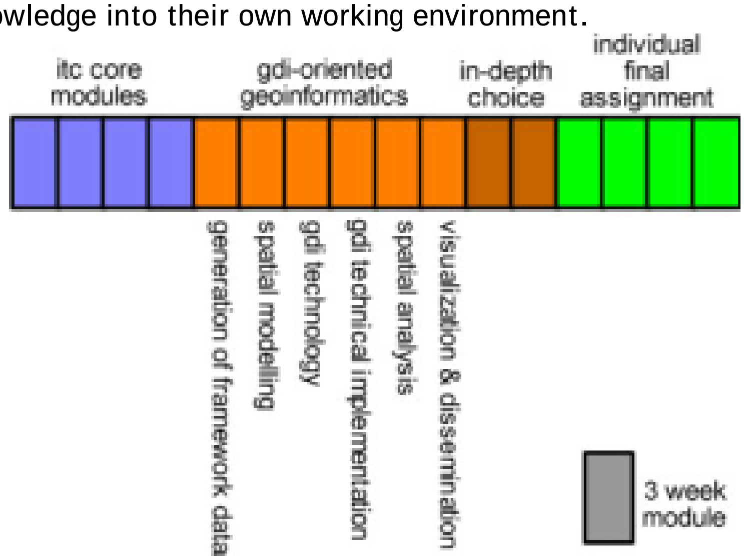

Figure 6. The modular structure of the Geoinformatics master.

As any course at ITC the re-engineered geoinformatics master (GFM3) starts with the core modules. These consist of an introduction to the geoinformatics programme explaining the geoinformatics concept and articulate the role of geospatial data products and services in addressing social and economic development issues, and aspects of good governance. This is followed by a modules on the principles of databases, the principles of GIS, and the principles of remote sensing. These modules should learn the students how to generate information about the Earth from remote sensing and data stored in Geographic Information Systems. This takes the first twelve weeks of the program (see figure 3). The second part of the new stream contains six modules that from a technical point of view all deal with the geospatial data infrastructure. The modules are related to the generation of framework data, spatial modeling, GDI technical design, GDI technical implementation, spatial analysis, and visualization and dissemination of geospatial data. This is followed by two more modules where the students can select topics of their liking to get more in depth knowledge. The topics offered stem from the former specialization Cartography, Photogrammetry and GIS. An Individual Final Assignment will end the program.

The individual modules dealing with the technological aspects GDI is supported by a case study that practically binds them together and runs through all modules. The knowledge acquired in modules 6-11 is used to build a coherent system for spatial data acquisition, storage, access, analysis and dissemination, that complies with GDI qualities and standards, within the framework of what can be achieved in the limited time and with the available resources. The use case is that of a planner that has to determine possible locations for a new business park somewhere within the Enschede municipal boundary. The planner should be able to use a simple, platform independent interface (ie. a web browser) to a GIS application that in turn uses data from two separate data sources: cadastral geodata and municipal topographic geodata. The students are developers of the system(s) that provide the data to the use case infrastructure. The emphasis is on the data infrastructure, not so much on the planning process (which is just serving as a data and service consumer and could be replaced or extended later with use cases from other domains). The cadastral geodata should be provided to the developers as an existing data source that has to be used "as is", meaning they'll have to study the existing data model and delivery mechanisms, but they cannot modify these, nor the contents. The municipal geodata is to be managed by the students (in the role of the Municipality). This includes first modelling and designing the data along the lines of skills and theory learned in modules. The implementation part would include gathering the required data, both from existing external sources (eg. top10Vector and Municipal GI for buildings and roads) and by acquiring new data (eg. landuse and newer infrastructure from aerial photos and/or fieldwork). At the end the planning system should be consuming the data from the cadastral and municipal geodata. It should also include some analysis tools and option to disseminate the data.

The need for OpenGeospatial and Opensource initiatives

During the re-engineering activities of the geoinformatics master ITC has chosen to follow the guidelines op the Open Geospatial Consortium (http://www.opengeospatial.org/) as much as possible and also to let the students work along opensource programming guidelines. This doesn't mean students will no longer work with other existing GIS software – this will certainly be the case, but when building new elements and working on the case described above opensource is the keyword. Although we realize that currently the opensource resources (see for instance http://sourceforge.net/) do not offer a full replacement for existing GIS software packages it is at the end a good low cost alternative, something that ITC customers in the developing countries should appreciate. Students will learn how to find, implement, extent and contribute to the existing opensource software, and how to link it to existing proprietary solutions.

To be well prepared ITC has joined 52° North (www.52north.org). It is an open partnership organization that develops open source software under the GNU General Public License. It was founded by the Institute for Geoinformatics at the University of Münster and Con Terra GmbH in 2004. The International Institute for Geo-Information Science and Earth Observation (ITC) in Enschede (The Netherlands) has joined as a full member at the beginning of 2005. Its name refers to the degree of latitude which intersects the city of Muenster, Germany – the home of its founding organizations. Enschede also happened to be located on that particular latitude. 52°North's mission is to advance the design, development and use of open source software in geoinformatics research, training and application. We will bridge the gap between open source and proprietary solutions.

ITC has joined this initiative for several reasons. From a research perspective it provides a common development platform for almost all software related research activities at ITC. As such it will become an integral part of all collaborative research activities within ITC and between ITC and external partners and as such ensure sustainability and maintainability of research results. But most important is the educational perspective. Since ITC is a global player on the educational market oriented for education in geoinformation science and observation in the lesser developed countries the opportunity to be able to use free software is very appealing especially for our Joint Educational Programs and all types of distance and blended.

Conclusion

The continuous changes in our society and more particular in the professional world of geo-information require a well thought approach to capacity building to be able to execute current and future tasks. Not only should we be able to 'play' according the rules of the current GDI trends – the geo-services and its protocols and standards – but also be flexible to be able to react to future developments which come faster and more often then before. We also have to realize that although geoinformation is special it will become more part of mainstream information provision which will result in others involved in the daily geoinformation activities and somehow a broader involvement of governmental organizations when it comes to policies.

In this field National Mapping Agencies have to continuously wonder about their position, their products and services that are or could be in demand. Up-dating educational programmes is an evolutionary step in the continuous adoption toward the needs in the market, and regularly need a complete re-engineering to offer the right life-long learning opportunities.

Further reading

Beerens, I.J.J. 2001: “Capacity Building For Geo-Spatial Information Handling InAfrica,The Itc Perspective”. International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, 2001, 19 pp.

Dale P. 2001: “Are National Mapping Agencies an Anachronism?”, Surveying World, 2001, pp28-29.

Ezigbalike, C. 2001: “The future orientation of geoinformation activities in Africa”. Commisioned by Committee on Development Information (Geo-Information Subcommittee) Development Information Services Division (DISD) United Nations Economic Commission for Africa. 37 pp.

Georgiadou, Y. and. R. Groot, 2002: "Beyond Education: Capacity Building in Geoinformatics", GIM International, February 2002, Volume 16, pp. 40-43

ITC, 2005: Strategic plan 2005-2009. International Institute for Geo-information Science and Earth Observation (ITC), Enschede, 2001, 42 pp.

Molenaar, M. and M. J. Kraak, 2000: Geoinformatica in de ITC Context. Workshop on Education. Netherlands Commission for Geodesy. Delft, 2000, 10pp.