The Challenges of GIS Education and Training: (GIS Use by Municipal Urban and Regional Planning)

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Abstract

In what follows, I want to sketch a profile on the challenges pertaining to GIS Education and Training, more specifically affecting the use of GIS by the Urban and Regional Planning profession in South-Africa. This paper is based on research which formed part of a Honours BSc (Hons) as well as Masters MSc Geography (GIS) degree qualifications during 2005 to 2007. The focus will be towards assessing as well as addressing GIS education and training issues within the Urban and Regional Planning profession towards better GIS use.

I will start to give a general background introduction of GIS Education and Training internationally (The National Center for Geographic Information and Analysis - NCGIA). Then, the focus will be towards GIS Education and Training in South Africa (South African Quality Authority-SAQA) and then GIS Education and Training received by municipal Urban & Regional Planners in Gauteng. Specifically, I will give a background assessment of GIS Education curriculum which will include problems experienced with GIS curricula (thus hindering GIS use in industry). This will include GIS Education and Training offered by tertiary education institutions, offering GIS Education and Training either as a stand alone Science degree, part of another qualification such as Urban and Regional Planning or an initiative by private vendors. I will also further provide a detailed analysis of current GIS curriculum context, issues and challenges with regard to how GIS Education and Training has been established and is affecting GIS use in industry (focusing on Gauteng municipal level). Finally, a conclusion will address possible solutions and benefits that could be considered, should GIS Education and Training be affectively addressed, specifically within an Urban & Regional Planning profession. The following aspects will be covered:

- *An introduction and overview of GIS use Education and Training i.e. traditional use, training and curricula changes to ensure quality of training.*
- *How GIS is used and education and training received by professional municipal Urban and Regional Planning departments is affected by GIS availability and use i.e. recent incorporation of the subject GIS that affect use in industry negatively.*
- *Specific shortcomings with regard to GIS Education and Training by tertiary institutions offering GIS i.e. profession specific study material, lecturer capacity/training and basic computers literacy.*

- *Who is responsible for GIS training provision and the format thereof? i.e. Formal GIS Science qualifications by universities or GIS as part of another qualification. Also short courses offered by private vendors.*
- *Current GIS qualification require in South Africa as prescribed in legislation for accreditation i.e SAQA and outcomes based education specifics.*
- *New GIS curricula challenges and responses i.e. GIS competency levels and the roles played by professionals involved in GIS.*
- *The design of education to support a system of spatial thinking i.e. educational goals, course material being appropriate for learners needs and matching educational content.*
- *Education measured as a capacity to support a system of spatial thinking i.e. capacity to Spatialize (by providing spatial data structures and coding for non-spatial data), to visualize (providing multiple representations) and perform function (by manipulating the structural relations of data sets).*
- *Specific competencies required during GIS education and training for better GIS use internationally i.e. Technical, Business, Analytical and Interpersonal of nature.*
- *Challenges in GIS education and training i.e. Time to train learners, design of curriculum, compatibilities, GIS focus, software trends and changes, measurements of education, teaching methods.*

I do not claim that where there is a lack of GIS education and training, that it is based on one factor specifically, but that merely the negative effects that exist are based on the development of GIS in education within the profession. Also that this development may have been influenced by a broader sphere such as GIS training of managers themselves, which also need to be in place towards better education and training, resulting in a better understanding and practical application potential of GIS in the Urban & Regional Planning profession.

My purpose in this paper is not to assign blame or ascribe responsibility for any negative effects, where applicable. I depict the possible consequences that may be experienced within the profession should education and training in industry not be stream- lined. Some of these consequences may be devastating and require everyone's serious consideration, as it does not only affect Urban & Regional Planning but other built environment professions as well.

1. Introduction

The need for high quality education and training for GIScience and users is recognized (Directors Magazine, Phoenix: 2000). The implementation by various markets including commercial and government agencies require well trained professionals, both technical and user of nature. This situation presents challenges and opportunities for educators at different levels of society, ranging from GIS at secondary school to universities offering either stand- alone GIS Science degrees or GIS as part of another professional qualification (Directors magazine, Foote, K.E Mar 07, 2005). All efforts towards not only providing spatial information, but also to promote specifically spatial thinking towards solving spatial problems making use of analytical techniques and reasoning.

GIS and GIScience demand new knowledge and skills. Though most GIS professionals are only trained in traditional curricula in departments such as Geography, Civil engineering and Computer Science, they have failed to develop insights into the critical linkage amongst these disciplines; consequently these curricular and structural changes need to form integral components of plans to produce GIS professionals, whom are also currently short in supply. It is even desirable to take formal steps in these GIS professionals preparation to ensure consistency and quality .This aspect of change in knowledge and skills which poses challenges, justified research (National Research Council US et al 2006: 27). Finding educators that can keep up with new tools, skills, and methods that are changing rapidly, is challenging enough. Further concerns raised related to the GIScience include the assumption that all are up to date with national and international geospatial standards. Despite this situation, educators are responding to the challenge.

Though workplaces more likely to have implemented a GIS, include municipalities (due to central government funds available), the process of education is still timely. Some universities and professions responded to this challenge through more up to date research, and then incorporating latest industry related GIS software and in-house training skills into their qualification curriculum, such as municipal Town & Regional Planning departments in Gauteng (Marais 2007:121). Therefore, there is a given efforts to incorporate new and updated GIS content into both GIScience curriculum (National Center for Geographic Information and Analysis- NCGIA) as well as to meet workforce related demands (University Consortium for GIS-UCGIS). Some data and experiences to access GIS though, are against the design and implementation criteria to support systems specifically for spatial thinking (National Academies Press U.S et al 2006:166).

Since GIS education is measured according to the requirements of a system, the different criteria for GIS design in context and GIS criteria for implementation of a support system, these aspects will be explored more in dept, focusing towards “learning to think spatially”. This is towards maximizing GIS use in industry through GIS education and training.

It needs to be realized that most GIS is not designed with education applications in mind, and are designed by and for experts. Therefore, market dominator GIS software such as Arc Explorer and Arc View is readily recognized as teaching software, whereas subsequent release have addressed some problems experienced with previous versions (National Academies Press U.S et al 2006 :167).

According to the literature, two common factors that cause the limited use of GIS, are GIS availability and GIS training (Longley et al 2001:346).

2. Background

The Gauteng province in South Africa is characterized by six municipal regions. Three of these have a municipal status of being Metropolitan municipalities and the other three smaller ones, classified as District municipalities (http://www. demarcation.org.za/). Of these six municipal regions, only four has a GIS implemented to some extent; two metro municipalities a fully developed Internet IMS and the other metropolitan municipality an Intranet GIS. One district municipalities do not have a GIS at all and another one just started to develop a GIS (Marais 2007:72).

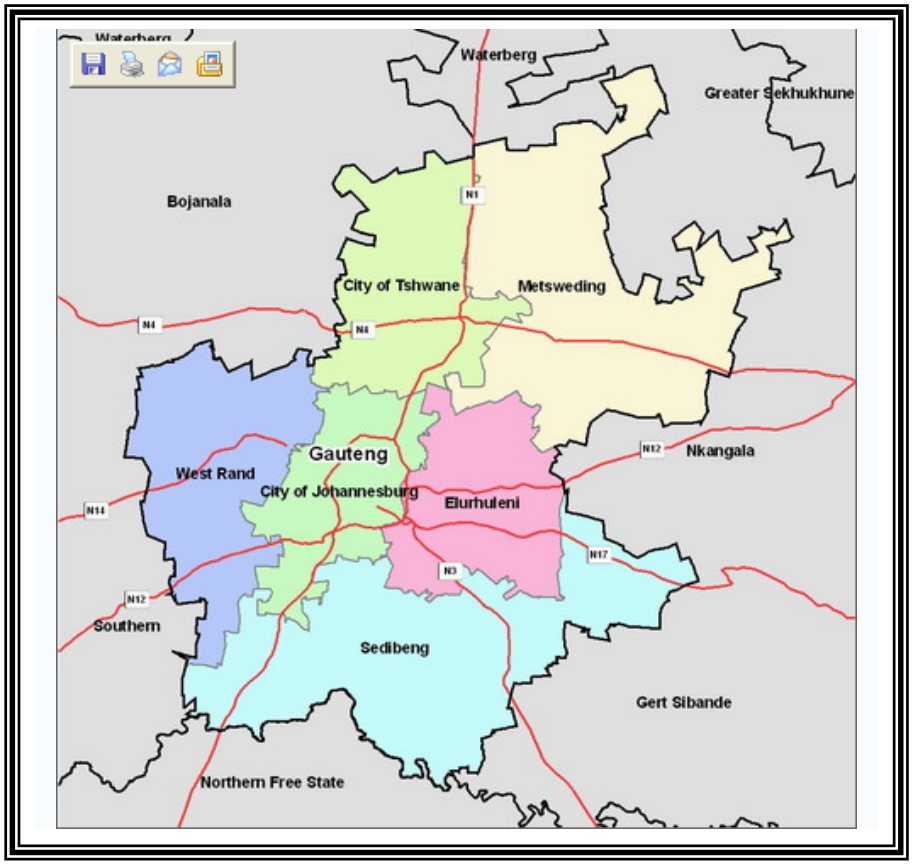

Figure 1.Municipal regions in the Gauteng Province
Source: (http://www.routes.co.za/municipalities /gp/index.html)

A total of 43% of all twenty three Town & Regional Planning departments do not use GIS because they do not manage access to a municipal GIS and/or Town & regional Planning data (Marais 2007:50). These GIS/data access problems are due to a limited server based GIS internally /externally to departments which are geographically located dispersed in some region.

Even though some of department offices could establish access to a GIS/data, GIS education and training (GIS knowledge) was further established to hinder the use of GIS by 46% of Town & Regional Planners (Marais 2007:100). Where a GIS could be used, it was further limitedly used because of the following aspects that relate to GIS education and training, namely ten (91%) of the eleven Town & Regional Planning offices that responded indicated that GIS training was inadequate.

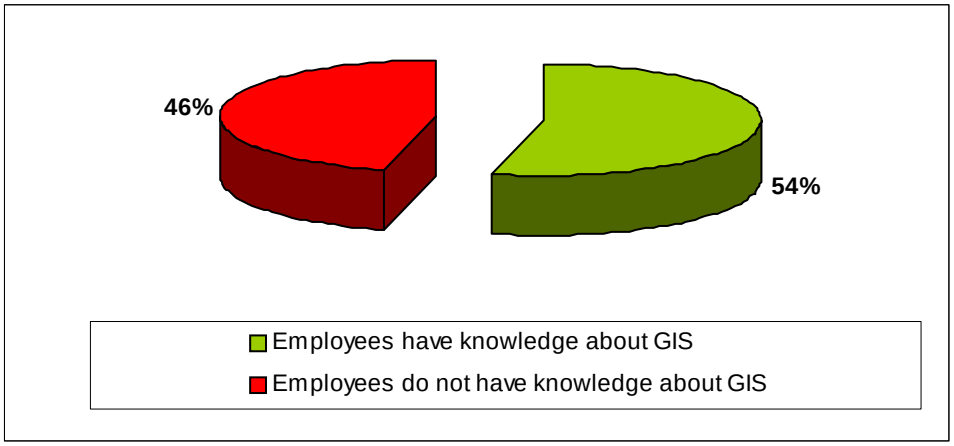

Figure 2. Town & Regional Planning department employees' knowledge about GIS

According to figure 3, nine (82%) of department offices indicated GIS and data availability to be a cause, as well as nine (82%) of the department offices experiencing a need for GIS short courses, probably because GIS was not included as part of the curriculum when some employees obtained their Town & Regional Planning qualifications. Eighty two percent of department offices also indicated the need for study material specifically for Town & Regional Planners (Marais 2007:57).

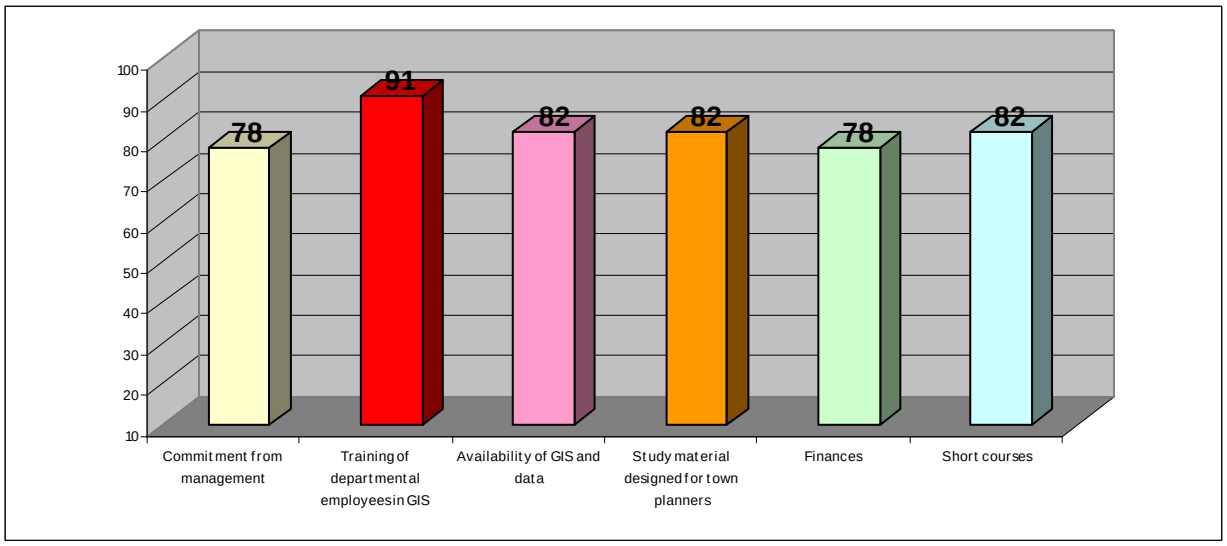

Figure 3. Factors that cause limited use of GIS in municipal Town & Regional Planning department offices in Gauteng

This situation of limited GIS education and training is the result of Town & Regional Planners whom receive an formal qualification from a tertiary institution in university in South Africa which offer TRP qualifications, where these tertiary institutions only recently, 90% since 1995 (of which 50% after 2000(have incorporated the subject GIS as part of the formal qualification curriculum (Marais 2007:116).

Also, exist specific internal problems related to the offering of the subject that is hindering the education and training of GIS by these lecturers/departments such as the use of external lecturers,

whom may not necessary be familiar with the Town & Regional Planning application together with limited computer literacy of learners and study material specifically designed for Town & Regional Planners (Marais 2007:123-124).

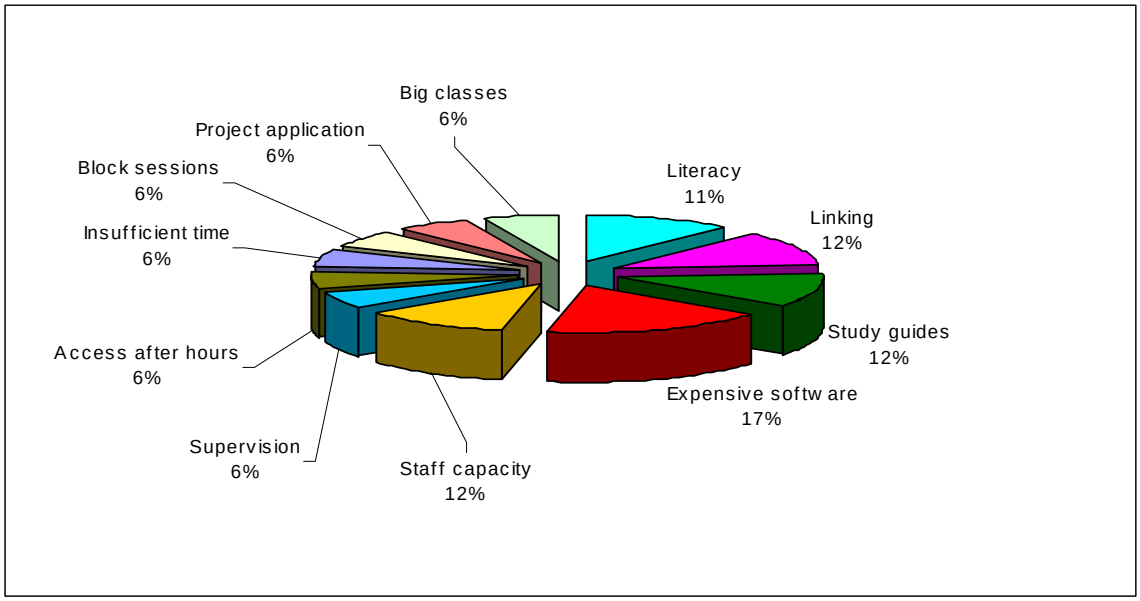

Figure 4. Problems experienced by lecturers when teaching GIS

The above, concernedly, illustrate the "status quo" of GIS education, training and use of GIS by municipal Town & Regional Planning department offices in Gauteng, a province internationally perceived to be the economic "hub" of the country South Africa.

3. Who Is Responsible For GIS Education and Training

According to literature, firstly, GIS education and training is often presented by private firms (such as Geographic Information Management Systems ~GIMS and Computer Foundation~ CF) as well as some organizational initiatives (such as City of Johannesburg's Corporate Geo-Informatics department) with regard to their specific software and application (National Research Council U.S, et al 2006:24). Secondly, GIS education and training is offered by some Colleges (such as Central Johannesburg technical) as well as universities (such as University of Pretoria ~ offering a pure Science qualification and University of Johannesburg ~ as part of the B-Tech Town & Regional Planning qualification) Where the first of these offerings are more science orientated qualifications, the latter is more hands on profession application based (Longley et al 2005:431). Lately, GIS has also been incorporated into school level (Green 2001:12).

A decent development of GIS education and training should entail both science knowledge as well as the skills pertaining to a specific profession (National Research Council U.S et al 2006:27).

4. Current GIS Qualification Requirements as Prescribed in Legislation For GIS Qualification Accreditation

Internationally, GIS training is done by completing various certificates or degrees offered by colleges and universities (Korte 2001:355). In South Africa, education and training is governed by the South Africa Qualification Framework (SAQA) towards accreditation of these qualifications offered also by various universities and colleges. Training is directed towards Outcomes based education specifics (http://www.saqa.org.za/). Some qualifications are structured to comprise of unit standards. Therefore, there exist associations whom register such GIS professionals.

4.1 BSc (Hons) Geo-informatics

The 1st category, an example of GIS Science qualification curriculum is the B Sc (Hons) Geo-informatics, offered by the University of Pretoria (Source: http:// allqs.saqa. org.za/showQualification.php?id=16114).

(a) The Purpose and Rationale of This Qualification

"The purpose of the interdisciplinary specialization is to provide the qualifiers with advanced knowledge and skills to apply the methods and techniques of geo-information management to problem solving activities in various application areas such as environmental sciences, environmental management, planning, engineering, business, utilities, health, education, etc. This degree builds on the knowledge and skills in respect of geo-information management obtained in undergraduate studies in various disciplines. The qualifier is empowered with advanced applied competence in matters such as Remote Sensing, Surveying, Geographic Information Systems, Cartography and Spatial Analysis. A further purpose of the qualification is to help alleviate the current shortage of adequately qualified personnel in the field of geo-information management. This will have a positive effect on information supply to the decision-making and development processes required for sustainable development in South Africa" (Source: http://allqs.saqa.org.za/showQualification.php?id=16114).

(b) The Different Exit Level Outcomes Required

- To demonstrate an advanced understanding of the theory relevant to geo-information management.
- Be able to apply advanced geo-information processes of collecting, managing, analyzing and presenting geo-information for decision-making.
- To apply the advanced geo-information processes, methods and techniques to various application areas and support problem analyses and problem solving in these areas.
- Know how to analyze geo-information requirements in an organization and to design, implement and manage a geo-information processing system.
- Be able to evaluate new theoretic and technical developments in the field of geo-information management and incorporate it into new applications.
- Effective communicate through appropriate media with all involved in the geo-information process.

- Effective participate in a Geo-informatics practice under professional supervision.

Integrated assessment:

This is done through Simulations, Written examinations and Oral examinations

4.2 Bachelor of Town and Regional Planning with subject GIS~ B (T&RP) Degree

The second, an example of GIS offered as subject, part of a qualification is Bachelor of Town and Regional Planning at the University of Johannesburg (Source http://allqs.saqa.org.za/showQualification.php? id=15887)

(a) Purpose and Rationale of The Qualification

The purpose of this professional qualification is to provide qualified learners with the competencies to design manage and implement innovative and integrated interventions in urban and regional spaces so as to ensure the equitable and sustainable development of people and places. GIS is then used to enhance spatial analysis and decision-making.

The Critical Cross-Field Outcomes:

The programme is intellectually demanding, interdisciplinary and designed to enable learners to demonstrate the following abilities: critical analysis skills, research skills, spatial interpretation skills, skills to utilize science and technology relevant to the discipline, problem solving skills, good writing, verbal and graphic presentation and communication skills, a concern with social justice and sustainable development, skills to solve problems and to design, manage and implement innovative and integrated interventions in urban and regional spaces across disciplines.

(b) Associated Assessment Criteria

Learners will be assessed on their ability to illustrate the exit level outcomes as stated.From the above, it is clear that there exist challenges in terms of GIS education and training requirements based on the end user's function within the GIS society. Therefore, it can be said that there is place for both focus areas, whether scientist or software user (application based).

The other aspect that needs attention is the recognition of prior learning, whereas an individual may be qualified based on pure experience, without any formal qualification as proof. Some universities offer qualifications that is based on unit standards, accumulated through the score of credits for each specific skills acquired.

But how does what is perceived internationally, compared to South African perception?

5. New Curricular Challenges and Responses

This section involves a variation of academic 4 yr science qualifications versus workforce specialist developments that look at competencies needed in industry (National Research Council U.S et al 2006:30). The National Center for Geographic Information and Analysis's (NCGIA) 3yr curriculum is developed, accepted and requested word-wide by 100 universities, but development was lessened since 1990, as ERSI took over GIS training, developing the offering of GIS also on school level (National Research Council U.S et al 2006:32). Universities Consortium for Geographic Information Science (UCGIS).

According to Dibiase et al 2006 and Mable (1997) there exist seven levels of GIS competencies, listed as follow:

Level 1	Public awareness of GIS and its uses
Level 2	Basic spatial and computer understanding
Level 3	Routine use of basic GIS software (Students interested in employment in firms and agencies to use off the shelf software)
Level 4	Higher level modelling of GIS applications (Abilities in spatial analysis, computer programming and database management)
Level 5	Design and development of GIS applications (Abilities of software engineering to some extent)
Level 6	Design of Geographic Information systems (Advanced analytical and technical skills that includes system analysis, database design and development, user interface design and programming)
Level 7	GIS research and development

(Source: National Research Council U.S et al 2006:27-28).

ESRI is also recognized as a leading research and development team in agencies in South Africa, specifically when it comes to being a software vendor as well as assisting and contributing to GIS in colleges and universities.

Apart from the levels, twelve roles are identified to be played by professionals by Geospatial workforce Development Center (GWDC). These involve

- Application development: (identify & develop tools & instruments to satisfy customer needs)
- Data acquisition: Collect geospatial and related data
- Coordination: Inter-organizational facilitation and communication
- Data analysis and interpretation: process data and extraction information to create products, drive conclusion, and inform decision making reports.
- Data management: efficiently and effectively apply a professions mission using technical and intellectual skills and resources to optimize the end result.
- Marketing: Identify customer requirements and needs and effectively communicate those needs and requirements to the organization, as well as promote spatial solutions.
- Project management: Effectively oversee requirements to produce prescribed outcomes on time and within budgets.
- System analysis: assess requirements
- System management: Integrate resources and develop additional resources to support spatial and temporal user requirements
- Training: Analyze, design and develop instructional and non instructional interventions to provide transfer of knowledge and evaluation for performance enhancement.
- Visualization: Render data and information into visual geospatial representations.

(Source: National Research Council U.S et al 2006:32)

From the above, it is clear that educating and training professionals in the use of GIS, is not a simple matter of theory only or practical skills only, but a joint integration that need to exist between the two.

6. The Design of A GIS System As A Support System For Spatial Thinking

According to literature, spatial thinking can be developed in the education and training of GIS by specifically focusing on the following outcomes:

(a) To meet educational goals

- Supportive of enquiry goals i.e. the question asked collect and possible answers - (National Academies Press U.S et al 2006:176).
- Be useful in solving a wide range of real world problems link between science and application thereof (National Academies Press U.S. et al 2006:177).
- To facilitate learning transfer across subject application i.e. interdisciplinary and multi disciplinary (National Academies Press U.S et al 2006:179).
- To provide a rich and generative environment for challenging problem solving i.e. its potential to display and explore (National Academies Press U.S. et al 2006:182).

(b) Be appropriate for learners needs through GIS

- Be developmentally and educationally appropriate for teachers, whom need a light weight version of the industrial GIS software used, and can be customized by teachers (if advance is not needed in training); data being made available applicable to a specific field of study such as Town & Regional Planning and separate from product purchase i.e. a component approach (National Academies Press U.S et al 2006:183).
- Assisting visual (and other) impaired learners through speech and voice input to find location) (National Academies Press U.S et al 2006:188).
- Meeting the needs of English language learners rather to develop English language, using tag menu's (National Academies Press U.S. et al 2006:190).
- Software products that are customizable since teachers have to adapt to software. This varies from minimum adoption and training to advance should a teacher not have had previous GIS software training.
- Be quick and intuitative for learning i.e. a teacher having to master GIS before integration into a field specific curriculum.

(c) To match educational content

- Be flexible enough to be efficient and enable a variety of modes of use that range from desktop to internet use for learning purposes and the learners can get interaction (National Academies Press U.S et al 2006:192).
- Be quick and intuitive to learn to use, where perception vs. reality and the extent needed to have mastered to teach GIS as integration is easier, though this situation currently is easier to adopt developed by vendors (National Academies Press U.S et al 2006:193).
- Be realistic in terms of expectations place on learner's teachers and infrastructure.

7. Capacity of GIS As A Support System For Spatial Thinking

Education is measured through the following three aspects, namely:

- the capacity to Spatialize i.e. by providing spatial data structures and coding for non-spatial data,
- visualization i.e. providing multiple representations and
- the functions performed i.e. by manipulating the structural relations of data sets.

(a) Spatialize Datasets: Assigning Co-Ordinate Codes to Each Data Item and Presented by Thematic Maps

Since GIS define space as a combination of geometry, projection and registration, and structures of space and geographic data is tightly bound in software, they become inseparable at application level. This provides infrastructure for GIS operations to be performed such as registration, re-projection, distance calculations and network analysis as well as interpolation. Therefore Local authorities can use GIS to improve products, processes and services (National Academies Press U.S. et al 2006:168).Size of GIS datasets may be a problem, although problems with Z is often experienced.

(b) To Visualize: Working and Final Results by Providing Multiple Forms of Representation

This can be established in the format to provide textual information, digital images, and diagrams as well as other graphical information. This is governed by geometry display (symbols and lifestyles), the visual variables that can be displayed (size, density, colour and shape or orientation) and mapping tool used to assign values (line thickness and symbol size).

(c) Perform Functions That Manipulate the Structural Relations of Datasets

This includes transformations, operations as well as analysis. Good teaching would include a wide variety of transformations (map projection or co-ordinates or from raster to vector), operations (spatial proximity or change over time) and analysis (patterns, locations to query, buffer, overlay, proximity, connectivity and modelling 3D. Things can also easily be added (National Academies Press U.S et al 2006:173).

8. Specific Competencies Part of Technical Successful GIS Education and Training

According to the (GWDC) the following thirty nine aspects are identified after 2001 (Guadel et al, 2003). These competencies are broadly categorized into four groups, namely

(a) Technical of nature (the ability to assess relationships among geospatial technologies)

- Cartography i.e. elements of scale, north arrows, farm and portions thereof understanding.
- Computer programming skills i.e. writing sql scripts
- Environmental applications i.e. dangerous areas recognition
- GIS theory and applications
- Geological applications i.e. soil areas of danger
- Geospatial data processing tools i.e. dissolving and joining datasets

- Photogrammetry i.e. 3D visualisation
- Remote sensing theory and applications
- Spatial information processing i.e. overlay and query
- Technical writing
- Technological literacy
- Topology understanding relationship between entities

(b) Business (The Ability to See The "Big Picture')

- Business understanding i.e. making money
- Buy in/ advocacy i.e. convince the benefit to others
- Change management i.e. change in focus of business area
- Cost benefit analysis i.e. cheapest way to achieve outcome
- Ethics modelling i.e. professional
- Industry understanding i.e. marketing
- Legal understanding i.e. standards to be maintained
- Organizational understanding i.e. each sections function or bachelor of many
- Performance analysis and evaluation
- Visioning

(c) Analytical (Creative thinking)

- Knowledge management
- Model building skills
- Problem solving skills
- Research skills
- System thinking i.e. project management

(d) Interpersonal of Nature

- Coaching i.e. transfer of knowledge to others
- Communication i.e. stability amongst employees
- Conflict management i.e. resolving disagreements
- Feedback skills i.e. immediate communication
- Group process understanding
- Leadership skills
- Questioning i.e. towards betterment
- Relationship building skills
- Self knowledge/ self management

However, GIS education and training certification is necessary to acknowledge an individuals qualifications and competencies whether offered as a short course, part of professional qualification or Science qualification GIS Certification Institute (http://www.gisci.org) . Even as part of continue professional development requirements (National Research Council U.S et al 2006:38, http://www.esri.com /news/arcuser/ 0706/curricula.html).

9. Challenges In Education and Training (k12) Pages 166-168: By National Academies Press (u.s.) - 2006

- Academics need to provide an in dept understanding of GIS that is needed to accommodate the fast growing GIS industry (National Research Council U.S et al 2006:28).
- An appropriate balance between software and concept understanding to use GIS intellectually also need to be established (Mable 2007).
- There is a wide spread tendency of button pushers vs. working through a problem from start to finish (Gober et al 1995, 1997:126).
- Coursework that crowd already overloads of university students. Therefore to make GIS part of the curriculum rather than an additional seems to be the tendency.
- Methods used to teach GIS is not sufficient to meet Science pedagogy/ teaching (National Research Council U.S et al 2006:29).
- There is also a tendency towards standardization of curriculum that should be developed further (National Research Council U.S et al 2006:29).
- The implementation of GIS on all levels is encouraged, resulting in different level outcome teaching material (National Research Council U.S et al 2006:56).
- Basic computer file management is often an obstacle that hinders spending time to learn new skills.
- Some GIS education and training exceeds the needs and capabilities of most teachers and students (sometimes, even users).
- As development was focused for commercial purposes, leading vendors like ESRI is now also developing GIS with education in mind.
- Most teachers rely on “off-the-shelf” GIS software and not extensions.
- Educators are responsible for new ways in teaching GIS.
- As software changes rapidly, a new release has more functionality, capacity and performance and need adjustment from educators. The framework for analysis however, indicates the extent of spatial thinking.
- Online GIS used is depended on budgets available for online availability to learners.
- No GIS can currently automatically handle error problems (National Academies Press U.S. et al 2006:171).
- Much work is still ongoing to simplify user interfaces and standardize terminology (National Academies Press U.S. et al 2006:173).
- Learners, through wizards can be guided through functionality rather that technical specialization.
- Topology however is neglected that would create a better understanding of spatial relationships, due to automation thereof.
- GIS software is often difficult to learn, to use and expensive to customize (National Academies Press U.S. et al 2006:183).
- Because making GIS available to the wide range of learners based on complexity required and geography is taught more (http://www.aag.org/giwis/ phase-one/phase-one-report.pd).

"The High Growth Job Training Initiative in this administration is aiming to give workers the skills they need to realize their dreams. It's a collaborative effort to help team up people with the jobs that are needed, to make sure that the changes in our economy don't leave people behind." (http://www.doleta.gov/ BRG/JobTrainInitiative/).

10. Conclusion

Since literature indicated the most two common factors that cause the limited use of GIS is GIS availability and GIS training the "nature" of GIS education and training will definitely contribute to GIS training problems should curriculum's and courses not be designed most concussively for a specific end user (Longley et al 2001:346).

From the above, it is clear that GIS Science degrees are well established with regard to literature and study material. However, it's the profession specific study material for Town & Regional Planners that needs attention in South Africa towards better education and training of these professionals. And, this can be based on existing curricula requirements developed internationally, to be adopted into specific Town & Regional Planning outcomes.

Also, need the availability of a GIS attention, since even the most well educated and trained municipal Town & Regional Planner in Gauteng cannot use a GIS system, unless the GIS is available (Marais 2007:96).

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