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A New GISc Framework and Competency Set for Curricula Development at South African Universities

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Abstract

In this study the commonalities and inconsistencies between three Geographical Information Science (GISc) competency sets are used to develop a new framework of essential competencies that can be used for curricula development at South African universities that meet local and international requirements. A prototype GISc framework of 16 knowledge areas (KAs), consisting of 20 fundamental and 89 core competencies, was introduced to a group of GISc experts to gauge its usefulness and to determine the relative importance of specific KAs. The responses showed that some KAs, in particular Physics *and* Organisational and Institutional Aspects *are considered less important than* Data Modelling *and* Geospatial Data. *However, all the KAs were considered essential by the workshop participants for inclusion in the GISc framework. A simple algorithm was developed and implemented to determine whether a particular competency should be included in the GISc framework. The new framework is an extension of the Geographical Information Science and Technology (GI S&T) Body of Knowledge (BoK) and consists of 14 KAs and can be used to develop curricula that meet the requirements of the South African and international GISc industries.*

1. Introduction

The Geospatial Workforce Development Center (GWDC) at the University of Southern Mississippi defines Geographical Information Science (GISc) as an information technology field of practice that acquires, manages, interprets, integrates, displays, analyses or otherwise uses data focusing on geographic, temporal and spatial contexts (Gaudet *et al*., 2003). In South Africa, a Geomatics practitioner is defined as '...a person who exercises skills and competencies in the science of measurement, the collection and assessment of geographic information and the application of that information in the efficient administration of land, the sea and structures thereon or therein...and who is registered in one or more of the branches of geomatics...' (South Africa, 2011: 9). This very broad definition of the Geomatics profession illustrates the wide range of knowledge, skills and abilities (competencies) needed by GISc practitioners and the diversity of applications of the technology. Although the versatility of GISc is one of its main strengths, its multifaceted nature complicates staff recruitment and the specification of job requirements. To better define GISc workforce needs, organizations need to know which core competencies employees must have to be GISc practitioners and to understand the roles, abilities and output requirements for geospatial work (Gaudet and Annulis, 2008). In turn, these requirements must be incorporated into the training programmes and academic qualifications for professional GISc practitioners to ensure that universities produce graduates who are adequately prepared for the South African and international job market. This requirement does not exclude specialisation and consequently the inclusion of additional units (and topics) in any particular KA.

The Geographical Information Science and Technology (GI S&T) Body of Knowledge (BoK) was initiated in 1997 as one of the education challenges of the University Consortium for Geographic Information Science (UCGIS) to provide a framework for the assessment of GI S&T curricula (Kemp and Wright, 1997). The Strawman Report was released in July 2003 (UCGIS, 2003). In 2005, the Model Curricula project resumed as an activity of the UCGIS Education Committee and the core component of the Model Curricula, the BoK, was published in 2006 (DiBiase *et al*., 2006). The BoK structure comprises three tiers, namely 10 knowledge areas, 79 units and 350 topics (DiBiase et al., 2006; Johnson, 2006). The BoK structure is currently being revised and it may include some recommendations which, together with those highlighted by other research, will call for certain requirements of the GISc profession to be added to the BoK (Reinhardt and Toppen, 2008; Reinhardt, 2012). Ahearn *et al*. (2012) in their position paper presented at the AGILE conference in Avignon, France introduced the BoK2 as a new environment that will enable the maintenance and expansion of the knowledge base of GI S&T in a dynamic, interactive, and collaborative way. However the current version of the BoK is, still, the most comprehensive guideline for GISc curricula development and is used in many countries throughout the world (DiBiase *et al*., 2006; Reinhardt, 2012).

Although GISc has been offered at South African universities since the early 1990s, the need for curriculum development and standardization only emerged in 2004 when GISc was professionalized. This process led to the generation and registration of the GISc Unit Standard Based Qualifications (USBQs) (South Africa, 1995) and the South African Council for Professional and Technical Surveyors (PLATO) model (PLATO, 1984, 2011). The GISc USBQ comprises four tiers called study areas, unit standards, outcomes, and assessment criteria. A total of 19 study areas and 128 unit standards, spanning the breadth of the GISc domain, were identified by the GISc Standards Generating Body (SGB). Each unit standard includes learning outcomes and assessment criteria that determine the knowledge, skills and abilities a learner is required to attain to be assessed as competent (Bruniquel and Associates, 2009). The unit standards are classified as fundamental, core and elective. The fundamental unit standards relate to Mathematics, Statistics, Business Management (Professionalism and Ethics) and Analytical Skills. These were regarded by the SGB as essential generic skills required in any branch of the geomatics profession. The core unit standards, such as those relating to Geographical Information Systems (GIS), Data Acquisition, Information Technology, Data Management, Photogrammetry and Remote Sensing, are associated with essential occupation-specific competencies for GISc practitioners. The elective unit standards allow GISc practitioners to specialize in occupations where the core business objectives concentrate on specific applications of GISc, such as Cartography and Web Applications but may include other job-specific non-core competencies (South Africa, 1995).

The PLATO model (PLATO, 2011) in terms of Act 40 of 1984 provides for the registration of three levels of practitioner competencies based on minimum number of lecture hours, namely technician level (600 lecture hours), technologist (900 lecture hours) and professional (1200 lecture hours). Each competency level contains common and category-specific subject areas with descriptions of their content. The model provides for the different streams in Geomatics *i.e*. GISc, Cadastral surveying, Engineering surveying, Mine surveying, Photogrammetry, etc. and each stream contains core and elective subject areas to meet occupation-specific requirements, while some subject areas may be common to the different streams.

The BoK, USBQ and PLATO models for GISc were qualitatively compared by du Plessis and van Niekerk (2012) at the level of knowledge area and theme. Their results showed that, although there is significant intersection between the three models, some themes are unique to specific models. A more detailed and quantitative analysis at topic, outcome and keyword level (du Plessis and van Niekerk, 2013) highlighted various commonalities and inconsistencies between the three models, suggesting that none of these models are comprehensive enough to represent the full competency requirements of the South African and international GISc industries. This supports Toppen and Reinhardt's (2009) view that it is difficult to determine the completeness of the BoK because it depends on personal views and perspectives. Similarly, the European GIS in Education Seminar (EUGISES, 2008) concluded that:

- The BoK primarily represents a geographic view and topics such as Computer Science are only weakly represented.
- The relevant work of International Organization for Standardization (ISO) TC 211 and Open Geospatial Consortium (OGC) as well as the basics for modelling services need more consideration.
- Issues concerning Geodesy and space-based satellite navigation systems such as Global Positioning Systems (GPS) issues are underrepresented.
- Web-related issues are not well covered.

Prager and Plewe (2009) made similar observations when comparing the BoK to two established GISc courses. They found that both courses included important topics not explicitly identified in the BoK. Such omissions require specific consideration during an assessment and evaluation of courses and curricula. They further pointed out that it is important to consider that the BoK may be predisposed toward a North American view of GI S&T and in this context they cite Reinhardt and Toppen (2008) who observed that in Europe the study of GI S&T occurs in a wide range of disciplines, ranging from Geography and Cartography to Computer Science, Engineering, Surveying and Photogrammetry.

The literature confirms that the BoK is a valuable resource for curriculum development, but it does not (on its own) represent a comprehensive list of GISc knowledge areas and competencies. Du Plessis and van Niekerk (2013) maintain that, should the BoK be used as a standard for GISc curricula development in South Africa, the knowledge areas and core competencies must be extended to include all the essential competencies listed in the GISc USBQs and the PLATO model. It is vital to include the core BoK competencies in South African GISc curricula to ensure the international recognition of South African trained practitioners. Du Plessis and van Niekerk (2013) emphasized the need for a comprehensive and detailed list of fundamental, core and non-core competencies as a standard for the accreditation of academic qualifications and the assessment of applications for professional registration.

The aim of the research was to develop a new academic framework consisting of a detailed list of fundamental and core competencies to support the development of GISc curricula at South African universities. The paper describes the first version (i.e. prototype) of the framework submitted to a group of GISc experts to gauge its comprehensiveness and usefulness, and to identify its weaknesses. Suggestions for improvement were incorporated into the latest version of the framework as outlined in this paper. The paper also advocates the inclusion of specific competencies such as Information Technology and Mathematical skills. Suggestions on how the new framework can be used to support curriculum development are made.

2. Method

Du Plessis and van Niekerk (2012, 2013) have highlighted the inconsistencies among the BOK, USBQ and PLATO model and suggested that the three models should be unified to meet the needs of both the international GISc community and those specific to the South African GISc community. This section describes the methodology to combine the three models to produce a new GISc framework consisting of a list of fundamental, core and elective competencies within specific KAs that represent the broad workforce requirements for professional GISc practitioners. The framework was modelled on the BoK which is the most comprehensive set of competencies available. This approach is similar to that of Reinhardt (2012) who uses the BoK for developing various Geographical Information (GI) courses, in Computer Science, Business Informatics and Civil Engineering programmes, based on the BoK. A competency is defined as the minimum knowledge, skills and abilities required by a practitioner to confidently perform a task. In the context of the framework development, a competency is equated to fundamental and core units together with their relevant topics and objectives. The following set of rules was used to select competencies from the BoK, USBQ and PLATO model for inclusion in the new framework:

1. Include a competency if it occurs in all three of the models.
2. Include a competency if it is considered core or fundamental in any one of the three models.
3. Include a competency if it is regarded as essential by the South African GISc community.

The first two rules involve a re-evaluation of the cross-tabulated results of du Plessis and van Niekerk (2013) and resulted in a prototype framework. This framework was presented to representatives of the GISc community for feedback, following which a final version of the framework was developed.

2.1 Competencies included in the prototype framework

According to DiBiase *et al*. (2006) the BoK core units are regarded as essential knowledge any person should master before being regarded as competent in GISc (GI S&T). Notable are the core units (shown in bold in the BoK) not covered by the USBQ or PLATO model that was identified by du Plessis and van Niekerk (2013). Specifically, units AM4 *Basic Analytical Operations* and AM5 *Basic Analytical Methods* are not covered in the USBQ and only partially in the PLATO model, whereas DN1 *Representation Transformation* is partially dealt with in the USBQ, but not at all in the PLATO model. Because these units are at least partially considered by one of the two South African models their content is regarded as important by the South African GISc community and consequently included in the framework as new units (by applying rules 1 and 2).

The core unit standards not incorporated in the current version of the BoK relate to three USBQ themes, namely *Professional Practice*, *Research Methodology*, and *Information Technology*. All three themes can be matched to specific BoK KAs. Unit standard 258798 deals with the South African Spatial Data Infrastructure (SDI) and relates to the unit *'institutional'* of KA *Organizational and Institutional Aspects* in the BoK. Considering the importance of SDI, specifically in a developing country, and the role of GISc professionals in the collection, maintenance, exchange and analysis of geographical information, it is appropriate that this content be included in the prototype framework. Moreover, although *Research Methodology* relates to BoK KA *Design Aspects*, the BoK only includes some basic principles of project management. Because the USBQ SGB regards proficiency in carrying out a research project as an important skill for any South African GISc practitioner, it was added as a separate KA in the prototype framework. The presence of the unit *Query Operations and Query Languages* in the *Analytical Methods* KA alludes to a level of competence in computer programming, but no explicit requirement is set in the BoK. Skills in Information Technology are, however, considered a core competency by the South African GISc industry (through the USBQ SGB) and given, that computer programming is often required in the application of GIS, particularly when existing software is unable to perform the required operations, it was included (by applying rule 2) in the framework under KA *Geocomputation*.

Much of the content in the PLATO model not explicitly listed in the BoK relates to Mathematics, Physics and Research Methodology. Discussions among European academics and professional practitioners at forums such as the EUGISES 2006 conference, highlighted similar inconsistencies between the BoK and the curricula of European universities (Reinhardt, 2012). *Physics* features in neither the BoK nor USBQ, while the South African Geomatics professional body (PLATO) explicitly specifies it as a fundamental competency requirement. This is likely due to the importance of Physics in survey applications such as electronic measurements where distances are derived from radio waves or infrared light and in Photogrammetry and Remote Sensing where data is remotely captured using sensors such as radar and lidar and light-reflection characteristics to record images on the earth's surface from space and airborne platforms. Although it is debatable whether Physics is vital for all GISc applications, some understanding of the subject's principles is essential when working with technologies such as space-based satellite navigation systems and remotely sensed imagery. Based on rule 2, *Physics* was included as a separate KA in the framework.

Training is included as a theme in the USBQ and as a topic in the BoK under the KA *Organizational and Institutional Aspects,* but is absent from the PLATO model. With important developments, such as work-integrated learning (WIL) as well as recognition of prior learning (RPL) where interns rely on guidance by a mentor (Unit Standards 14299 *Mentor and Advice Learners in Higher Education and Training* and Unit Standard 116587 *Develop, Support and Promote RPL Practices*), these are important topics to be included in the new framework (by applying rule 2).

Table 1 shows the prototype framework resulting from the application of rules 1 and 2. This framework was presented to representatives of the GISc community attending a dedicated workshop held at the Ukubuzana Conference in October 2012. The 17 participants included experienced GISc academics, professional practitioners and industry representatives that constituted a representative sample of the South African GISc community. The workshop particularly aimed to determine which of the candidate KAs and associated competencies are essential for inclusion in academic curricula. The participants were asked to complete a questionnaire in which they had to:

- Comment on the relevance of each of the KAs; and
- Identify missing KAs and units (competencies) (if any).

Table 1: Prototype framework used at the workshop for input from the GISc community.

	Knowledge Areas	**Academic fundamental competencies in GISc**
1	**Geographical Science***	**Human and Physical Geography; Environmental Science; Earth Science:** Geography its Nature and Perspective (e.g. location, space, place, scale, pattern, regionalization, globalization), Population (e.g. distribution, change), Cultural Pattern and Process (e.g. cultural landscapes) Political Organization of Space (eg. territorialization of politics) Agricultural and Rural Land Use, Industrialization Cities and Urban Land Use (e.g. models of urban systems, eternal city structures), Physical Geography (e.g. earth systems , resources) Earth Science Concepts (atmosphere, hydrosphere, pedosphere, biosphere).
2	**Physics***	**Mechanics; Kinematics; Electricity; Wave Theory; Electromagnetic Spectrum** Kinematics, Newton's laws of motion, work, energy, power, rotational dynamics, torque, angular momentum, gravitation, periodic motion, simple harmonic motion, interference, wave motion, diffraction, refraction and reflection of waves, Doppler effect, electric charge and field, electric potential, capacitance, resistance, electric current, electromagnetic induction, magnetic field, electromagnetic spectrum.

3	**Mathematics and Statistics***	**Calculus; Algebra; Trigonometry; Descriptive Statistics; Sampling; Statistical Computer Packages; Multivariate Statistics** Differential and integral calculus of functions of one variable, differential equations, partial derivatives, mean value theorem, solving systems of linear and non-linear equations, functions (e.g. trigonometric , hyperbolic), conic sections, complex numbers, matrix algebra, intersection of lines/planes, distance from points to lines/planes, differential geometry. Series and polynomials. Statistics: Descriptive statistics, Univariate, Sampling and the collection of data, frequency distributions and graphical representations. Descriptive measures of location and dispersion. Probability and inference: Introductory probability theory and theoretical distributions. Sampling distributions. Estimation theory and hypothesis testing of sampling averages and proportions (one-and two-sample cases). Identification, use and interpretation of statistical computer packages and statistical techniques. Multivariate statistics, curve fitting (e.g. regression and correlation).
	Components	**Core Academic Competencies in GISc**
4	**Analytical Methods****	**Unit 1:** Query Operations and Query Languages **Unit 2:** Geometric Measures **Unit 3:** Basic Analytical Operations **Unit 4:** Basic Analytical Methods **Unit 5:** Analysis of Surfaces **Unit 6:** Spatial Statistics **Unit 7:** Geostatistics **Unit 8:** Geocomputation **Unit 9:** Data Mining **Unit 10:** Network Analysis
5	**Conceptual foundations ** **	**Unit 1:** Philosophical and Social Perspective **Unit 2:** Domains of Geographical Information **Unit 3:** Elements of Geographical Information **Unit 4:** Geospatial Relationships **Unit 5:** Imperfections in Geographic Information
6	**Data manipulation****	**Unit 1:** Representation Transformation **Unit 2:** Generalization and Aggregation **Unit 3:** Change Management of Geospatial Data
7	**Data modelling****	**Unit 1:** Basic Storage and Retrieval Structure **Unit 2:** Database Management Systems **Unit 3:** Tessellation Data Models (e.g. Raster Data Model) **Unit 4:** Vector and Object Data Models **Unit 5:** Three-Dimensional, Temporal, and Uncertain Phenomena Data Models
8	**Cartography and visualization ****	**Unit 1:** Data Considerations **Unit 2:** Principles of Map Design **Unit 3:** Graphic Representation Techniques **Unit 4:** Map Production **Unit 5:** Map Use and Analysis **Unit 6:** Map Evaluation
9	**Design aspects****	**Unit 1:** The Scope of GIS System Design **Unit 2:** Project Definition **Unit 3:** Resource Planning **Unit 4:** Database Design **Unit 5:** Analysis Design **Unit 6:** Application Design **Unit 7:** System Implementation
10	**Information Technology (Geo-computation)*****	**Information technology**, emergence of geo-computation, computational aspects and neuro-computing; GIS software skills; GIS customization; hardware, operating systems; communications; programming; systems development; databases; data mining

11	**Geospatial Data****	**Unit 1:** Earth Geometry **Unit 2:** Georeferencing Systems **Unit 3:** Datums, SA coordinate system, UTM **Unit 4:** Map Projections **Unit 5:** Land Partitioning Systems **Unit 6:** Data Quality **Unit 7:** Spatial Data Compilation **Unit 8:** Field Data Collection **Unit 9:** Metadata, Standards, and Infrastructure
12	**Photogrammetry and Remote Sensing (Imaging Knowledge) ****	**Unit 1:** Cameras and Photography **Unit 2:** Radiometry, Detection and Sensing **Unit 3:** Frame Geometry **Unit 4:** Image Measurements **Unit 5:** Stereoscopy and Parallax **Unit 6:** Mathematical Modelling and Analytical Photogrammetry **Unit 7:** Computer Vision **Unit 8:** Estimation, Adjustment, Statistics, and Error Propagation **Unit 9:** Stereo Restitution **Unit 10:** Rectification and Resampling **Unit 11:** Mapping and Cartography **Unit 12:** Topography and Digital Elevation Modelling **Unit 13:** Digital Photogrammetry **Unit 14:** Project Planning **Unit 15:** Close-Range Photogrammetry **Unit 16:** Satellite Photogrammetry **Unit 17:** Remote Sensing **Unit 18:** Active Sensing with Lidar **Unit 19:** Applications
13	**GIS&T and Society** (KA: Legal and Ethical Aspects of GIS)**	**Unit 1:** Legal Aspects, PLATO Act and Rules; GIS Legislation; Spatial Data Infrastructure Act. **Unit 2:** Geospatial Information as Property **Unit 3:** Dissemination of Geospatial Information **Unit 4:** Ethical Aspects of Geospatial Information and Technology, Professional Execution of Daily Functions; Planning and Control **Unit 5:** Critical Thinking about GIS.
14	**Organizational and Institutional Aspects** (KA: Management and Organization Aspects)**	**Unit 1:** Management Aspects **Unit 2:** Economic Aspects **Unit 3:** Organizational Structures and Procedures **Unit 4:** GIS Workforce **Unit 5:** Institutional and Inter-institutional Aspects **Unit 6:** Coordinating Organizations (National and International)
15	**Research Methodology***	**System Design or Spatial Analysis; Reporting and Presentation of Results:** The research project must have a system design and/or spatial analysis component and include reporting and presentation of final results. The time spent on research-topic selection, development of a research proposal, analysis and interpretation, progress reporting, and liaison with research supervisor must be a minimum of 300 hours.
16	**Training******	**Mentor and advise learners during work-integrated learning (WIL); Develop, support and promote continuous professional development (CPD) in the profession**

* *Content derived from the PLATO model.*
** *Content derived from the UCGIS BoK, topics not shown due to space constraints.*
*** *Content derived from the UCGIS BoK, the USBQ and PLATO model.*
**** *Content derived from the USBQ.*

3. Results and Discussion

3.1 Feedback from the GISc community

The results of the workshop are summarized in Table 2. The participants were requested to rate the importance of each KA on a scale of 1 to 5, with 1 representing low importance and 5 high importance. Units occurring in KAs with an average importance rating of more than 3 were regarded as fundamental or core competencies.

The *Data Modelling* and *Geospatial Data* KAs were rated the most important, while *Physics* was rated the least important KA for inclusion in GISc curricula. *Geographical Science* received a score of 4.5 as the most important fundamental competency. A number of respondents suggested that Human and Physical Geography (including Earth Science and Geomorphology) be included in this KA. One participant requested the inclusion of Geophysics; another maintained that the scope of Mathematics should be restricted to geospatial applications.

Table: 2: Perceived importance of each KA according to workshop attendees

KA Description	Level	Average Importance Rating (1-5)
Data Modelling	Core	4.7
Geospatial Data	Core	4.7
Geographical Science	Fundamental	4.5
Analytical Methods	Core	4.5
Cartography and Visualisation	Core	4.5
Mathematics and Statistics	Fundamental	4.2
Conceptual Foundations	Core	4.2
Data Manipulation	Core	4.2
Design Aspects	Core	4.2
Information Technology	Core	4.2
Research Methodology	Core	4.0
Training	Core	3.9
GI S&T and Society (Legal and Ethical Aspects of GISc)	Core	3.7
Photogrammetry and Remote Sensing	Core	3.5
Organizational and Institutional Aspects (Management and Organisation Aspects)	Core	3.1
Physics	Fundamental	3.0

Concerning the core competencies *Data Modelling* and *Geospatial Data* were most highly rated (4.7). *Analytical methods* and *Cartography* and *Visualisation* followed at 4.5, and *Conceptual Foundations, Data Manipulation, Design Aspect* and *Information Technology* all rated slightly above average at 4.2. *Research Methodology*, *Training* and *GI S&T and Society* (*Legal and Ethical Aspects of GISc*) received below average ratings. Some participants suggested that research be restricted to the third-year level of study. One participant emphasized the importance of the Land Survey Act and the Information Communication Technology Act as part of the *GI S&T and Society* KA and another participant appealed for the inclusion of basic survey methods under *Photogrammetry and Remote Sensing*. The relatively low score (3.5) achieved by *Photogrammetry* *and Remote Sensing* suggests that GISc practitioners do not need a high level of understanding of these techniques and that a dedicated KA is unwarranted. Photogrammetry and Remote Sensing was consequently included in the *Geospatial Data* KA of the new framework (see Table 2). Although *Organisational and Institutional Aspects* also scored poorly (3.1), it is listed as a KA or theme in all three models considered in the comparative analysis (i.e. it adheres to rule 1) and was therefore kept as a separate KA in the framework.

3.2 The structure of the new framework

The new framework is based on the design of the BoK, but includes four additional KAs. An outline of the framework is provided in Table 3. A complete list of KAs and associated competencies is available at http://academic.sun.ac.za/cga/downloads/GISc_competency_list_V1.6.xlsx .

The KAs are structured into two categories, namely fundamental and core, and allow for specialization through the inclusion of non-core competencies. The BoK's *Analytical Methods, Conceptual Foundation, Data Manipulation* and *Data Modelling* were preferred over the PLATO subject area *Geospatial Information Science* as these KAs give curriculum designers and learner a better understanding of the diversity of competencies required in the GISc profession. *Design Aspects and Geocomputations* were retained as separate KAs in preference to *Information Technology (IT)* as used in the PLATO model. *Data Acquisition, Coordinate Systems and Projections* were grouped with *Photogrammetry and Remote Sensing* in a single KA titled *Geospatial Data* owing to the increased accessibility of digital space and airborne imagery and the advances in technology to analyse such imagery. Competencies related to Research, Physics, Mathematics and Geographical Science were grouped under the *Research Methodology, Physics, Mathematics and Statistics* and *Geographical Science* KAs. The new structure of the GISc framework consisting of 14 KAs with their respective criteria and units is detailed in Table 3.

Table 3. New GISc framework, with fundamental and core competencies defined by their respective KAs and units. Non-core competencies (units) are excluded from the table.

FUNDAMENTAL COMPETENCIES	CORE COMPETENCIES CONTINUE
Knowledge Area GS: Geographical Science	**Knowledge Area GC: Geocomputation**
Unit GS1 Human geography	Unit GC10 Computer programming
Unit GS2 Physical geography	**Knowledge Area GD: Geospatial Data**
Unit GS3 Environmental geography	Unit GD1 Earth geometry
Knowledge Area MS: Mathematics and Statistics	Unit GD3 Georeferencing systems
Unit MS1 Mathematics	Unit GD4 Datums
Unit MS2 Spatial statistics	Unit GD5 Map projections
Knowledge Area PS: Physical Science	Unit GD6 Data quality
Unit PS1 Kinematics and Newton's laws of motion	Unit GD7 Land surveying and GPS
	Unit GD10 Aerial imaging and photogrammetry
CORE COMPETENCIES	Unit GD11 Satellite and shipboard remote sensing
Knowledge Area AM: Analytical Methods	Unit GD12 Metadata, standards, and infrastructures
Unit AM3 Geometric measures	**Knowledge Area GS: GI S&T and Society**
Unit AM4 Basic analytical operations	Unit GS6 Ethical aspects of geospatial information and technology
Unit AM5 Basic analytical methods	

Knowledge Area CF: Conceptual Foundations Unit CF3 Domains of geographic information Unit CF4 Elements of geographic information **Knowledge Area CV: Cartography and Visualization** Unit CV2 Data considerations Unit CV3 Principles of map design Unit CV6 Map use and evaluation **Knowledge Area DA: Design Aspects** Unit DA4 Database design **Knowledge Area DM: Data Modelling** Unit DM2 Database management systems Unit DM3 Tessellation data models Unit DM4 Vector and object data models **Knowledge Area DN: Data Manipulation** Unit DN1 Representation transformation Unit DN2 Generalization and aggregation	**Knowledge Area OI: Organizational and Institutional Aspects** Unit OI5 Recognition of Prior Learning and Work Integrated Learning Unit OI6 Institutional and inter-institutional aspects Unit OI7 Coordinating organizations (national and international) **Knowledge Area RM: Research Methods** Unit RM1 Research methodologies Unit RM2 Research problem and methods Unit RM3 Analysing the results and discussion Unit RM4 Writing an academic paper, article or thesis

4. Conclusion

The aim of this paper was to develop a framework and compile a comprehensive list of competencies for use in developing GISc curricula. The key finding is that the existing BoK is the most comprehensive set of competencies available, but needs to be extended to include four additional KAs and 15 units (competencies). The new KAs and units relate to fundamental and core competencies in the USBQs and PLATO model absent from the BoK, and to those competencies regarded as essential by representatives of the GISc community.

The adoption of the proposed framework by South African universities will significantly simplify the process of programme accreditation as it will provide a common reference. By extension, the framework and list of competencies will be invaluable in the assessment and registration of practitioners with professional bodies. The framework will assist learners and universities with articulation agreements and guide employers in formulating work descriptions and recruitment criteria. At the international level, the findings of this study should support existing efforts to update and modify the BoK so that it meets international requirements.

In its current format the new framework, which consists of 14 KAs, 6 fundamental, 33 core units, 48 non-core units and 355 topics, is unwieldy. The development of an easy-to-use and accessible assessment tool, ideally in the form of a Web application, is recommended. Such a tool should be designed to support curriculum development, guide the accreditation of university programmes and facilitate the registration of professional GISc practitioners.

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