A Comparison of Geographical Information Science Competency Requirements

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Abstract

Because universities often provide training in geographical information science (GISc) as part of geography, surveying as well as environmental and computer science programmes, the content, outcomes, extent and quality of training can vary significantly. Very little research has been done on how the existing sets of competency requirements for GISc overlap or differ. No literature exists that identifies commonalities and inconsistencies (gaps) at detail level that could assist with developing a framework that incorporates both South African and international GISc curricula guidelines.

Three sets of competency guidelines, namely the U.S.-developed Geographic Information Science and Technology (GI S&T) Body of Knowledge (BoK) developed by the University Consortium for Geographic Information Science (UCGIS), the South African Unit Standards-Based Qualifications (USBQ) and the South African Council for Professional and Technical Surveyors (PLATO) model, are compared qualitatively and quantitatively to identify commonalities and inconsistencies. The exercise identified duplication among the three models and highlighted themes that the South African GISc community deems to be important. The study further identifies topics in the GI S&T BoK that the GISc community in the U.S. considers to be essential knowledge for anyone wishing to practice in the GISc field. The BoK offers the most comprehensive and detailed set of GI competencies, but lacks generic competencies such as physics. Some competencies are unique to a specific set, for example physics and geographical science in the PLATO model, while training is unique to the USBQ. The authors conclude that a new competency set based on the findings of the research is needed to best serve the GISc industry and academia. Recommendations for further research are made.

Keywords

Curriculum design, data acquisition, geographical information science (GISc), knowledge and skills requirements, mathematics, photogrammetry, physics, professional body, unit standards-based qualification (USBQ), remote sensing, statistics.

1. Introduction

The South African Council for Professional and Technical Surveyors (PLATO), established as a professional body in terms of Act 40 of 1984 (South Africa, 1984), is the statutory body responsible for regulating the geomatics profession. A geomatics practitioner is defined by the Draft Geomatics Bill 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 definition includes geographical information science (GISc) practitioners.

Historically, much of the early design of geographical information systems (GIS) education was initiated by university academics. This has led to the emergence of GISc as a new profession, but little research has been done on what GISc professionals should know or be able to do. A set of competencies, knowledge and skills needed by professionals in the workplace is required to design appropriate education programmes and to guide those responsible for controlling quality within the profession (through certification) as well as in educational institutions (through accreditation) (Kemp & Wiggins, 2003).

GISc courses at universities are offered as part of geography, earth science, surveying, town planning as well as environmental and computer science programmes. Consequently, the content, outcomes and quality of training and education vary significantly. Many programmes require that students take one or two introductory GIS courses to be able to produce simple maps and carry out basic spatial operations. In-depth knowledge of geospatial concepts and theories are not required. However, many of these students eventually seek employment as professional GIS practitioners, an occupation for which they are often ill-prepared. The same problem has been noted internationally with graduates often finding themselves ill-equipped when seeking employment in one of the many public and private sector organizations that make substantial use of GISc (Kemp, 2003). According to Gaudet, Annulis & Carr (2003:22) '... [in] the absence of recognized standards or industry certification, it is no surprise that organizations equipped with increased geospatial technology capabilities for decision support are questioning the kind of people to hire.' PLATO assessors experience similar difficulties when considering individuals for registration as professional GISc practitioners (PLATO, 2008).

Three main problems exist in South Africa concerning the professional registration of GISc practitioners: 1) the inconsistencies found in the knowledge and skills development of GISc professionals; 2) the lack of a standard set of competency requirements to assess individuals and accredit academic programmes; and 3) the challenges faced by universities to prepare learners for professional registration with the PLATO council. This situation is unlikely to improve in the absence of a GISc curriculum framework. Such a framework should not only guide the design of new university programmes, but should also be used to evaluate existing programmes for accreditation.

Currently there are two curriculum frameworks that serve as guidelines for accreditation and programme development: the South African Qualifications Authority (SAQA) Unit Standards-Based Qualifications (USBQ) (South Africa, 1995) and the PLATO model (PLATO, 2011). It is problematic to use the set of competencies in the USBQ for programme evaluation because it focus mainly on technical skills, while many GISc practitioners have indicated a concern that the competencies in the PLATO model appear to be biased towards surveying. Another concern is that at theme level both frameworks differ from the Geographic Information Science and Technology (GI S&T) Body of Knowledge (BoK) which is used by many international universities for GISc curriculum development and assessment (Du Plessis & Van Niekerk, 2012). A revised edition of the BoK is currently under consideration and future editions may contain some generic competencies such as physics and mathematics as a result of contributions from European geo-informatics practitioners.

Conformity to international academic requirements will facilitate opportunities for articulation with international universities and registration bodies. It is therefore essential that the competency sets derived for professional GISc practitioners, such as the USBQ and PLATO models, are compared with the GI S&T BoK to identify significant gaps (Unwin, 1997; DiBiase, 2003; DeMers, 2009). According to DiBiase et al. (2006) and Johnson (2006), assessment and curriculum evaluation are the primary intended uses of the BoK. During the European GIS in Education Seminar (EUGISES, 2006) the Association of GI labs in Europe (AGILE) commenced with an initiative to deal with certain aspects of the BoK, such as the "completeness" of the BoK (Reinhardt 2012). Another aspect was the incorporation of an "European view" that includes but is not limited to the following important aspects:

- The BoK represents primarily a Geographic point of view and excludes important aspects such as Geodesy and Computer Science.
- The definition of topics related to basics in Natural Sciences, Mathematics, and Computer Science etc. is as important as the definition of GI Science topics.
- An indicator for the depth of teaching should be added to the topics, e.g. Blooms taxonomy.

Both Toppen & Reinhardt (2009) regard the BoK as valuable work that is very important and helpful for a number of tasks such as curriculum design. It is, however, not clear which BoK requirements are absent from the USBQ and PLATO models. Some requirements identified by the South African GISc industry may not be included in the BoK. An identification of the discrepancies among the different frameworks will provide a good foundation for establishing a comprehensive set of competencies to be used for a curriculum framework for GISc (Forer & Unwin, 1999; Council on Higher Education, 2004a and 2004b; Toppen & Reinhardt, 2009; DeMers, 2009).

This paper reports on a comparative content analysis using the competency sets derived from the GI S&T BoK, the USBQ and the PLATO model to develop a comprehensive set of competency requirements for professional GISc practitioners in South Africa. The paper concludes with recommendations on how the set of competency requirements can be developed into a meaningful concept framework that can be used by educators charged with the planning of professional degree programmes to outline the minimum course content for the development of a GISc curriculum that will meet the PLATO requirements for accreditation, and for entering into reciprocal and articulation agreements with national and international institutions.

2. Existing Competency Frameworks

Brief overviews follow of some U.S and South African efforts to develop GISc curricula.

2.1. Efforts to develop GISc curricula

A number of attempts have been made in the U.S. to develop GISc curricula. In 1988, the National Center for Geographic Information and Analysis (NCGIA) consortium of the University of California, the State University of New York, and the University of Maine developed and distributed for comment the NCGIA core curriculum modules (Goodchild & Kemp, 1990; DiBiase et al., 2006). In 1995, the NCGIA announced plans for a new core curriculum in GIScience. In 2001, NASA mobilized a team of specialists at the University of Southern Mississippi to identify key competencies for geospatial professionals. The Geospatial Workforce Development Center (later reorganized as the Workplace Learning and Performance Institute (WLPI)) convened workshops to identify the key competencies and roles expected of geospatial professionals by employees (DiBiase et al., 2006).

The curriculum development efforts described above, contributed to the establishment of the UCGIS Model Curricula project and the development of the BoK for GI S&T. The BoK was initiated in 1997 as one of the UCGIS' education challenges to provide a framework for the assessment of GI S&T curricula (Kemp & Wright, 1997). A task force was organized under the auspices of the UCGIS in 1998 to identify a comprehensive set of 'knowledge areas' and their constituent 'units' and 'topics', comprising a 'body of knowledge' for the GI S&T domain. An initial '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 GIS&T BoK, was published in 2006 (DiBiase et al., 2006). The BoK structure (Figure 1) comprises three tiers, namely 10 knowledge areas, 79 units, and 350 topics (DiBiase et al., 2006; Johnson, 2006).

Knowledge Area – Two-letter code (KA) and description

Unit – Number and title with brief description (references as applicable)

Topic – Unit number and individual number and descriptive title
- At least one educational objective (Total number of objectives = 1660)
- Key readings that include references to materials for the KA

Figure 1. BoK structure (DiBiase et al. 2006:28; Johnson, 2006).

In summary the BoK KAs encompass the domain of GI S&T. Each KA is made up of units that include a title and brief description. Units are made up of topics that include a short descriptive title and bulleted educational objectives (Johnson, 2006).

2.2. South African efforts to develop GISc curricula

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 USBQs (South Africa, 1995) and the PLATO model (PLATO, 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 which 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. The core unit standards, such as those relating to geographical information systems, data acquisition, information technology, data management, photogrammetry and remote sensing, are associated with occupation-specific competencies essential for GISc practitioners. The elective unit standards allow for specialization of GISc practitioners in occupations where the core business objectives focus on a diversity of outcomes such as occupations in the health and environmental sectors (South Africa, 1995).

The South African geomatics registration model, also known as the PLATO model (PLATO, 2011), provides for the registration of three levels of practitioner competencies, namely technician, technologist and professional. Each competency level contains common and category-specific subject areas with descriptions of their content. The model is further divided into non-common core and elective subject areas to meet occupation-specific requirements.

3. Methods

Qualitative and quantitative methods were used to do a comparative content analysis of the BoK, the USBQ and PLATO model (2012 edition). The comparison was done at the most detailed level and involved a systematic comparison of the USBQ unit standard outcomes, the descriptions of the PLATO model for professional registration and the BoK topics. The PLATO descriptions were transformed to keywords and phrases, representing competencies, to enable direct comparison with the other two frameworks. The outcomes, keywords, phrases and topics were regarded as specific GISc competencies.

The USBQ and PLATO sets of competencies were cross-tabulated with the BoK, which was used as a common framework, mainly because it has the most comprehensive structure and also because it is an internationally-accepted framework (DiBiase et al., 2006). The result was two matrices of which the rows represent the 350 BoK topics and the columns respectively represent the 296 USBQ outcomes and 211 PLATO keywords and phrases. Altogether 177,450 comparisons were made to determine the level of correspondence between the BoK, the USBQ and PLATO model.

An example on how the topics of the BoK *Analysis of surfaces* unit was quantitatively compared to the outcomes of unit standard (US) no. 258803 (*Perform 2.5D vector surface queries*) is shown in Table 1. Each outcome of the US is systematically compared to all the topics in the BoK and where the respective rows and columns intersect a value ranging from 0 to 1 is allocated. A value of 0 implies no correspondence between the outcome and the respective topic and a value of 0.5 implies a 50% correspondence or partial match between the outcome and the topic, while a value of 1.0 denotes 100% correspondence. In Table 1 the BoK unit includes the topic *Calculating surface derivatives* which has seven objectives namely:

- List the likely sources of error in slope and aspect maps derived from Digital Elevation Models (DEMs) and state the circumstances under which these can be very severe.
- Outline a number of different methods for calculating slope from a DEM.
- Outline how higher-order derivatives of height can be interpreted.
- Explain how slope and aspect can be represented as the vector field given by the first derivative of height.
- Explain why the properties of spatial continuity are characteristic of spatial surfaces.
- Explain why zero slopes are indicative of surface specific points such as peaks, pits and passes; and list the conditions necessary for each.
- Design an algorithm that calculates slope and aspect from a triangulated irregular network (TIN) (DiBiase et al., 2006).

When these objectives are compared to specific outcome 1 of the US 258803, namely to *understand and explain the principles of a triangular irregular network (TIN) in the context of a surface,* there is clearly some overlap but the specific BoK topic also includes many other concepts relating to DEMs and terrain analysis not covered by outcome 1 of US 258803. In this particular case the overlap was interpreted to be approximately 10% (or 0.1 using a scale of 0 to 1). The other outcomes of US 258803 were compared to the *Calculating surface derivatives* topic in the same manner and a 10% overlap resulted with all four of the US outcomes. On the perimeter of the matrix the sum of each row is calculated to provide a value indicating the total overlap (0.4) between the US and the *Calculating surface derivatives* topic. When done for all the topics in a unit, the totals of the columns can be used to indicate how much overlap there is between each US outcome and all the topics in a unit. The total of the last column (0.2) indicates the degree of correspondence between US 258803 and the BoK *Analysis of surfaces*. For this particular example, there is a 20% overlap. It should be noted that the level of correspondence is a subjective value assigned by the researchers. A more robust approach would have been to use several assessors to evaluate each of the 177,450 corresponding pairs of competencies and to use the mean correspondence values. However, such an approach would have been prohibitively time-consuming and costly. For the purposes of this paper the subjective values were deemed sufficient as indicators of where there is no correspondence, partial correspondence or full correspondence between the relevant data sets.

Table 1: Comparison of topics in the BoK *Analysis of surfaces* unit with the outcomes of Unit Standard no. 258803 *Perform 2.5D vector surface queries*

	US 258803				
	Perform 2.5D vector surface queries				
Topics in the BoK analysis of surfaces unit	**Overlap with outcome 1**	**Overlap with outcome 2**	**Overlap with outcome 3**	**Overlap with outcome 4**	**Total overlap with US**
Calculating surface derivatives	0.1	0.1	0,1	0.1	0.4
Interpolation of surfaces	0.1	0.0	0.0	0.0	0.1
Surface features	0.1	0.0	0.0	0.0	0.1
Intervisibility	0.0	0.1	0.0	0.0	0.1
Friction surfaces	0.0	0.0	0.0	0.0	0.0
Total overlap of the respective outcome with all the topics.	**0.3**	**0.2**	**0.1**	**0.1**	**0.7/4=0.2**

This cross-tabulation method was applied to all of the BoK topics to facilitate a systematic identification of overlaps and gaps between the different curriculum frameworks. Once completed, a second set of tables was created that summarized the overlap at knowledge area (KA) level. For example, Table 2 summarizes the USBQ comparison with the BoK *Analytical methods* KA units. The three columns on the right for each unit of the KA respectively record the number of topics that match fully, match partly, or do not match at all with the set of USBQ outcomes. This procedure was carried out for all KAs and for the USBQ and the PLATO model.

Table 2: The level of correspondence, at detail level, between the topics of the *Analytical methods* BoK KA units and the USBQ outcomes

The BoK KA Analytical methods and unit descriptions	**Total number of BoK topics in each respective unit**	**Number of BoK topics in each unit that are matched by one or more USBQ outcome**	**Number of BoK topics in each unit that are partly matched by one or more USBQ outcome**	**Number of BoK topics in each unit that are not matched by any USBQ outcome**
Academic and analytical origins	2	0	0	2
Query operations and query languages	3	0	3	0
Geometric measures	6	0	4	2
Basic analytical operations	4	0	0	4
Basic analytical methods	8	0	0	8
Analysis of surfaces	5	0	4	1
Spatial statistics	7	0	2	5
Geostatistics	5	0	3	2
Spatial regression and econometrics	4	0	1	3
Data mining	4	0	4	0
Network analysis	7	0	7	0
Optimization and location-allocation modelling	4	0	0	4
Total	59	0	28	31

Of the 59 topics not one topic could be matched 100% by one or more USBQ outcome. While 28 topics could be partially matched and 31 topics could not be matched by any USBQ outcome.

4. Results and Discussion

The results of the content analysis are summarized in Table 3. Only 35 (10%) and 9 (3%) of the BoK topics are covered by the USBQ and the PLATO model respectively. However most (57% and 65% respectively) of the BoK topics are partly covered by the USBQ and the PLATO model. This suggests that despite much overlap between the South African frameworks and the BoK, there is a lack of depth in the existing national curriculum guidelines. It may also indicate that the South African frameworks are not as detailed as the U.S. guidelines. Of most concern is that about one third (33% and 32% respectively) of the BoK topics is not covered by the USBQ or the PLATO model at all. Either some of the topics in the BoK have been overlooked when the South African frameworks were designed and compiled (i.e. they can be considered gaps) or these topics were excluded on purpose because they are unimportant in a South African context.

Table 3: Results of the analysis of the matrices containing the BoK topics and USBQ outcomes, and BoK topics and PLATO model keywords (study areas), expressed in numbers and percentages.

	USBQ outcomes		**PLATO model keywords (study areas)**	
Number of BoK topics that are matched by one or more	35	10%	9	3%
Number of BoK topics partly matched by one or more	186	57%	213	65%
Number of BoK topics not matched by any	108	33%	107	32%

The levels of correspondence between the BoK topics and the USBQ outcomes as well as the PLATO model keywords (study areas) range between 67% and 68%. As much as 85% of the USBQ outcomes and 55% of the PLATO model key words (study areas) are contained in the BoK. It is concluded that the BoK includes most of the content of the USBQ, but there is a significant (45%) component of the PLATO model not represented by the BoK units. Much of the excluded content relates to mathematics, physics and research methodology which are not explicitly listed in the BoK. Discussions by European academics and professional practitioners at forums such as AGILE mentioned similar inconsistencies between the BoK and curricula at European universities (Reinhardt, 2012).

Table 4 considers the particular BoK units that are fully, partially or not covered at all by the USBQ or the PLATO model. A distinction is made between the core and non-core BoK units, where the core units (in bold) are regarded as essential competencies to be included in any professional qualification.

Table 4: Identification of the BoK units (core units in bold) fully, partially or not covered at all in the USBQ and the PLATO model.

USBQ	**Fully covered**	**CV2, CV3, DA4**, **GD6**, GD8, **GD10**, **GD11**, **GS6**, OI4
	Partially covered	AM2, **AM3,** AM6, AM7, AM8, AM9, AM10, AM11, **CF3, CF4**, CF6, CV1, CV4, CV5, **CV6,** DA1, DA2, DA3, DA5, DA6, DA7, DM1, **DM2, DM3, DM4**, DM5, **DN1, DN2**, DN3, GC1, GC8, **GD1, GD3, GD4, GD5, GD7**, GD9, GD12, GS1, GS2, GS3, GS4, GS5, GS7, OI2, OI3, **OI5, OI6**
	Not covered	AM1, **AM4, AM5**, AM12, CF1, CF2, CF5, GC2, GC3, GC4, GC5, GC6, GC7, GC9, GD2, OI1
PLATO	**Fully covered**	**GD4**
	Partially covered	AM1, AM2, **AM3, AM4, AM5**, AM6, AM7, AM10, CF2, **CF3, CF4,** CF5, CF6, CV1, **CV2, CV3**, CV4, **CV6,** DA1, DA2, DA3, **DA4,** DA5, DA6, DA7, DM1, **DM2, DM3, DM4,** DM5, DN3, GC8, **GD1,** GD2, **GD3, GD5, GD6, GD7**, GD8, GD9, **GD10, GD11, GD12,** GS1, GS2, GS3, GS4, GS5, **GS6**, GS7, OI2, **OI5, OI6**
	Not covered	AM8, AM9, AM11, AM12, CF1, **DN1, DN2,** GC1, GC2, GC3, GC4, GC5, GC6, GC7, GC9, OI1, OI3, OI4

From Table 4 one can determine which units in the BoK do not correspond with the USBQ or the PLATO model and which units are regarded as core. Of the 16 units in Table 4 not covered by the USBQ two are regarded as core units by the BoK, namely AM4 *basic analytical* *operations: buffers, overlays, neighbourhoods, map algebra* and AM5 *basic analytical methods: point pattern analysis, kernels and density estimation, spatial clusters analysis, spatial interaction, analysing multidimensional attributes, cartographic modelling, multi-criteria evaluation, spatial process models*. A number of the non-core units that are excluded from the USBQ are important for South African GISc practitioners. For example, AM12 *optimization and location-allocation modelling* and CF5 *relationships* include important topics such as p-median problems and topology respectively. At least some of these fundamental concepts should be included in GISc curricula. A total of 18 BoK units, including two core units (DN1 and DN2) are not covered and consequently do not correspond with any keywords or study areas (phrases) in the PLATO model.

It was determined that 45 USBQ outcomes and 7 unit standards within three themes are not included in the BoK. These themes are: *Information technology* (unit standard numbers 115387, 115381 and 115382), *GIS&T and society* (unit standard 258798) and *Research methodology* (unit standards 258816, 242915, 117434). Similarly, there are 94 sets of keywords (study areas) and two themes (subject areas), namely *Physics* and *Research methodology* that are not specified in the BoK. *Research methodology* is the only common theme in the USBQ and the PLATO model not included in the BoK. *Physics* only appears in the PLATO model as a theme, while the two themes *Information Technology* and *GI S&T and society* appear in all three models, although certain unit standards and their outcomes are unique to the USBQ.

5. Conclusion

This paper compared the GI S&T BoK, the USBQ and the PLATO model at detail level, i.e. topic, outcome and keyword (study area) levels, to identify commonalities and inconsistencies. The USBQ and the PLATO model for professional GISc practitioners correspond well with the BoK, particularly regarding the themes directly related to GISc. Significant duplication was identified between the different components of the three models. Clearly, the competencies that occur in all three sets are essential in any GISc curriculum. The competencies that the South African GISc community regards as important for inclusion in GISc curricula, but which are not considered necessary in the BoK, were also highlighted. These competencies mostly relate to the fundamental sciences and research methods. In Europe similar inconsistencies were identified (Reinhardt, 2012). A number of competencies that the U.S. GISc community regards as essential are not represented in the USBQ and/or the PLATO model. It is critical that these competencies are included in South African GISc curricula and that a detailed list of fundamental and core competencies is developed that can be used as the minimum academic requirements that a learner must fulfil to be regarded as being competent in GISc. This list should be a union of the core BoK topics, the USBQ outcomes and the PLATO model keywords (study areas) at detail level. Educators charged with planning GISc certificate, diploma and degree programmes should use the list to outline the minimum course content. The list should also be used by reviewers of academic programmes to determine their quality and it will be valuable for prospective students to choose educational programmes that are aligned with their interests and career goals. Institutions which agree to specify course topics and objectives consistent with the list of competencies may find it easier to execute articulation agreements. Statutory or professional bodies, such as PLATO, will be supported if the GISc competencies are consistently applied to accredit learners and university programmes and to enter into reciprocal agreements with other countries. The list will also assist human-resource professionals to develop job descriptions and to set interview protocols.

The authors recognize that the GISc industry and its requirements are not static. This research thus provides a baseline for the development of a list of GISc competencies. The value of the list will ultimately be measured by its implementation as a tool for training and education at universities, as a standard for the accreditation of university programmes and the registration of professional practitioners with the relevant statutory body. It is recommended that future research focus on the development of a concept GISc framework for curriculum development which must also be subjected to a public participation process. The minimum requirements regarding contact hours (lecture hours), directed study hours and credits for each component must be determined. An easy-to-use and accessible assessment tool, ideally in the form of a Web application, that would support curriculum development, the accreditation of university programmes and the registration of professional GISc practitioners, will also have great value for the South African and the international geospatial communities.

6. References

Bruniquel and Associates 2009, '*Unit standards, a plea for common sense',* viewed 2 February 2009, <http://www.e-biznews.co.za/uploads/files/biznews1st2009.pdf>.

Council on Higher Education 2004a, 'Framework for programme accreditation', viewed 22 October 2009, <http://www.che.ac.za/documents/d000080/>.

Council on Higher Education 2004b, 'Criteria for programme accreditation', viewed 22 October 2009, <http://www.che.ac.za/documents/d000084/>.

DeMers, MN 2009, 'Using intended learning objectives to assess curriculum materials: The UCGIS body of knowledge', *Journal of Geography in Higher Education,* vol. 33, no.1, 70-77, viewed 16 October 2009, <http://dx.doi.org/10.1080/03098260903033980>.

DiBiase, D 2003, 'On accreditation and the peer review of education in geographical information systems and science', *URISA Journal, vol.* 15, no. 1, 7-13, viewed 13 October 2009, <http://www/urisa.org/files/DiBiasevol15no1.pdf>.

DiBiase, D, DeMers, M, Johnson, A, Kemp, K, Luck, AT, Plewe, B & Wentz, E (eds.) 2006, '*GIS&T body of knowledge: University Consortium for Geographic Information Sciences',* Association of American Geographers, Penn State University, viewed 26 February 2009, <http://www.ucgis.org/priorities/education/modelcurriculaproject.asp>.

Du Plessis, HJ & Van Niekerk, A 2012, 'A curriculum framework for geographical information science (GISc) training at South African universities', *South African Journal for Higher Education,* vol. 26, no. 2, in print.

Forer, P & Unwin, D 1999, 'Enabling progress in GIS and education', in PA Longley, MF Goodchild , DJ Maguire & DW Rhind (eds), *Geographical information systems. Management issues and applications,* 7th edition, pp747-756, John Wiley & Sons Inc, New York.

Gaudet, CH, Annulis, HM & Carr, JC 2003, 'Building the geospatial workforce', *URISA Journal,* vol. 15, no. 1, 21-30, Viewed 13 October 2009, <http://www/urisa.org/files/Gaudetvol15no1.pdf>.

Goodchild, MF & Kemp, KK 1990, *Introduction to GIS: NCGIA core curriculum*. National Centre for Geographic Information and Analysis. University of California, Santa Barbara.

Johnson, AB 2006, '*Developing a GIS curriculum'*. ArcUser, viewed 20 October 2009, <http://www.esri.com/news/arcuser/0706/curricula.html>.

Kemp, KK 2003, 'Update on the UCGIS model curricula project'. *URISA Journal,* vol. 15, no.1, 47-49, viewed 12 April 2009, <http://www.urisa.org/files/Kempvol15no1-5.pdf>.

Kemp, KK & Wiggins, L. 2003, Introduction to the special issue on GIS education, *URISA Journal,* Vol. 15 no. 1, 4--6. Viewed 11 April 2009. <http://www.urisa.org/journal/protect/vol15no1/wigginskemp.pdf>.

Kemp, KK & Wright, R 1997, '*UCGIS identifies GIScience education priorities',* Viewed 23 June 2011, <http://www.ucgis.org/priorities/education/priorities/geoinfosystems.html>.

PLATO 2008, Minutes of the Annual Meeting of PLATO Council held in Wynberg, Cape Town, October 2008.

PLATO 2011, viewed 29 April 2012, < http://www.plato.org.za>.

Reinhardt, W 2012, 'Statement of usage of BoK in our institute', viewed 3 April 2013, <http://www.geo-informatie.nl/rip001/edumapping/AGILE_2012-Reinhardt.pdf>.

South Africa 1984, Professional and Technical Surveyors Act as amended, Act 40 of 1984. *Government Gazette* Vol. 226 No. 9157, 11 April 1984. Government Printer, Pretoria.

South Africa 1995, The South African Qualifications Act, (No.58 of 1995)*, SAQA decision number 0012/08 2009*. Field 12 -- Physical Planning and Construction: Physical Planning, Design and Management: GISc SGB, SAQA, Pretoria.

South Africa. 2011. Geomatics Profession Bill. *Government Gazette* Number 34319 dated 30 May 2011. Government Printer, Pretoria.

Toppen, F & Reinhardt, W 2009, 'A European approach towards the UCGIS Geographic Information Science and Technology Body of Knowledge a discussion paper', viewed 3 April 2013, <http://itcnt05.itc.nl/agile_old/Conference/2009-hannover/WS2/Ws2_Agile09_abstracts/2009_paper_Toppen_Reinhardt_AGILEws-2009.pdf>.

UCGIS 2003, Task force on the development of model undergraduate curricula: The Strawman Report, viewed 12 April 2009, <http://www.ucgis.org/priorities/education/priorities/FINALSTRAWMANTEXT.Pdf>.

Unwin, DJ 1997, *Curriculum design for GIS: NCGIA core curriculum in GIScience,* viewed 26 February 2009, < http://www.ncgia.ucsb.edu/giscc/units/u159/u159_f.html>.