The aim of this article is to give an international overview of the geographical information science (GISc) workforce, the roles and expected competencies of persons working in the industry, including the importance of professionalism through certification and licensing and the adherence to a code of conduct based on ethical principles. As an introduction to the next article in this series, which deals with assessment criteria and methodologies used in South Africa, some interesting comparisons between the international and South African GISc industries are briefly noted.

The Geospatial Information and Technology Association (GITA) reports that approximately 70 to 80% of the information managed by business is somehow connected to a specific location – an address, street, intersection, or “xy” coordinate. The importance of location is drawing geospatial technology into nearly every corner of the business world, a phenomenon that is contributing to widespread and diverse applications, which touch the lives of almost every person on the street [1]. This circumstance contributes to the exceptional growth in the geospatial sector and the demand for qualified, skilled and competent employees.

A report prepared by the Geospatial Workforce Development Center at the University of Southern Mississippi, defines the GISc industry as an information technology field of practice that acquires, manages, interprets, integrates, displays, analyses, or otherwise uses data focusing on the geographic, temporal, and spatial context. The report goes further and includes the development and life-cycle management of information technology tools to support the above [2].

The reality for today’s innovative workplace is that organisations need skilled and talented people to compete in a market where technological changes, new applications and consequently improved solutions are the order of the day. To better define GISc workforce requirements, organisations need to know what knowledge, skills and abilities employees require in order to be able to work in a GISc environment.

Employers also need to have an understanding of the roles, competencies, and outputs that are required for geospatial work [3]. Job opportunities in GISc are directly linked to the demands of the industry for suitably qualified persons to fill key positions during high growth periods where there is a high demand for competent and skilled workers. Unfortunately the training of potential employees to fill these gaps does not always keep track of the growth in the industry. The National Centre for O*NET (Occupation*New and Emerging Technologies) Development reported that a recent USA survey of geospatial products and service providers revealed that 87% of respondents said that they had difficulty filling GISc positions [4]. Similarly, South Africa is also experiencing a growing demand for GISc practitioners. Consequently, there is an increasing demand for well-trained GISc professionals, which puts pressure on universities to train future GISc professionals. The geospatial industry has a role to play in determining the academic output of university programmes that produce human capital in the tangible and intangible skills necessary to excel in GISc [5].

The debate between the academic views of what GISc practitioners should learn and the professional view of what skills and knowledge are required from a competent GISc professional practitioner have been on-going among academics for well over 30 years.
and continue to be a challenge [6]. While much of the early design of GIS education was motivated by university academics, the emergence of the GIS profession has provided impetus to the need to design qualifications that truly reflect the demands of the employment market. Successful organisations need the right people with the right skills and knowledge to reach strategic goals in a competitive market [3]. Research and consequently various articles and reports, mainly from the USA and Canada, have investigated this GISc academic requirement from several different perspectives [6]. These academic requirements in GISc include: the need to identify the full set of competencies, knowledge, and skills required by professionals in the workplace (through efforts to define necessary competencies and appropriate university curricula); the appropriate design of education programs and exploration of emerging delivery mechanisms (designing curriculum content and providing distance learning opportunities); and the question of quality control among both professionals and educational opportunities (through the certification and accreditation of university programmes by relevant professional bodies) [6]. Graduates registered as candidate professional GISc practitioners with a relevant professional body usually undergo a period of two or more years of practical training under the personal supervision of a professional GISc practitioner. During this period the candidate will receive work integrated learning opportunities exploiting existing academic knowledge while being mentored in the principles of professionalism and ethics in the work environment.

**Professionalism and ethics in GISc**

Pugh (1989), cited by Huxhold & Craig [7], identified certain criteria for defining a profession within a field, which include the existence of a specialised body of knowledge, a formal professional organisation, a common language, a particular culture and lore, and a code of ethics.

The independent Geographic Information Systems Certification Institute (GISCI) is managed by a wide range of stakeholder groups that include the Urban and Regional Information Systems Association (URISA). One of the many contributions that the GISCI has made has been to define the GIS profession and to adopt a formal professional certification program and code of ethics.

The GISCI, GIS Professional Certification Program and the GIS Professional Code of Ethics, contain valuable guidelines to assist professional practitioners in GISc to make professional career and ethical choices from time to time as part of their professional careers. Practitioners who comply with the requirements for certification and who signed the code of conduct are recognised by the industry as having demonstrated professional competence and integrity in the field of GISc through the maintenance of high standards of professional practice and ethical conduct. If required, the certification program and the code of ethics will provide a basis for judging the validity of allegations or complaints involving GISc practitioners during disciplinary hearings. Consequently, the Code of Ethics serves as a moral foundation on which GISc professionals can evaluate their own work and the work of others. The adoption and implementation of a code of good conduct by a professional body contributes to the preservation and enhancement of the public trust in the discipline and it is likely that those who violate this code will be criticised by their professional colleagues, and, quite possibly, lose their certification (registration) credentials [7].

**Certification and licensing: key differences**

The terms certification and licensing are widely used in professional and technology driven practices, and are often confused. Certification programs and licensing programs are used for different purposes. The certification of GISc practitioners is a means to establish professional and ethical standards in the profession, whereas licensing of professionals is meant to protect the public from any damage that an incompetent professional may cause. The difference between certification and licensing in the USA and many other countries is that any professional or voluntary organisation can certify practitioners under its own authority, whereas licensing is established through legislation and effected by a statutory body.

**Assessment criteria**

**Knowledge and competencies in GISc**

Du Plessis and Van Niekerk [8] compared in detail the competency requirements for the GISc field of study, using models mainly in the
To ensure interoperability with corresponding documents in Computer Science, Information Science, Project Management, and other fields, the Geographical Information Science and Technology (GI S&T) BoK 2006 is presented (see Fig. 1) as a hierarchical outline composed of three tiers, called knowledge areas, units, and topics. The first tier consists of ten knowledge areas that span the breadth of the GI S&T domain. It represents more-or-less discrete clusters of knowledge, skills, and applications areas that are pertinent to, the undergraduate, graduate, and postgraduate/professional sectors of the GI S&T education infrastructure.

Each knowledge area consists of several units that are meant to be coherent sets of topics that embody representative concepts, methodologies, techniques, and applications. Units are designated as either "core" or "elective." Core units are those in which all graduates of a degree or certificate program should be able to demonstrate some level of mastery. Elective units represent the breadth of the GI S&T domain, including advanced topics related to the upper levels of Marble’s competency pyramid [9], such as application design, system design, and research and development.

**Marble’s pyramid of competency levels**

Marble identified a pyramid of six competency levels (Fig. 2) that undergraduate degree programmes should prepare students to achieve. Marble warned that the base of the pyramid is expanding at an explosive rate while the upper levels have been permitted to crumble [11]. Marble indicated that the notion of a curriculum must advance beyond some of the current attempts of some institutions to specify the content of one or two introductory courses to a full-fledged examination of the entire spectrum of courses required to support an adequate GIS education at each level of the pyramid. “We must cease confusing mastery of software commands with attaining a grasp of critical intellectual concepts” [11 p. 28-29].

**The Geospatial Technology Competency Model**

USA and South Africa. The key points derived from their study are summarised below.

**GI S&T Body of Knowledge**

DiBiase et al. [9], considered the importance of generic technical, analytical, business, and interpersonal skills required in the development and preparation of GISc practitioners for the workplace. Their work in this regard is confirmed by the Workplace Learning and Performance Institute (WLPI) which concluded: “For geospatial technology professionals to be successful in today’s marketplace, it is critical to understand that the knowledge, skills, and abilities required for their jobs include a blend of technical, business, analytical, and interpersonal competencies” [2 p. 25].

<table>
<thead>
<tr>
<th>Rating</th>
<th>Scale</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>Unfamiliar</td>
<td>Learning experience: The topic is not covered at all or, at most, in passing. Abilities: The individual has never heard of this topic, or has heard of some of the terms but is unable to define or apply them to any particular task.</td>
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<tr>
<td>1</td>
<td>Familiar (Marble levels 1,2)</td>
<td>Learning experience: The topic has been specifically addressed, probably in multiple forms (e.g. textbook, lecture and hands-on lab assignments), covering both conceptual models and technical application. Abilities: The individual is able to define basic terms, and can perform simple tasks with supervision or explicit step-by-step instruction.</td>
</tr>
<tr>
<td>2</td>
<td>Competent (Marble level 3)</td>
<td>Learning experience: There have been significant conceptual activities (e.g. writing, independent or group-based active learning) that require the learner to critically reflect on and synthesise relevant concepts. There has been significant applied experience (at least several hours), in multiple situations and with decreasing supervision. Abilities: The individual can perform common tasks without supervision, and is able to locate and use support resources to learn more advanced tasks. The individual is able to explain, justify and/or refute relevant theoretical concepts.</td>
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<tr>
<td>3</td>
<td>Expert (Marble levels 4,5)</td>
<td>Learning experience: The learner has a wide range of experiences including formal and informal education and several occasions of overcoming difficult obstacles with little to no help. Experience has likely included the teaching and/or management of others working with the topic; it has also included the development of original applications of relevant concepts. Abilities: The individual can perform both common and advanced tasks, and develops new techniques when necessary. The individual is able to integrate and apply theoretical concepts to solve advanced practical problems. The individual can also teach and support others.</td>
</tr>
<tr>
<td>4</td>
<td>Research and development (Marble level 6)</td>
<td>Abilities: The individual has a fairly complete knowledge of the state of the art in this topic, and is actively involved in advancing the theory, techniques and/or technologies of this topic. There are generally very few individuals who have attained this level of expertise for any given topic.</td>
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Table 1: The competency scale. (Source: [9])

In collaboration with the GeoTech Center, the United States Department of Labour, Employment and Training Administration, (DOLETA), has worked with industry and education leaders to develop a comprehensive competency model for Geospatial Technology [12]. The Geospatial Technology Competency Model (GTCM) is depicted as a pyramid with nine tiers. This depiction illustrates how occupational and industry competencies can be built on a foundation of personal effectiveness, academic, and workplace competencies. Each tier consists of one or more blocks representing the skills, knowledge, and abilities essential for successful performance in the industry or occupation represented by the model. At the base of the model, competencies apply to a large number of occupations and industries. As a user moves up the model, the competencies become industry- and occupation-specific [12].

**Assessment methodologies: Models of Geographical Information Science competency**

Competency models are built around the creation of an integrated model that is based upon key success
The competency scale
Table 1 shows the measurement system derived from the BoK (2006).

Factors (competencies) that are required for excellent performance in a particular work role. Role definitions, competencies, outputs, and quality requirements are important components of successful work performance that is often contained in the structure of the competency model [13].

**Explaining competency**
According to Dalton 1997 as cited by Gaudet, Annulis & Carr [13], competencies represent the knowledge, skills, abilities, motives, and values required to accomplish a particular task or job within a particular work role. Additionally, they have been described as those behaviours that distinguish effective work performance from ineffective performance.

**Models in GISc competency**
Models in GISc competency can be used for career guidance, curriculum development and assessment, recruitment and hiring, continuing professional development, criteria for voluntary certification, and marketing efforts intended to communicate characteristics of the geospatial field to the public [13].

**The competency scale**
Table 1 shows the measurement system derived from the BoK (2006).

**Visualising the GI S&T Body of Knowledge**
The depth and breadth of the GI S&T BoK is one of its primary strengths. Visualisation enables the recognition of broad patterns in large volumes of data, and should enable a "big picture" view of course curricula and individual competency in relation to the BoK content. Though qualitative, the visualisation provides new insight into the structure and content of desired and actual outcomes as characterised in the objectives and competency database.

An effective visualisation of the BoK distributes the topics and/or units within a space, and variations in symbols (hue, value, size, etc.) can be applied to portray the competency levels for a selected GISc programme or for a single person in the case of student or professional assessment [5]. The visualisation illustrates the depth and breadth of the knowledge areas, units and topics as detailed in the BoK [9].

It is important to note that the inclusion of a unit does not imply that every topic in that unit is covered to equal depth. For example, to cover a unit to the familiar level, it is adequate that a large portion of the topics are covered to the familiar level, perhaps one or two to the competent level, while some advanced topics may not be covered at all. At the degree programme level, the core units can be used to ensure that the collective curriculum is addressing the set of issues considered fundamentally important to the broader GISc community. Given that the focus of the BoK core is to support an entire GIS&T curriculum, we can not expect the entire BoK core to be covered completely and in depth in a single introductory course (i.e. certificate or diploma level).

**Quantitative analysis**
A quantitative analysis is useful as it allows a "gut check" of the appropriateness of the course emphasis. Secondly, it provides the ability to perform side-by-side comparison of multiple courses in a manner that allows the emphases of each course to be examined in context. In doing so, the visualisation can be used in conjunction with the quantitative analysis to evaluate both appropriateness of curriculum content and the alignment of course
objectives with the desired outcomes of the overall curriculum. Table 2 illustrates how the assessment database can be used to examine the general demeanour of a course. The specification (Spec) column contains the competency level specified for that unit during the objectives specification phase. In turn, the average coverage (Ave. Coverage) column indicates the average expected competency given the actual course content. The results of the quantitative analysis are also useful for ensuring that individual curriculum elements are appropriately contributing to the learning objectives specified at the onset of the assessment and evaluation process. The notion of alignment is critical in ensuring that course-level objectives are leading to an appropriate specification of desired course outcomes. While the visualisation can give a general sense of the focus of a given course, a quantitative analysis offers perspective on the emphasis of any given subject area, as well as the distribution of emphasis across subject areas for an entire course. Given that data on student outcomes may be collected and similarly quantified, this approach facilitates a complete view of the curriculum and its effectiveness [5].

Conclusion
There is a worldwide shortage of well-trained individuals that are competent in GISc. The more advanced the level of knowledge and skills requirements are, the scarcer the available human resources become. A successful organisation relies on the right people with the right skills and knowledge to reach its strategic goals and give it a competitive advantage in the market place.

Professionalism and ethics are regarded as fundamental requirements for the GISc industry where the integrity of geospatial information and subsequent decisions may affect the lives and livelihoods of people. Consequently the importance of registration (certification and licensing) allows the profession together with the state to take responsibility and control through legislation to regulate the quality of services in the industry.

Universities are under pressure from employers to turn out individuals in sufficient numbers that are competent in GISc to meet the demand of the industry. To meet these demands academics need to understand what competencies the industry requires and what the roles of the GISc workforce are. In this regard, the assessment criteria derived from the GI S&T BoK, the roles and competencies of practitioners as specified in the WLPI, as well as Marble's [11] and the Geospatial Technology Competency Model (GTCM), provides valuable insight into the levels of competency requirements for the industry and practitioners.

Qualitative assessments methodologies such as visualisation can be used in conjunction with quantitative analysis to evaluate both appropriateness of curriculum content and the alignment of course objectives with the desired outcomes of the overall curriculum.

Finally from the lessons learned, it is concluded that it is possible to use the assessment criteria and methodologies discussed in this paper in order to derive an assessment methodology that will meet the South African requirements for the accreditation of university programmes as well as for the assessments of individuals wishing to register with the South African Council for Professional and Technical Surveyors (PLATO) [14]. It is recommended that further research be done on the development of an assessment methodology for the accreditation of South African universities as well as for individuals wishing to register with PLATO.

References


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