A review of GISc education, its value and use in the mining and exploration industries

Heindrich du Plessis[1], Hennie Grobler[2], Curtis Mashimbye[3]

[1]Professional Geomatics Practitioner (GISc and Eng Surveying), dupfam@iafrica.com
[2]University of Johannesburg
[3]Esri South Africa

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Abstract

The purpose of this paper is to investigate the geographical information science (GISc) competencies, knowledge, and skills required by practitioners working in the mining and exploration industries. The paper promotes the appropriate design of education programs including short learning programs (SLP) as well as emerging delivery mechanisms such as distance learning opportunities. Programs are submitted for quality control through certification and accreditation at quality control councils such as the Council for Higher Education (CHE), South African Qualifications Authority (SAQA) and the South African Geomatics Council (SAGC). The paper concludes with a proposed module composition that is still subject to further consultation and input from the mining industry.

Keywords: *Geographical Information Systems (GIS), Geographical Information Science (GISc), Short Learning Program (SLP), Curriculum, Accreditation, Professional Body.*

1. Introduction

The mining industry has an intimate relationship with the surrounding landscape i.e. above and below the earth's surface. The search for resources during mining and exploration is an intrinsically spatial activity that involves geographical information systems (GIS), which are designed to collect, store, analyse, visualise and manage large volumes of geographic data. GIS provides the tools that can enable mining companies to have a clearer and more thorough insight to press ahead with planning and execution of mining operations.

The production and updating of mine plans are prescribed by the Mine Health and Safety Act and falls under the responsibility of the Mine Surveyor appointed in terms of the Act (DMR, 2011). In most cases mine plans are updated from information gathered daily by mine surveyors. With the commencement of the fourth industrial Revolution (IR4.0) and accelerated development of new technologies in information science and computer processing abilities, the mining industry adopted technologies such as Remote Sensing, digital Photogrammetry and Global Positioning Systems (GPS). These technologies allow data to be collected using various platforms including Satellites and

Remote Piloted Aircraft (RPAS) equipped with laser scanning and various smart sensors, this resulted in an upsurge of data, most of which may not be in the traditional domain of mine surveying. A consequence is that data collected in this manner is not always disseminated in the most efficient manner and value is lost in the process. Applications in GISc has been developed to address these challenges, however the mining industry still largely lacked the necessary human capital that is competent in the use of GISc and related technologies to find solutions that will address such challenges.

The draughtspersons and surveyors on a mine are often considered to be the repository of corporate spatial information and consequently is normally the first port of call for related enquiries. Some mining companies have started developing independent GIS departments but in many instances GIS departments are still not recognized as an essential custodian and disseminator of corporate spatial information and related data. The traditional Minerals Council qualification route for draughtspersons do not address the developments in GIS and as a result an opportunity in developing GIS competencies including GISc professionals in the mining industry is underutilized.

With IR4.0 that is gaining momentum and acceptance in all industries, GIS based “smart mines” that include the integration of systems must form part of the modern mine’s response in dealing with the large amounts of data generated during normal operational and mineral exploration activities. It is suggested that a more appropriate term for this may be Mine Information Management Systems (MIMS) as an adaptation of the Business Information Management Systems (BIMS) used in the construction industry.

A report prepared by the Geospatial Workforce Development Centre at the University of Southern Mississippi with the assistance of industry stakeholders, defines the geospatial technology industry as “... an information technology field of practice that acquires, manages, interprets, integrates, displays, analyzes, or otherwise uses data focusing on the geographic, temporal, and spatial context. It also includes development and life-cycle management of information technology tools to support the above” (Gaudet, Annulus & Carr 2001: 10).

The reality of today’s innovative workplace is that organizations need skilled and talented people. Successful organizations are recognized by their competitive advantage based on talented human capital in the workplace. To better define geospatial workforce needs, organizations need to know what employees need to know and be able to do, or alternatively what roles, competencies and outputs are for geospatial work (Gaudet & Annulis, 2008).

An important trend fuelling the growth of GIS technology in the mining industry is the increasing adoption of GIS technology by organizations and persons previously unacquainted with GIS and other related geospatial technologies. This trend is not only relevant in the environment of operating mines but as improved sensors and platforms becomes available extensive data is collected during the mining and exploration stages of the mining operation.

“New technologies such as location-based services, cell phones, the internet and the WWW with Google Earth services have contributed towards public awareness of geospatial technologies and their impact on daily professional and personal activities. With greater understanding comes greater demand for geospatial skills and applications across a wide range of other sectors including the mining industry" (du Plessis & van Niekerk, 2011).

"The ultimate driver of growth in GISc is likely to be the everyday users, a category which potentially an expanded population using embedded geospatial technologies such as car navigation systems and Web-based mapping and imagery display applications" (du Plessis & van Niekerk, 2011).

"Organizations need skilled and talented people. Talented people are the competitive advantage of organizations, and they are essential to the latter's success. Human capital development means the creation of a culture that supports talent development at every level of the organization. Successful organizations realize that having the right people with the right skills and knowledge to help the organization reach strategic goals is a smart competitive advantage" (Gaudet & Annulis, 2008).

The Institute of Mine Surveyors of Southern Africa (IMSSA), The Geo-Information Society of South Africa (GISSA) and the South African Geomatics Institute (SAGI) has embarked on an extensive marketing programme to improve the image of geospatial technologies by integrating their resources to make a greater impact on the youth, decision makers in government and in politics. Since 2007 the three organisations have developed a message through workshops, seminars and conferences that demonstrates geospatial technologies as an enabler of other locational applications. Together they have developed an academic and industry communications strategy using publications such as *Position IT,* newspapers, bursary schemes and engaged with the South African Qualifications Authority (SAQA), the Council for Higher Education (CHE), national and provincial education departments, schools and universities (Geomatics Education Meeting, 2007).

Worldwide, there is a growing demand for GISc practitioners. The large number of GISc vacancies in every sphere of the South African geomatics industry including mining and exploration emphasize the need for a strategy to provide the industry with a well-trained workforce. The Department of Higher Education and Training (DHET) has listed GISc as a scarce skill which is in short supply (DHET, 2014). The matriculation examination results of the past number of years confirmed that graduates in computer science, mathematics and physics are (and will remain so in the foreseeable future) the most difficult to recruit.

2. Background

Geospatial data is the bedrock of mining, and geographic information systems (GIS) are making this data clearer and more detailed (Miller & Lynch, 2014). A brief review of developments in survey technology and procedures highlights that the need for spatially accurate data is becoming increasingly important in the process flow of a modern mining operation. Glukhov, Antsyferov, Vorobjov and Kozirenko (2007) suggests the development of a graphic documentation system for surveyors through the application of GIS. While Dima, Herbei and Veres (2007) discussed the development of modern technologies towards realizing a geographic information system to help in identifying suitable development areas that may have been affected by the mining exploitation activities.

The concept of incorporating graphic information into a Geographic Information system (GIS) through the integration of mining systems was introduced by Zejtts & Dziankevich (2007) which led to the development of a system for digital mining (Wu, Che, Liu, Yang and Guo, 2007). This concept was highlighted at the 2007 Congress of the International Society of Mine Surveyors. In a further development of potential applications of GIS in mining, Blachowski, Chrzanowski and Szostak—Chrzanowski (2013) argues for the application of GIS methodologies in the assessment of subsidence caused by mining on surface infrastructure.

While many industries require detailed knowledge of geography, geology or spatial measurements, industries in the mining sector have an intimate relationship with the earth, above and below the surface. The search of resources to mine is an intrinsically spatial activity, and as such, the effective collection and presentation of geospatial data is an indispensable part of the operation. Geographical information systems (GIS) are central to these efforts and are designed to collate, analyse and display massive volumes of geographic data. Over time the application of GIS technology in the mining sector will replace paper surveys and give mining companies a clearer and more thorough insight through data and subsequent information to press ahead with operations. Digital data in general, has become increasingly central to the industry over the years, as it reduces risks by tracking geographic variables that might otherwise have been missed (Miller & Lynch, 2014).

GIS technology, such as the ArcGIS platform, for example integrates with other systems in the mining sector to bring diverse datasets together. These range from basic geological maps, satellite and geophysical imagery to operational data. Using this technology users can effectively and accurately explore and calculate economic potential, automate repetitive tasks to increase efficiency and productivity, manage risk, conduct environmental assessments, and analyse other concerns affecting mining and exploration. The global application of GIS technology over the past decade in mining has resulted in improved accessibility with consequent functionality to efficiently collect, manage, display, analyse and share geospatial data, maps, and related information. Sadly, it appears that the mining industry in South Africa have not fully recognized the value that GIS can add to operations. Advances in Information Technology (IT) has enabled GIS to be deployed beyond server or desktop platforms and it is now accessible on mobile devices, over the web and in the cloud. The technology allows data collected in the field to be automatically updated on corporate servers. Consequently, maps and data can now be easily accessed by field workers on their mobile devices over secure web portals. This allows everyone in the organisation to obtain accurate and up-to-date information needed for better decision-making. The most important feature is that all of these platforms are safe and secure.

Increased application of GIS technology in the South African and African mining industry combined with the necessary knowledge, competence and skills has become an imperative for the industry to survive in the present and future post Covid-19 economic climate. GIS can provide mining and exploration companies with powerful tools to integrate multidisciplinary data to enable the geographic advantage and ensure health, safety and environment program compliance by leveraging industry best practices. These include, monitoring, reporting activities and incidents, adhering to corporate and government laws and regulations such as the South African Code for reporting Exploration Results, Mineral Resources and Mineral Reserves (SAMREC) and Chapter 17 of the Mine Health and Safety Act, Act 29 of 1996.

The Mining Quality Authority (MQA) in its National Sector Skills Plan (2018-2019, 2019) noted that:

- The primary reasons for the skills gap are a lack of specialized knowledge and experience in updated and new technology, poor basic education, insufficient experience, low levels of mathematics and science.
- The industry is becoming more conscious of the growing need to protect the environment by mining in an environmentally sustainable way.

The above highlights the need for the urgent implementation of GISc educational programs through the introduction of appropriate SLPs, curricula development and courses at institutions of higher education that offer programs to the mining sector.

3. Opportunities

The introduction of new or revised GISc learning programs through contact as well as distance learning will offer new opportunities at mining houses especially for existing employees. Draughtspersons in the mining industry will gain new competencies as operators of Geographical Information Systems at mining houses where they no longer enjoy a clear career path and almost no opportunity for promotion.

The reality is that visual cartography has become an important resource at mining houses and consequently there is a need to develop an appropriate GIS database where employees and managers at different levels can access data and information in the form of maps, statistics and dashboards for informed decision making. The increased accessibility of applications in 3D mapping, cloud base mapping, RPAS, including unmanned aerial vehicles (UAVs), drones and remote sensing technology, etc. have changed the traditional role of many existing employees in the mining industry thus, opening new career opportunities for them to progress towards registration with their respective professional bodies as Professional and Technical GISc practitioners with the necessary knowledge and competencies in the mining industry.

Employees in the mining industry with existing tertiary qualifications as well as those with no post matric qualification will with the introduction of appropriate distance learning programs have the opportunity for new career milestones such as certificates and post grade qualifications that were not previously available.

The following target groups have been identified:

1. Persons (draughtspersons) from the mining industry working towards a Diploma in GISc or a certificate in GIS for draughtspersons.
2. Persons who have qualified as Geomatics Technicians: Mine surveying and working towards an advanced certificate / diploma in GISc for mining.
3. Persons with a degree in mine surveying and working towards a certificate / honours degree in GISc to complement their existing qualification(s).

4. Existing academic frameworks used to identify GISc content for the mining industry

The academic frameworks (models) used as criterion by the Education Advisory Committee (EAC) of the SAGC provide academics and program developers with valuable insight. These frameworks were developed and compared using international standards that are applied in Europe, the Americas, and Asian countries.

In order for a Geomatics Program to be accredited in South Africa it is essential that the program comply with the minimum requirements specified in the SAGC academic framework. Thus, it is advisable to evaluate the GISc academic requirements for each level of registration with similar models used by the SAGC before embarking on the design and development of new or revised programs/courses/modules.

The GISc content prescribed for Professional and Technical Geomatics Practitioners (Surveyors) are very similar and therefore the two levels need consideration when designing appropriate GISc programs for the mining industry (SAGC, Academic Model Overview, 2019). This will form part of the consultation process with the mining industry in order to address the industry's unique requirements on the functional advantages of GISc in the mining and mineral sector.

In the case of GISc for a Geomatics professional: Engineering Surveying, the required outcomes are the ability to apply Geographical Information Systems (GIS) in solving survey related problems and include topics such as the nature of geo-spatial information, geo-spatial information in planning and decision-making, the applications of geo-spatial data using spatial analysis, spatial modelling and spatial statistics, visualisation, representation of geo-spatial information (including digital cartography), etc. While the GISc content for a Geomatics Technician: Engineering Surveying requires the ability to apply Geographical Information Systems (GIS) in solving survey related problems and include topics such as the introduction to principles of GIS; Data sources, data models, databases, spatial analysis, metadata, etc.

The SAGC prescribes that the GISc content for the Geomatics Technician: Mine Surveying requires the ability to apply the related technology in solving standard mine survey applications. Topics and themes covered in this category amongst others include an introduction to GIS; maps and types of maps; cartographic design principals; visualisation and spatial interpolation. Using these basic GISc requirements specified for Geomatics Technicians, it is proposed that the short learning programmes (SLP) for draughtspersons employed in the mining industry concentrates on the introductory levels of GISc and the application thereof in the mining industry.

5. Proposed Short Learning Programmes (SLP's) leading to qualifications for mining officials

5.1. SLP Certificate in GISc for Mining Draughtspersons.

The proposal here is to offer SLP consisting of modules through contact and or distance learning at an introductory level that have been accredited by the SAGC, CHE and SAQA and which will eventually be recognised towards a formal qualification (certificate) in terms of recognition of prior learning (RPL). The expected outcome will be the ability to use GIS in solving mine related problems in the normal execution of their duties. Useful content will be the introduction to principles of GIS; Data sources, spatial analysis, metadata, contours and Digital Terrain Models.

The proposed SLP can in time be converted into an accredited certificate for mining draughtspersons once registered with the relevant quality control councils.

5.2. SLP/Certificate/Diploma in GISc for Geomatics Technicians: Mine Surveying.

The proposal here is to offer SLP(s) consisting of modules in GISc that have already been accredited by CHE, SAQA and SAGC and which will eventually be recognised either as a standalone qualification (certificate) or in terms of RPL can be incorporated in an existing program such as the Diploma in Mine Surveying. The module(s) can be presented using a mixed methodology that include contact and distance learning. The expected outcome will be the ability to apply GIS in solving mine surveying related problems. Content will be aligned with the academic framework approved by the SAGC and registered with the respective quality control councils.

5.3. SLP/Advanced Certificate / Higher Diploma/ Honours in GISc for Geomatics Professionals: Mine Surveying.

Again, the proposal is to offer a module or modules that have already been accredited by CHE, SAQA and SAGC and which will eventually be recognised as a standalone qualification in terms of RPL or can be incorporated in an existing program leading to an Advanced Certificate/Higher Diploma or become part of an Honours degree in mine surveying. These modules can also be presented using a mixed methodology that include contact for practical training and distance learning to cover the theoretical part of the module. See Table 1 for the proposed module composition.

Table 1: Proposed module composition for the Advanced Certificate / Higher Diploma / Honours degree. University of Johannesburg (2019)

Module	Topic
Module 1	GIS Introduction/Overview
Module 2	Coordinate Systems
Module 3	GIS technology and cartography + practical training session
Module 4	Data Models + practical training session
Module 5	Data acquisition and remote sensing + practical training session
Module 6	Spatial Data Management+ practical training session
Module 7	GIS data analysis in mining operations+ practical training session
Module 8	Advanced GIS analysis+ practical training session
Module 9	Spatial interpolation and geocoding in GIS
Module 10	Decision support systems in mining
Module 11	GIS applications in mining+ practical training session

The proposed module composition and content is still subject to further consultation and input from the mining sector and academia in order to meet the needs of the industry. Content such as the nature of geo-spatial information, geo-spatial information in planning and decision-making, the applications of geo-spatial data using spatial analysis, spatial modelling and spatial statistics, visualisation, representation of geo-spatial information (including digital cartography), etc. need to be considered and incorporated where required. However, the focus must be on mining and mineral exploration in order to address the unique needs of the mining industry.

6. Conclusion

The article proposes that program developers look at existing qualifications with GIS content such as the Diploma in GISc offered at Esri South Africa, the Honours degree for Mine Surveyors offered at University of Johannesburg (UJ) as well as other institutions of higher education in South Africa before developing new modules for the above programs. The assumption is that these modules have already been accredited by the relevant quality control bodies and theoretically can be immediately implemented while commencing with the formal processes of registering new qualifications.

The inclusion of GIS in the existing academic qualifications through the development of a suite of courses to qualify persons employed as draughtsmen in the mining industry as GIS operators will have a long-term beneficial impact on the mining industry as well as the careers of this occupational group. The importance of a single source of spatially accurate and verified information linked to the survey network of a mine is essential if advances in remote mapping and autonomous mining is to be realized.

By promoting the competencies, knowledge, and skills required by practitioners working in the mining (geomatics) industry and the appropriate design of education programs and supportive short learning programs (SLP), the benefits of GIS can be widely disseminated into the mining industry. Appropriate quality control through certification and accreditation of modules and programs at quality control councils and regulatory professional bodies will provide the necessary controls to ensure a formalised and sustainable qualification route for personnel in the mining industry working with Geographical Information Systems (GIS).

The adoption of GISc in the mining industry is an essential component of moving towards IR4.0 within an industry that collects data from a variety of sources and applications. A fully integrated GIS system will allow mining companies to exploit opportunities provided by laser scanning, remote sensing, RPAS and related technologies to add direct value to the process of exploring mineral and other mining resource to its full potential. Data collected and disseminated in this manner can assist in the development of new resources, provide an understanding of the complex issues facing mining and provide information to government departments. The ultimate goal would be to have access to human capital with the right knowledge, skills and competencies to assimilate data from different mining operations into a collective GIS data base for large mining companies to manage "smart mines" in the future.

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