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Introduction of Geographical Information Systems (GIS) in Technical University Education in Ghana: Challenges and the Way Forward

Prince C. ACQUAH[1]
Kumasi Technical University, Kumasi, Ghana

Jack N. ASAMOAH[2]
Kumasi Technical University, Kumasi, Ghana

Daniel D. KONADU[3]
Cambridge University, Cambridge, UK

Abstract

Geographic Information System (GIS) continue to play very important role in improving spatial thinking skills of graduates from higher educational institutions. However, teaching and learning of GIS at the technical university level in Ghana remains very limited due to some implementation challenges. This paper reviews the implementation of GIS in higher education in Ghana and also highlights the major implementation challenges of teaching and learning of GIS at the technical universities in Ghana. The status of GIS education in the technical universities in Ghana is also highlighted. An exploratory and descriptive research approach was adopted for the study focusing on the implementation challenges of teaching and learning of GIS in technical universities in Ghana. The findings of the study reveal the wide acceptance and the need for GIS education in engineering and built environment departments in the technical universities in Ghana. The paper then concludes with some recommendations that would help to improve teaching and learning of GIS technology at the technical universities in particular and higher education in Ghana in general.

Keywords

Geographic Information System; GIS Education; Technical University; Polytechnic; Challenges

[1]Corrospending Author: Department of Civil Enginering, Faculty of Engineering and Technology, P. O. Box 854, Kumasi Technical University, E-mail: acquahprince[at] gmail.com
[2]Faculty of Engineering and Technology, P. O. Box 854, Kumasi Technical University, E-mail: jaccephas[at] yahoo.com
[3]Department of Engineering, Cambridge University, Trumpington Street, Cambridge, CB2 1PZ E-mail: konadu [at]gmail.com

Geographic Information Systems (GIS) since its introduction into higher education in the early 1990s (Zhou et al., 1999) has proven to be a very resourceful educational tool for both educators and students in higher education. Teaching and learning of GIS at the tertiary level provides important technical skills for students who are interested in applying GIS technology directly as a major application tool in industry and also improves the competence of those who may indirectly utilize GIS approaches in decision-making processes (Whyatt et. al., 2011). GIS has greatly improved spatial decision-making processes in universities and industries (Baker et al., 2012) by bringing together spatial datasets of different referencing systems for effective manipulation and analysis in a computer environment. Some important justifications for GIS introduction in education have been outlined by Bednarz (2004). Bednarz 2004 described GIS in education as an "educative tool that enhances student's spatial thinking skills and also as workplace skills where GIS is needed as a tool for future knowledge in geospatial technologies". In furtherance to that, geospatial technologies have been used by educators to enhance classroom teaching and learning environment (McClurg and Buss 2007). Currently, schools all over the world are introducing GIS in their curricula to help their students gain valuable knowledge and skills with which to face global challenges (ESRI 2011). Apart from tertiary institutions, GIS as a teaching and learning tool has been introduced in basic schools in some countries, including the USA (Bednarz, 2004), Canada and a number of European countries (Broda and Baxter 2003; Kerski 2003; Wigglesworth 2003; Bednarz and Van der Schee, 2006). Countries such as France, Finland and Sweden have also included GIS in their secondary school curriculum but had some implementation challenges (Johansson and Pellikka, 2006). India, in 2000, also introduced GIS at the secondary school level as part of geography curricula under the National Framework for School Education project (NCFSE, 2000).

GIS was introduced into Ghana's educational system at the tertiary level first in the universities and later in the polytechnics now known as technical universities. Although the prospects of GIS education and development in Ghana are high even at the secondary school level (Oppong and Ofori-Amoah 2012), much has not been accomplished by the ministry of education, policy makers and other stake holders to fully integrate it across all levels of education system. Workforce studies suggest that the services of surveyors, computer programmers, agricultural technicians and experts in logistics with spatial database expertise would be sought for in today's technologically driven world economy (Estaville, 2010; Rudibaugh and Ferguson, 2010). In contrast, the teaching and learning of GIS in Ghana is not widespread even at the tertiary level. Currently, majority of professionals graduating from higher education in Ghana lack the needed spatial thinking skills and abilities that could make them competitive in today's job market. This notwithstanding, the introduction of GIS education in Ghana especially at the technical university level has shown to improve graduates spatial thinking skills and prepare them adequately for the challenges in their professional endeavors. However, there still exist some challenges that have impeded the effective implementation of GIS education at the technical university level. A cross-sectional survey was conducted to investigate the implementation challenges in teaching and learning of GIS in the technical universities in Ghana. The need and the acceptance level of GIS technology were also assessed. This paper presents the findings of the

study and finally concludes with recommendations that would improve the teaching and learning of GIS technology in the country.

The Current State of GIS Education in Ghana

GIS was introduced into higher education in Ghana in 1998 as an undergraduate course in the department of geomatic engineering, Kwame Nkrumah University of Science and Technology (KNUST). It was later extended to the graduate level in civil engineering, planning and land economy departments at KNUST. In 2002, Environmental Systems Research Institute (ESRI), the developers of ArcGIS software application suite, supported the geomatic engineering department of KNUST with a grant to establish a GIS laboratory to assist in teaching, learning and research in the university community and the West African sub-region. The setting up of the GIS laboratory empowered the department to organize short courses and training in GIS for students, lecturers, researchers and members of the university community. Currently, besides the geomatic engineering department, GIS is taught as core course in the Civil Engineering department at the graduate level, and at both graduate and undergraduate level at departments of geography, geophysics, planning, environmental science, land economy, material science engineering and geological engineering all in KNUST.

Besides KNUST, GIS is treated as core course at geography, environmental and geomatic engineering departments in all public universities in Ghana. Other private institutions including central university and catholic also teach GIS as core course. Kumasi, Takoradi, Wa, Koforidua and Sunyani technical universities are the five out of the ten technical universities in Ghana that offer GIS as a core course. Kumasi Technical University (former Kumasi polytechnic), was the first technical university to introduce GIS as a core course in 2008. It was introduced as a modular course in the civil engineering department at the Higher National Diploma level. In 2010 and 2012, it was introduced to Bachelor of Technology (first degree) students of civil engineering and estate management departments respectively. In 2012, ESRI, through its local representative, embarked on a country-wide distribution of ArcGIS educational packages as grant to some selected second cycle and tertiary institutions in Ghana with the aim of making GIS accessible for all. Two of the traditional public universities, one private university college, one technical university and six-second cycle institutions benefited from this grant.

GIS Application Areas in the Technical Universities

Geographic information, in its simplest form, is the knowledge about what is where, when and where. GIS as described by Catlin Dempsey, (2012) is a technological field that incorporates geographical features with tabular data in order to map, analyse, and assess real-world problems. The power of GIS is its ability to integrate both spatial data and attribute data of features they represent. GIS has been used extensively to support decision making in many organisations, government, educational and research institutions over the years. The wider applications and benefits associated with GIS have resulted in it being taught across a much broader range of professional disciplines in recent times than was previously limited to geography and environmental science (Bearman et. al., 2015). Across the technical universities in Ghana, the main areas where GIS is needed as a core course include departments in the faculties of built and

natural environment, engineering, creative arts and technology and in the applied sciences. In civil engineering for example, GIS is used extensively in highways and transportation planning, road and traffic management, water and sanitation and environmental monitoring. The use of GIS as a database platform for managing and monitoring transportation infrastructure has proven to be very effective (Miller and Shaw, 2015). In electrical and electronic engineering, the use of GIS for automated route selection of new power lines, load forecasting and optimization planning for substations in power system is known to have significantly enhanced the efficiency in the power sector (Rezaee et al., 2009).

The application of GIS in the oil and gas industries, from the exploration to the production, refining and transportation is also phenomenal. GIS is used to collect, store, analyse and display the spatial locations of wells, pipelines and other features in the environment for better decision making. In surveying and estate management, GIS has been used in keeping proper inventory of land and property records necessary for property valuation and facility management (Dale and McLaren, 1999). GIS is also applied in the building and construction industry for quantities take off and construction estimates by the building and architectural professionals (Cheng and Yang, 2001; Bansal and Pal, 2007). Moreover, GIS is widely applied in regional and urban planning (Waddell, 2002), as well as municipal administration and management of the natural and built environment. In tourism and hospitality industry, GIS is used to assist tourist in finding nearest hotels and restaurants and also in finding shortest and fastest routes to their destination of choice (Gill and Bharath, 2013; Chen, 2007). GIS is able to show a large amount of tourist information in an easy to read indexed map. GIS has also been used extensively in environmental studies, resources engineering and management, business and management studies (Chinchu and Selvakumar 2012). This notwithstanding, the teaching and learning of GIS is not widespread across the technical universities in Ghana who are noted for the training of highly skilled professionals to take up the supervisory role in the industry

Materials and Methods

An exploratory research design was adopted for the study, focusing on the teaching and learning of GIS in the technical universities in Ghana. The questionnaires were structured to include close-ended and rating-scale questions arranged in accordance with the objectives of the study. Out of one hundred and two (102) self-administered questionnaires distributed, sixty-one (61) were returned representing 59.8% return rate. Purposive sampling method was therefore used in administering the questionnaires across the ten (10) technical universities in Ghana. Thirty-five (35) lecturers from different academic departments responded to the survey. In addition, ten (10) heads of departments and sixteen (16) technicians also responded to the survey. Descriptive statistics were used to analyze the data collected with the help of Statistical Package for Social Sciences (SPSS) and Microsoft Excel applications. The outliers in the questionnaires, which could potentially affect the results and the subsequent discussions were detected and removed. The responses were coded in the SPSS for further analysis and the results presented in the form of bar and pie charts. Table 1 provides the summary of the teaching staff sampled and their respective faculties.

Table 1

Distribution of respondents

ID	FACULTY	PERCENTAGE
1	Built and Natural Environment	26.23%
2	Engineering	63.93%
3	Other faculties	9.84%
Total		**100.00%**

63.93% of the teaching staff came from the faculty of engineering, 26.23% from the built and natural environment and the remaining 9.84% came from mathematics, computer science, agricultural science and industrial arts departments.

Findings

GIS Implementation Challenge

The challenges of GIS in education globally have been found to be both practical and conceptual. The practical challenges have to do with the funding and maintenance of the needed hardware and software and other infrastructural needs whereas that of the conceptual challenges bother on the reorganisation of the curricula and the adoption of new teaching methods (Foote et al., 2012). The introduction of GIS into the technical university education, the then polytechnics in Ghana in 2008 had to contend with these challenges. The conceptual challenge in Ghana can be linked to the lack of policies in the curriculum development and regulatory standards in spatial data acquisition and sharing.

The Availability of GIS Facilities

The availability and the level of adequacy of GIS facilities in the technical universities such as laboratory space, software and hardware availability and geospatial data were surveyed to determine the current state of GIS facilities in the technical universities. Figures 1a, 1b, 1c and 1d graphically show the results of the level of adequacy of existing GIS facilities in the technical universities.

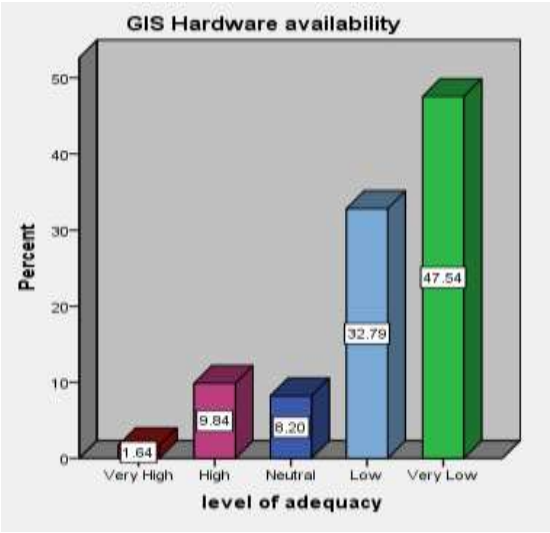

Figure 1a. GIS hardware availability

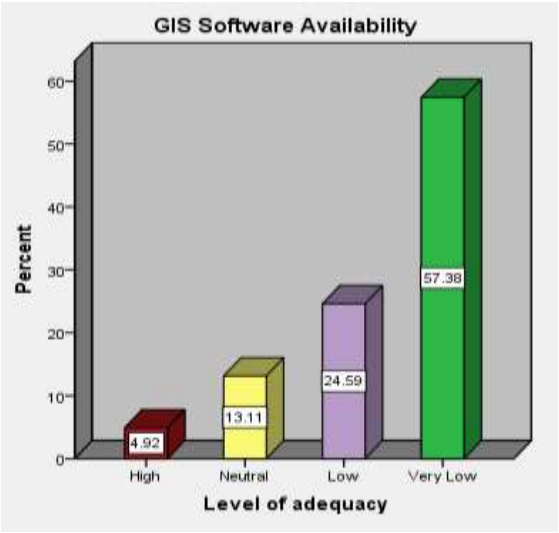

Figure 1b. GIS softwareware availability

More than half of the respondents (57.38%) agreed that the level of adequacy of GIS software is very low in the technical universities. The results clearly depict the poor state of GIS facilities in the technical universities and how they contribute to the current challenges in the teaching and learning of geospatial technologies in Ghana. About 80% of the respondents collectively agreed that the level of adequacy of GIS hardware is either low or very low. 52.46% of the respondents also agreed that access to geospatial data is very low at the universities.

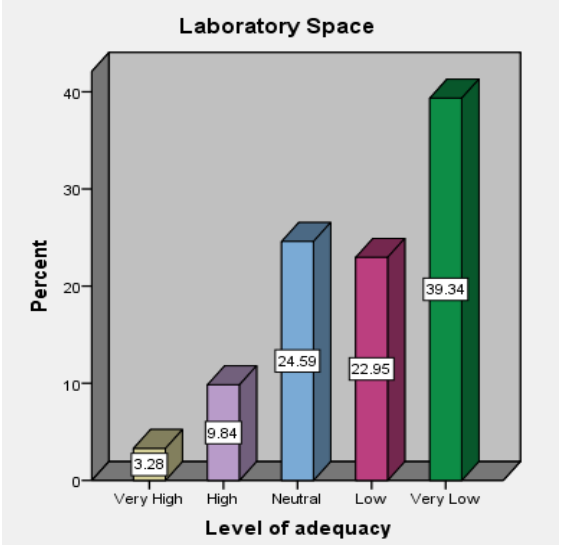

Figure 1c. GIS Laboratory availability

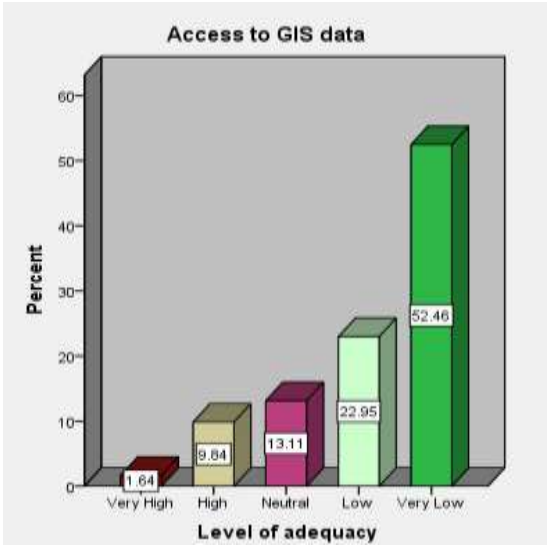

Figure 1d. GIS data availability

The practical challenges such as infrastructural challenges, lack of access to digital spatial data and GIS instructional materials and low level of Information and Communications Technology (ICT) knowledge and skills among students in the technical universities were also surveyed and analysed.

Infrastructural Challenges

Acquisition and maintenance of GIS software and hardware packages have been identified as some of the major implementation challenges for the technical universities. This is attributed to the poor funding of polytechnic education on the part of government (Nyarko, 2011). GIS software packages are generally expensive and require considerable investment for initial acquisition and maintenance. However, in Ghana, one major setback in the education system is the lack of financial support to acquire software and programs for teaching and learning purposes.

The acquisition of the hardware component of GIS infrastructure is also a major impediment in the successful implementation of GIS programmes in the technical university. A quarter of respondents (25%) strongly agreed and 43.33% agreed that high cost of GIS software is one of the major challenges as indicated in Figure 2. In addition to the high cost of GIS software, GIS software has been designed to run on high speed computers with larger storage capacities. These kinds of computers are very expensive, coupled with the need for furnished laboratories with efficient and reliable internet connectivity involve substantial capital cost.

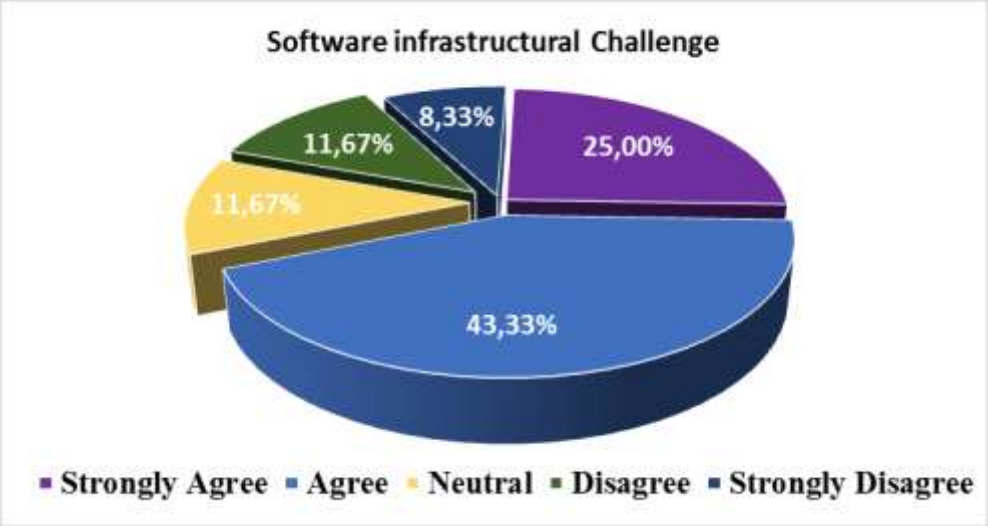

Figure 2. GIS software infrastructure

Other hardware components of the GIS setup such as digitizers, scanners and plotters also require huge sums of money to procure and maintain. 68.33% of respondents collectively are of the opinion that challenges with the acquisition and maintenance of hardware has a negative impact on the implementation of GIS education. 30% of the respondents strongly agreed and 36.67% agreed to the fact that lack of laboratory space to support teaching and learning in the technical universities is also a challenge.

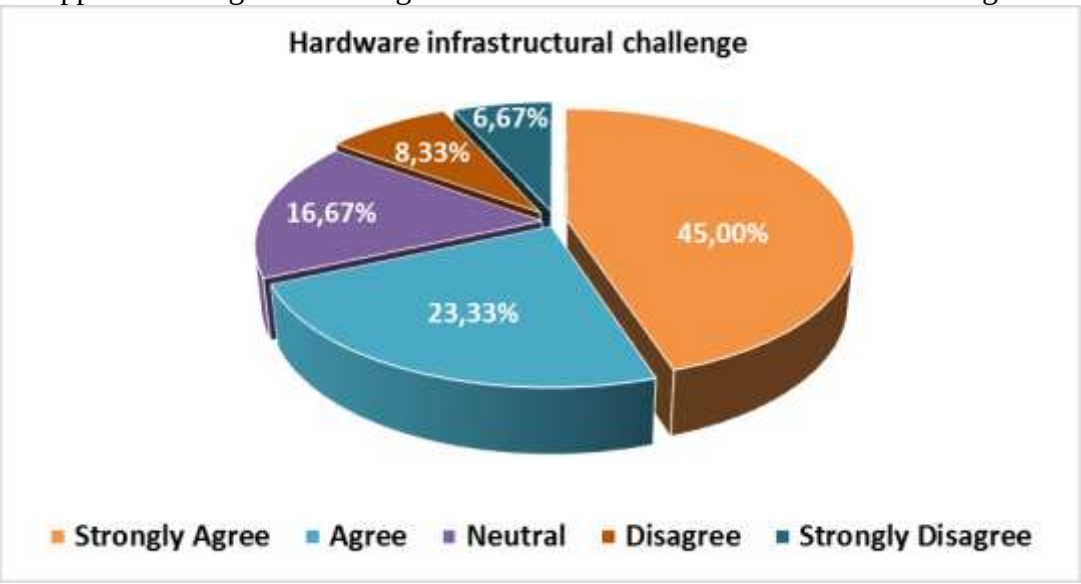

Figure 3. GIS hardware infrastructure

In addition to this, 68.33% of the respondents collectively believe that the poor state of ICT infrastructure in the country also poses a challenge for the adoption of free source GIS packages and other internet-based GIS programs like the Google and Yahoo maps.

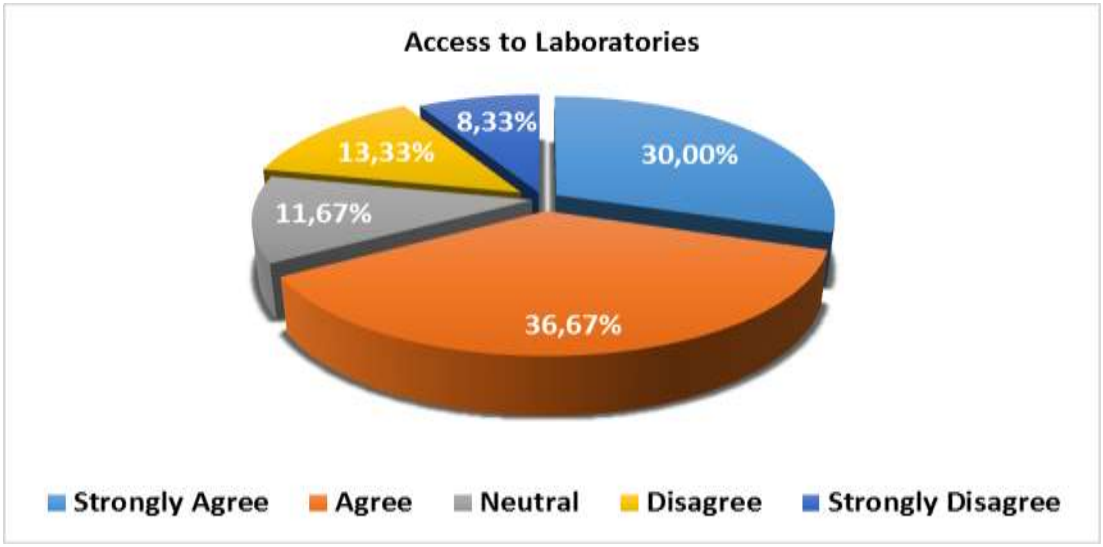

Figure 4. Access to GIS laboratories in the technical universities

Lack of Access to Digital Geographic Data

Besides the infrastructural challenges, 50% of teaching staff collectively agreed that access to digital spatial data and instructional materials for teaching and learning is also a challenge. Acquisition and transfer of digital spatial data for academic purposes in Ghana are extremely difficult and expensive. The digital data and the few hard copy maps available are also not up to date and the facilities and infrastructures such as scanners and digitisers for their conversion into the digital formats are also not readily available. In addition to accuracy and currency of spatial data, many of these data are of different projections system which brings about compatibility issues. In other jurisdictions, there are number of organisations and clearinghouses that provide GIS data either for free or at a very low cost for academic purposes. On the contrary, there is no such centralised database in Ghana where students and educators could easily download data either for free or at a low cost.

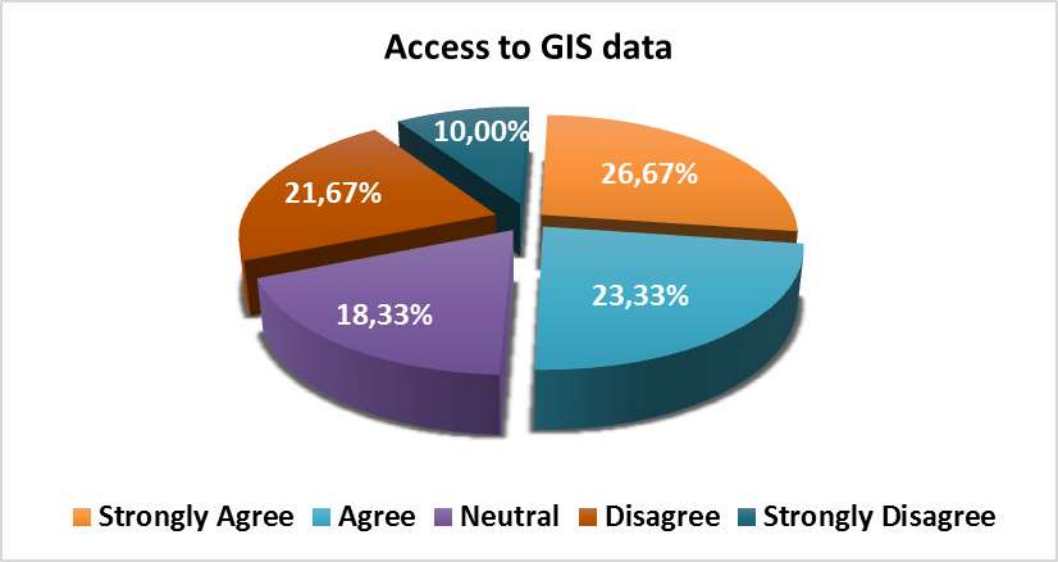

Figure 5. Access to GIS data

Low Level of ICT Knowledge and Skills of Students

Another contributing factor that the researchers considered was the level of ICT knowledge and skills of students in the technical universities. Since GIS is a computer-based application, the basic requirement for effective teaching and learning of GIS is the basics in computer literacy. Experience has shown that students who exhibit a high level of computer literacy tends to understand the concept and the application of GIS better and are able to use the system effectively than their counterparts with low knowledge in computers.

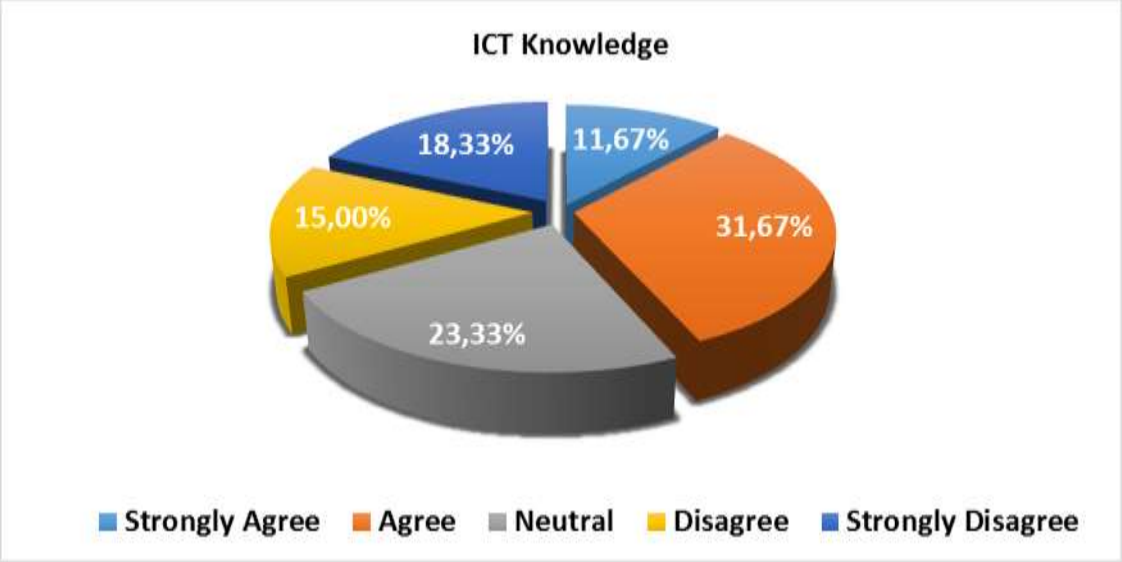

Figure 6. Level of ICT knowledge and skills

Despite government's effort of improving ICT education in Ghana by the enactment into law an ICT for Accelerated Development (ICT4AD) policy in 2003 and the subsequent ICT in education policy in 2008 which was reviewed in 2015 with the goal of creating the building blocks for integrating ICTs into education sector, 43.34% of the respondents believe that ICT knowledge and skills is still low and it is impacting negatively in the technologically based courses in higher education including the teaching and learning of GIS.

Recommendations for Improvement

The challenges associated with the implementation of GIS in technical universities in Ghana discussed points to the need for GIS educators, policy implementers and other stakeholders to devise comprehensive measures to improve the current situation. Discussed below are some suggested recommendations that would help improve the teaching and learning of GIS in technical universities in particularly and higher education in Ghana in general.

Improvement in GIS Infrastructure in Technical Universities

Placing more emphasis on skills acquisition with the project-based approach to teaching and learning of GIS in the technical universities will require an improvement in the existing GIS infrastructure. These must include a well-furnished GIS laboratories in the technical universities with high speed computers and other accessories such

scanners, plotters and digitisers. Improvement of the weak ICT infrastructure in Ghana will also go a long way to improve teaching and learning of GIS in school through adoption of e-learning, spatial data sharing and transfer. It will also promote the adoption of short courses on the internet to augment classroom lessons.

Teaching and Learning Approach

The conventional approach to teaching and learning in schools and colleges in Ghana and in many developing countries has not been student centred. There is more concentration on educators imparting knowledge to students with little or no emphasis on the acquisition and demonstration of skills by students in the learning process. Researchers, Favier and Van de Schee, 2007 and Bednarz, 2004 have all emphasised the importance and the need to combine knowledge and skills acquisition in geography education. Favier and Van de Schee, 2012 also explored and outlined the characteristics of design principles for GIS supported inquiry-based geography education. As noted by Schultz (2012), active learning, when put together with inquiry based and problem-based learning system creates a mechanism by which GIS technology can be practiced to a point of fluency. The best approach to teaching and learning GIS in the technical universities therefore is the project-oriented approach. This, therefore, will require more hands-on training with the software by allowing students to be actively involved in the learning process.

Collaboration with Universities and Other Institutions

A distinctive feature of GIS education is the way educators have worked collaboratively often across disciplines and national boundaries to innovate and improve practice (DiBiase et al, 2012). An effective collaboration with established institutions such as public universities in Ghana that have built reputation in GIS education over the years will help to address some infrastructural challenges in the institutions. Additionally, the technical universities have to establish links with GIS software suppliers, consultants and a wide range of users. If such collaborations are already in place, it could be further enhanced in the pursuit of better and efficient GIS education in other technical universities. At the initial stage of GIS implementation and the efforts by the technical universities to confront the infrastructural challenges, the technical universities can establish relationship with the geography and geomatic engineering departments in the public universities with the requisite experience and expertise.

Restructuring of Geography and ICT Education in Ghana

Restructuring of ICT education in schools and colleges especially at the second cycle level will help to improve GIS education in Ghana. Experience has shown that, an improvement in ICT training at the secondary school level will produce students with high literacy rate in ICT who can easily appreciate GIS technologies. These students end up in the technical universities and in other tertiary institutions in Ghana. Over the years, government has introduced many ICT policies in education and interventions including the recent ICT for education policy 2015 focusing on the use of ICT as learning and operating tool and also as a career option for students. These efforts must be strengthened in order to improve ICT education in Ghana. In addition to this, introduction of GIS into the second cycle education as part of geography curriculum as suggested by Oppong and Ofori-Amoah (2012) will also give students entering the

higher educational institution in Ghana a brief introduction of GIS and will prepare them adequately for higher education and training in GIS.

Conclusions

GIS has proven to be a very useful professional tool since its introduction into technical university education in Ghana. This notwithstanding, there are significant implementation challenges that have been outlined in this paper that require urgent attention in order to realise the full potentials of GIS education at the technical university level in Ghana. Addressing these challenges would require collaborative efforts of GIS educators, government and other stakeholders in the GIS industry. In spite of the implementation challenges discussed in this paper, the prospects of GIS in Ghana remain high. There is an increasing awareness of GIS application in various professional disciplines, which suggest that an adequately trained workforce will continue to be in high demand. Thus, it is imperative that GIS educators and other stakeholders in the industry work consciously to improve the current infrastructure and human resource in order to realize the full potentials of GIS at the technical universities level in particular and in Ghana as a whole.

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Biographical statements

Prince Charles Acquah is a full time Lecturer at Kumasi Technical University, Ghana. He joined the department of civil engineering as a Lecturer in 2008 right after graduating from the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. Prior to that, Acquah worked as a teaching and research assistant at the department of Geomatic Engineering, KNUST from 2003 to 2005. He holds a Master of Philosophy (MPhil.) degree in Geomatic Engineering and a Bachelor of Science (BSc.) degree in Geodetic Engineering from KNUST. He has also worked with several Surveying and GIS related consultancy firms and also as a freelance surveyor. His research interest is in the application of geospatial technologies in environmental monitoring and management. He is a professional member of Ghana Institution of Surveyors and a graduate member of Ghana Institution of Engineers

Jack Nti Asamoah works with the civil engineering department, Kumasi Technical University as a Lecturer. He joined the department as a service personnel in 2010 and later confirmed as a Senior Technician in 2013. He became a full time Lecturer in the department in January, 2016. Jack is currently the examination officer of the department. He completed Bachelor of Science (BSc.) degree in Geomatic engineering from KNUST in 2010. He also holds a Master of Science degree in Geomatic engineering from KNUST. He is a professional member of Ghana Institution of Surveyors and a graduate member of Ghana Institution of Engineers. He has worked as a freelance surveyor and also with surveying consulting firms in cadastral, engineering and topographical surveys. His research interest is in the area of using Remote Sensing techniques and related technologies in urban planning and management.

Dennis Daniel Konadu is currently working as a Research Associate of the Whole System Energy Modelling (wholeSEM) Consortium at the Engineering Department, Cambridge University. He is currently working on land and water connections to UK energy systems and applying the Foreseer tool. Prior to joining the University of Cambridge, Dennis studied for a PhD in Environmental Science at the University of Lancaster, which he completed in 2013. His

PhD research focused on analyzing and mapping terrestrial carbon sequestration opportunities across UK landscapes. He holds a MSc. in Water Science, Policy and Management from Christ Church, Oxford University and a BSc. degree in Geodetic Engineering from Kwame Nkrumah University of Science and Technology, Ghana.