

ISSUES TO CONSIDER IN INCORPORATING ARTIFICIAL INTELLIGENCE LEARNING FOR GEOMATICS EDUCATION IN BOTSWANA

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Abstract: In the last couple of years, Artificial intelligence (AI) applications in education have received a lot of attention from both the research and the general community at large. Several international reports describe AI in education as one of the emerging fields of interest in educational technology. Despite AI technology being around for almost 30 years, it is still unclear for geomatics educators how they can take pedagogical advantage of it on a broader scale and how it can impact meaningful teaching and learning in higher education. As a result, learners miss out on opportunities to study AI-propelled smart technologies and big data-driven approaches to solve societal problems. Moreover, they are deprived of developing skills to think in terms of AI use and AI-inspired innovations to improve current processes. It is necessary to investigate meaningful ways and approaches to incorporate AI literacy and AI thinking in the school curriculum to increase the knowledge gap among learners and encourage critical thinking. Therefore, this study investigates major issues to be considered in incorporating artificial intelligence concepts in geomatics education in Botswana particularly the opportunities, challenges, ethical considerations, and overall curriculum requirements for a successful integration. Furthermore, it has designed a conceptual framework that demonstrates how artificial intelligence and data science technologies can be incorporated into geomatics education in Botswana to produce well-rounded graduates.

Keywords: Artificial Intelligence, Machine Learning, Deep Learning, Geomatics Education, Geographic Information Systems, Geospatial Technologies

1. INTRODUCTION

The Geomatics profession is a multidisciplinary field that includes several disciplines such as geodesy, surveying, remote sensing, photogrammetry, mapping, and geographic information systems (GIS). According to Klinkenberg [1], the geospatial industry can be regarded as an information technology field of practice that collects, manages, interprets, integrates, displays, and analyses data on the geographic, temporal, and spatial contexts. It is an integrated academic field that has a diverse number of applications. These include urban planning, facilities management, land surveying and management, business geographics, precision farming, automated web mapping, real estate management, environmental management, land administration,

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telecommunication, and so on. Other location-based applications such as vehicle and object tracking, and radio frequency identification (RFID) tags can be regarded as part of geospatial technologies. Therefore, graduates of geospatial technologies have an opportunity to pursue varying, exciting yet challenging careers.

Geospatial technologies particularly GIS have a strong connection with other information and communication systems such as data acquisition, data sharing, database management, networking, computer graphics, and visualization. The surveying field of geomatics also can benefit greatly from the advanced technological infusion of artificial intelligence (AI). For example, advancements in instruments such as electronic distance measurement, data collectors, 3D laser scanners, total stations, and automatic levels have improved surveying applications in many ways.

The computation of geospatial data sometimes requires the integration of data from different sources. For example, it may be necessary to analyze satellite images with drone imagery and crop health data in real or near real-time, which is not an easy task when performed manually. Such issues can be addressed by applying AI methods. In recent times, AI technologies have made significant strides in several industries including education, engineering, and the business community [2]. Education providers in high schools and tertiary levels need to recognize the competitive advantage that AI technologies can have in improving teaching and learning. Unfortunately, such knowledge and recognition are lacking in developing countries like Botswana. Therefore, these countries fail to benefit from a 'smart university' concept powered by AI which provides seamless platforms for automation, advanced information discovery, and dissemination, through machine learning (ML) and natural language processing (NLP) technologies. Moreover, such institutions miss out on opportunities to automate duties which include administration, curriculum development, assessment, and the highly sensitive issuance of official transcripts and degrees.

Several research studies have been conducted in the past to demonstrate how geospatial technologies can be integrated with AI methods in data mining, machine learning, and high-performance computing to extract insights and knowledge from spatial big data [3-7]. However, most of these studies have concentrated in Western countries with well-defined and structured education systems, with little focus on developing nations. It is necessary to investigate how AI technologies can benefit the latter to enhance their spatial analysis and decision support systems in education, which eventually can lead to more accurate, effective, efficient, and sustainable delivery of curricula and the production of well-rounded graduates.

The objective of this study is to conduct a comprehensive study on how AI technologies can seamlessly be incorporated into geomatics education in developing countries taking Botswana as a case study. It aims to explore the potential benefits and limitations of incorporating AI in geomatics education in Botswana and outline possible mitigation strategies for addressing the identified challenges. The structure of this paper is as follows: Section 1 introduces the subject matter and highlights key areas where geomatics education can benefit from AI technologies. It further emphasizes challenges and missed opportunities that universities could be taking to improve current processes and service delivery within the campus. Section 2 is a review of the literature on AI and its associated technologies on how they handle the processing of complex geospatial data and further outlines key challenges associated with AI integration and their possible mitigation measures. Section 3 provides a review of the Data and Methods currently used in the industry to incorporate AI into tertiary education in particular geomatics education to provide insights on how a comprehensive framework can be developed for a seamless integration of AI technologies in Botswana. A data collection study was conducted in Section 4, to examine the extent of understanding and use of AI technologies at the University of Botswana. Section 5 develops the conceptual framework that demonstrates how key components identified in this study, crucial for AI integration in geomatics can be incorporated such that the objectives of this research are adequately achieved. Section 6 discusses the findings of this study and highlights some anticipated benefits of the framework components. Section 7 concludes the study by summarizing the achievements of the research and outlining future research prospects.

2. LITERATURE REVIEW

The education sector could benefit from assistive technologies in AI for their critical thinking, geographic research, learning, and overall curriculum development. Platforms like chatting robots commonly known as 'chatbots' enable users to interact directly via text-to-text, and image-to-text prompts to benefit from several technologies such as deep learning, unsupervised learning, and instruction fine-tuning to better deliver learning material to students. AI has many sub-fields and advanced technologies which include [8]: a) artificial neural network – simulates the working neurons of the brain, b) natural language processing – produces systems that can understand, translate, and disseminate information in human languages, c) theorem provers – facilitate the computation of mathematical problems and the discovery of new mathematical concepts, d) knowledge-based systems – encodes expert human knowledge so that computers can reason with it, and e) case-based reasoning – simulates how humans reason based on past experiences.

Complex systems such as geographic information systems (GIS) need advanced reasoning mechanisms to deal with spatial data contained in their database management systems. Nonetheless, their utilization is limited particularly in systems where the data is dynamic and of a large volume. Hence, the need for futuristic technologies such as AI. From the several AI sub-fields discussed, GIS mainly uses artificial neural networks (ANN), designed to model the human brain and its ability to learn tasks using mathematical models. Unlike other forms of computer intelligence systems, ANN is not rule-based, it is trained to recognize and generalize relationships between a set of inputs and outputs. Such a training mechanism which involves learning from data, helps ANN solve complex problems by 'learning' from prior applications. Neural networks have previously been applied by the GIS community for many years as alternative tools for image classification and feature extraction purposes [9], while others have been used to perform land suitability analysis [10] and to model travel forecasts for transportation planning in metropolitan areas [11], to mention but a few. Most projects that utilize AI tools for GIS applications are done to improve selection approaches in spatial patterns or to assess the predictive accuracy and appropriateness of a spatial modeling technique, and lastly to gain insights into crucial spatial functions and processes via rule extraction [8].

Remote Sensing (RS) is another geospatial application area where AI techniques are used for several purposes which include image analysis, automation, land use, and land cover detection using imagery data. RS involves the collection of geospatial data without direct contact with the subject, using sensors to measure various types of energy, such as electromagnetic radiation and acoustic signals emitted, reflected, or scattered by the object of interest. As technology advances, more sensors have been developed and the amount of data collected increased to provide more insights because of improved quality. Nonetheless, such data volume increases and quality improvements require computational platforms and effective tools to handle and extract valuable information from the collected datasets. Janga, et al. [12] stress that AI tools can be used to manage large volumes of observations, modeling, and analysis, and that they have proven effective in reducing noise in the data collected. Other capabilities that AI tools can manage with remote sensing data include object detection [13] and data fusion [14].

AI algorithms, especially deep neural networks (DNNs), are changing how real-world tasks are approached. Although still new in geosciences, DNNs show promise in tasks like classification, anomaly detection, regression analysis, and space or time-dependent state predictions [15]. DNNs are increasingly used in geomatics because they learn data abstractions well. Initially seen as "black boxes", these models now need to be interpretable and explainable [16]. Another tailored computational model of AI designed to deal with complex computational geospatial data is called Deep

Learning (DL). The model is essential for dealing with complex statistics, multiple outputs, noise, and high-dimensional spaces associated with geographic data. In most cases, DL models fit observations well when conducting predictions. However, their projections may sometimes be inconsistent due to extrapolation or biases [17].

2.1. Anticipated challenges and strategies to mitigate them

According to Wilby and Esson [18], AI is viewed as a 'weapon of mass deception' and facilitates criminal activities in the digital world. The fears are exacerbated by the sudden releases of platforms such as OpenAI, ChatGPT, and Gemini whose consequences are felt mostly in education and research [18]. Unfortunately, most AI platforms do not have access to real-time information which can make them obsolete or irrelevant when seeking current information. For example, the open version of ChatGPT was trained on data only up to September 2021. As for the quality of the answers produced by these platforms, Ray [19] argues that they are dependent on a user asking unambiguous questions or clarifying queries, else they produce unsatisfactory or irrelevant responses. As a result, they have challenges in handling ambiguity which could be resolved by enhancing their ability to handle ambiguous queries which subsequently would improve their utility and user experience. According to Yeo-Teh and Tang [20], conversational AI models often struggle to maintain the context of a conversation, especially when it spans multiple turns. Such challenges can be improved by training the models to better track and manage context to present more consistent and relevant responses [20].

AI models like ChatGPT cannot provide personalized experiences for users as they fail to adapt responses based on users' preferences, interests, and conversational styles [21]. As a result, they are unable to provide enhanced user experiences to clients which needs further scrutiny and development. The emergence of AI technologies also presents threats to academic integrity through cheating and plagiarism [22]. Such concerns can be addressed by redefining university statutes and codes of conduct about the utilization of AI, and by explicitly outlining acceptable uses in teaching and assessment [18]. As lamented by George and Wooden [23], organizations venturing into this new educational paradigm need to thoroughly explore potential pitfalls which include the potential for job losses, educational quality, risks of bias, safety concerns, and privacy breaches. A study of AI models by [24], observed that they often lack common sense understanding or the ability to reason logically through a problem. Improving their reasoning capabilities through continuous work on its training data would lead to more accurate and insightful responses. Conversational AI models can be vulnerable to attacks and malicious inputs, so it is necessary to enhance their robustness when dealing with security and privacy issues to ensure their reliability [25].

Issues of the legal and regulatory framework are a concern for integrating AI with geomatics, particularly those related to liability, intellectual property, and accountability [26]. Robust legal and regulatory frameworks that focus on ethics and legal implications of AI in geomatics are imperative for a responsible deployment. To harness the full potential of geomatics with AI, interdisciplinary collaborations between policymakers, data scientists, geospatial scientists, and community leaders are important to navigate challenges.

The successful integration of AI with geomatics is reliant on a skilled workforce capable of adequately utilizing these technologies. An observation by Lang, et al. [27] is that there is a desperate need for experts well versed in both geospatial sciences and AI methodologies. Such a challenge can be mitigated by conducting interdisciplinary training programs essential to harness the full potential of the integration.

Despite the outlined challenges, this study believes that future advances in AI platforms and other language models such as ChatGPT can address these shortcomings. They have transformative potential in geomatics education and knowledge production which can sufficiently support critical thinking, synthesizing abilities, and potential for data extrapolation if used properly. By enhancing their AI literacy, geographers and educators can provide an environment for the responsible and effective use of these assistive technologies in academic practice.

3. METHODOLOGY

The evolution of AI models from their predecessors to the current state has made it an invaluable resource for advancing geomatics research and education with impacts felt across various applications including data analysis and processing, hypothesis generation, and interoperability. The geomatics community needs to give extraordinary attention to the research and development of AI models. This section explores and elaborates on the methodology of incorporating AI models into geomatics education and investigates key application areas to the different fields of the profession. Furthermore, it highlights issues to be considered and how they could be addressed in the geomatics field for a successful integration.

Practitioners particularly in academia must familiarise themselves with emerging technologies such as AI to establish means in which the existing curriculum of geomatics can be revised adequately to meet current demands. Nowadays, the geomatics profession has grown due to technological advancements from engineering and cadastral surveys and has expanded to newer areas of geospatial information

systems engineering. For example, the current status of a land surveyor is the most vulnerable profession in this digital technology era. Other than the material resources required to conduct the surveys and a human being to perform the work, its procedures are the same, despite the project scope. In the past, human beings would be required to perform repetitive tasks of surveying, often marred with errors, resource costs, and time constraints. Computers have become the best tools to perform routine and computationally intensive tasks of a surveyor's activities with precision and within a short period. Thus, it is evident that these technological advancements in surveying are inevitable.

Equipment manufacturers have fully embraced innovation and advances in technology to boost their sales by integrating mathematical and scientific aspects of surveying into their products. Such strategies enable untrained people to conduct surveys of an acceptable standard without necessarily understanding the underlying science involved. Indeed, this is a threat to the industry that key players particularly in academia, known to be innovators should lead, embrace, and establish effective ways of addressing these challenges. To modernize the geomatics curriculum to meet market needs, it is necessary to examine the legal implications, educational requirements, and professional strategies required for a successful implementation.

Currently, the curricula for traditional surveying practiced in Botswana are designed for graduates to precisely locate positions on the earth's surface. Such a profession requires physical fitness, inquisitiveness, high mental capacity, above-average skills in mathematical calculations, and an ability to work in harsh conditions where necessary. However, technological advancements have rendered most of these requirements outdated and no longer pre-conditions. Recently, several tools and techniques have been developed to acquire survey data with high precision, flexibility, and reduced cost. For example, ground surveys nowadays are performed using electronic total stations and Total Scan systems which provide direct measurements to establish spatial locations of physical objects. AI algorithms are characterized by the ability to emulate human-like intellect. As a result, they have become indispensable in geomatics because of their ability to process large amounts of geospatial datasets swiftly and accurately. This capability is crucial in geomatics applications particularly surveying which at times can be large in volume, often overwhelming traditional methods. Thus, the integration of AI into surveying facilitates the expedited processing and analysis of large datasets, which subsequently increases speed and enhances the accuracy of the surveying process [28].

For urban planning projects, it has been identified by Smith, et al. [29] that AI combined with geomatics facilitates the creation of intelligent models that are data-driven for sustainable urban development.

4. DATA COLLECTION AND SIMULATION

To examine the extent of understanding and use of AI technologies at the University of Botswana, approximately 122 engineering students were engaged at the Faculty of Engineering, in an online questionnaire via SurveyMonkey platform. They were engaged for three months, April, May, and June 2024. The findings indicate student's familiarity with the use of AI models, particularly ChatGPT, and their positive perceptions towards the use of AI tools in learning. Almost all respondents 104 (85%) reported that they were familiar with ChatGPT and more than half of them, 68 (56%) used it regularly. Regarding their feeling towards the use of AI language tools and other chatbots in education, a large proportion of students, 94% expressed their delight towards these platforms.

Even though about 73% of the respondents articulated their desire for AI tools to be integrated into the geomatics curriculum, they were unsure if the university had regulations and guidelines regarding the responsible use of AI. Questions on ethics and plagiarism concerns, received mixed feelings amongst the students, as some 47% felt the use of AI would be unethical as it might encourage laziness and negatively affect their critical thinking skills. Nonetheless, other respondents, 53% expressed their desire to have AI tools regulated such that they become integral to their academic study routines to enhance their everyday learning.

Approximately three-quarters, 73% of the respondents reported making positive use of ChatGPT as a personal tutor and a tool that enabled them to derive insights about topics, which they later expanded using relevant literature. However, an in-depth analysis of the results obtained from the study revealed negative uses of ChatGPT, about 40% of students used it to complete their assignments. Most students, 96% reported awareness of regulations on academic dishonesty principles of cheating, copying, and plagiarism and the consequences of such. A follow-up question that asked if students desired AI tools to be fully incorporated into their curricula with proper guidance from the university received a similar outcome as the previous question. In terms of privacy, accuracy, and security issues, about 65% of respondents reported that they trust AI tools and the accuracy of the information they produce.

The data collection activity described here demonstrates the need for a balanced approach that harnesses the potential of AI tools while mitigating their risks. Nonetheless, there is a bigger challenge for the academic community on how such new technologies and tools can be leveraged to improve learning and to provide a conducive safe, and secure online environment for students. Some studies in the past [30-32] have shown that applications such as ChatGPT can broaden knowledge and learning processes on diverse subjects, promote personalized learning experiences

[33], facilitate the writing process [34], and give learners the autonomy to increase their sense of control over their learning processes and further strengthen their sense of ability [35]. It is anticipated that all these benefits can improve the learning experiences of students even in developing countries like Botswana. AI tools if properly used with honesty, can increase the involvement of students in the learning process and increase their ability to critically analyze information and ask pertinent questions, thus increasing their problem-solving skills.

5. FRAMEWORK DEVELOPMENT OF AI INCORPORATION INTO GEOMATICS EDUCATION

This study has designed a conceptual framework that demonstrates how key components identified in this study (from the review of literature and the data collection study), crucial for AI integration in geomatics education can be incorporated such that the objectives of this research are adequately achieved. Geomatics education can effectively be integrated with AI technologies to equip learners with skills and knowledge necessary to excel in a data-driven geospatial environment. The consideration of the framework components does not only enhance academic learning, but also fosters innovation and adaptability in the field of geomatics.

The impact of AI on geomatics is still in its early stages, but it has the potential to be transformative. AI is already used in a variety of geomatics applications, and its use can increase in the future. There is a need for clear policies, guidelines, and frameworks to responsibly integrate AI in geomatics education. Empirical research to understand user experiences and perceptions is also necessary. The findings of this study represented in the conceptual framework outline the main issues to be addressed, anticipated benefits, and key curriculum development aspects to focus on, for a successful integration.

The framework components further provide insights that can guide future research efforts in understanding the implications of incorporating AI systems in geomatics education. By addressing the outlined challenges in the framework, AI integration in geomatics learning can be a powerful tool for advancing education, although a comprehensive collaborative effort from governments, educational institutions, and the technology industry is required to effectively address these challenges.

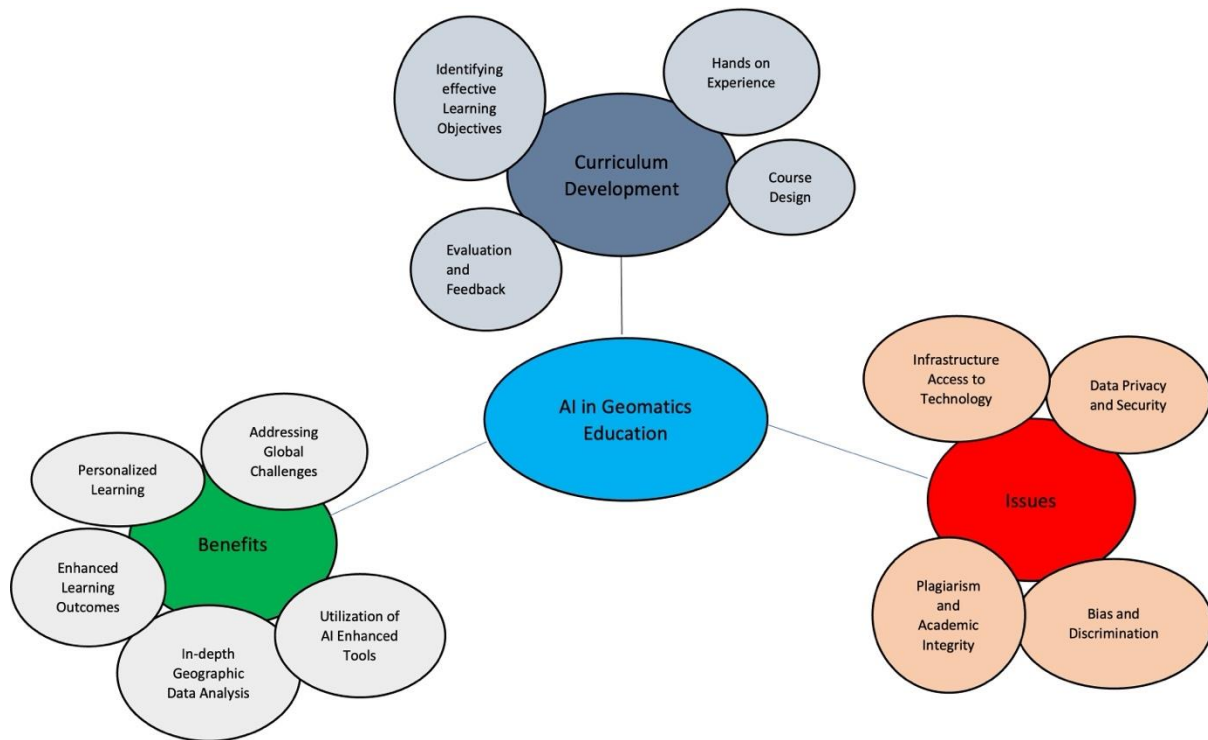


Figure 1. Conceptual framework for incorporating AI techniques into geomatics education.

6. RESULTS AND DISCUSSION

For the incorporation of AI into geomatics education to be effective, educational institutions need to confront immediate implications for academic integrity and design new policies, ethical standards, and sufficient training for staff and students. Faculties need to investigate effective ways of integrating AI ethics into curricula. Moreover, it is necessary to develop tools to detect text written by AI platforms. The automation of geospatial data analysis, propelled by machine learning algorithms, expedites the identification of intricate patterns and the extraction of meaningful geographic features [36].

As AI empowers geomatics with predictive modeling capabilities, researchers in academia should explore how professionals can simulate and analyze different scenarios, to aid in strategic decision-making. For example, the capacity of AI to handle intricate spatial relationships makes it a cut above the rest in geomatics. AI algorithms can manipulate complex patterns and relationships in geospatial data which naturally may elude traditional systems. Such capabilities further extend to the identification of trends over a period providing insights important for informed decision-making in diverse applications, such as infrastructure development and urban planning [37].

The growth of AI into geomatics holds immense potential for applications like predictive modeling, scenario analysis, and decision support systems. Predictive modeling utilizes historical data to anticipate future trends in the spatial domain, which can provide valuable foresight for professionals. Scenario analysis allows users to model and simulate various conditions to provide a strategic advantage in decision-making avenues [38]. The integration of both predictive modeling and scenario analysis by AI models empowers professionals to simulate and evaluate the potential impacts of various situations on the areas of study. In a nutshell, the integration of AI into geomatics education can usher in a transformative era in the profession. In addition, the precision, speed, and learning capabilities of AI technologies have elevated geospatial data analysis to high levels of accuracy and efficiency, hence the need for their consideration and inclusion in the curricula of geomatics education.

This study recommends strategies for integrating AI into geomatics education to create positive outcomes which include: raise awareness about disruptive change, train faculty, change teaching and assessment practices, partner with students, impart AI learning literacies, bridge the digital divide, and conduct applied research.

7. CONCLUSION

Overall, it is believed that universities incorporating AI with geomatics education can lead to the achievement of personalized learning trajectories, and enhanced accessibility to learning materials. The incorporation of AI into geomatics education facilitates complex data analysis, which enables the recognition of sophisticated spatial patterns and the extraction of meaningful objects. Therefore, more accurate results are obtained that support informed decision-making processes, which subsequently contribute to sustainable development. The dynamic nature of AI and geomatics education requires continual research and development efforts. There is a need for in-depth explorations to keep pace with evolving technologies to ensure that geomatics applications benefit from the latest improvements. These include research on novel AI algorithms and tools, improved geospatial data collection and analysis methods, and enhanced integration techniques. Therefore, future work acknowledges that current AI platforms are lacking in terms of recency as they work on latent training data. They may not be sufficient to geomatics education as up-to-date data and processing capabilities are required to produce tangible results. Therefore, future research will focus on investigating innovative ways of establishing AI techniques that can train data on a regular basis such that the profession can offer unprecedented opportunities for graduates, professionals, and the local community for sustainable and informed development practices.

DATA AVAILABILITY STATEMENT:

Data is available on request.

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DECLARATION OF INTEREST:

The authors declare no conflict of interest.

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