BODHIVRUKSHA JOURNAL OF DIVERSE DISCIPLINE (BJDD)
E-ISSN :
An Open Access, Peer-Reviewed, Multidisciplinary Scholarly Journal
Bi-monthly | Multilingual | Academic Research
Email: editor@bjddjournal.org Website: www.bjddjournal.org
DOI : 10.5281/zenodo.17186293

Building The Educational Bridge: Machine Learning As The Blueprint For South Africa's Higher Education Revolution

Dr. Stephen Chinedu Nwafor
Department of Mathematics, Natural Sciences and Technology Education, Faculty of Education, University of the Free State, Bloemfontein, SOUTH AFRICA.
Email: nwafor.SC@ufs.ac.za
ORCID: https://orcid.org/0000-0003-2220-9748

Prof. Maria Tsakeni
Department of Mathematics, Natural Sciences and Technology Education, Faculty of Education, University of the Free State, Bloemfontein, South Africa.
Email: TsakeniM@ufs.ac.za
ORCID: https://orcid.org/0000-0003-3208-1362

Abstract

University education represents the highest level of academic accomplishment. It is an important level of education in South Africa and ensures the continuous production of human capital for national development. In developed countries of the world, the adoption of cutting-edge innovations such as machine learning, AI-powered adaptive learning platforms, interactive learning videos and audio books and automated assessment has been notable. South African universities even though seem to have incorporated the use of information and communication technology (ICT) into learning; they still lag behind in the full integration of artificial intelligence (AI) and machine learning (ML). The question of how such integration can be achieved is left hanging as a lot of challenges are bound. This chapter examined the practical applications of ML in higher education, its barriers and potential benefits at South African universities and suggested how it might affect the nation's educational system.

Keywords: Machine learning, higher education, machine learning techniques, application, challenges and educational implications

Introduction

Globally, the adoption of technology in higher education has received significant advancement. This is not unrelated to the technological revolution happening all over the world and the increasing need for inclusive and adaptable education. This transformation presents opportunities and challenges for institutions worldwide, including those in South Africa. The white paper released by the Department of Education in 2004 was aimed at making South African managers, teachers, and learners in all levels of education ICT literate by 2013 and ensuring the full integration of ICT in education

BODHIVRUKSHA JOURNAL OF DIVERSE DISCIPLINE (BJDD)
E-ISSN :
An Open Access, Peer-Reviewed, Multidisciplinary Scholarly Journal
Bi-monthly | Multilingual | Academic Research
Email: editor@bjddjournal.org Website: www.bjddjournal.org

(DOE, 2004). However, the goal was not realised and was subsequently incorporated in the Department of Basic Education's action plan to 2019. These actions were done to ensure leveraging ICT to improve students' learning outcomes and to transform education. African universities according to Jagwani (2019), are moving from the traditional classroom teaching to a multifaceted learning where the traditional classrooms and online approach are utilised. This is enhanced by high investment in learning management systems (LMS) like Blackboard which uses technologies such as ML and AI to support learning. For Holmes et al. (2019) averred that the integration of ML technologies helps to facilitate effective teaching in university education.

Machine learning is an aspect of AI used in making decisions using algorithms. Machine learning, according to Okaforcha (2024), is a subfield of AI which involves creation of models and algorithms that permit digital devices grasp from data, anticipate outcomes, and take action without explicit programming. It involves the creation of self-learning algorithms that learn from the data in order to generate predictions. It is the capacity of the machines to take in real-time data and feedback and gradually improve performance. One of the most significant technical approaches to AI is machine learning, which is the foundation of many recent developments and commercial AI applications. Machine learning algorithms may evaluate patterns, forecast outcomes, and produce insights that can guide analysis processes by utilising data deluge and complex algorithms. This innovative technology can optimise research and educational outcomes, improve teaching approaches, and personalise learning experiences within universities (Hilbert et al., 2021).

ML is therefore an aspect of AI that uses algorithms to allow computers to recognise patterns and make predictions on data without precise programming. Here, statistical models are applied systematically to analyse sequences and connections existing in data to ensure that analytical decisions are made towards adapting new information over time. This is usually done using different algorithms to analyse data sets as no algorithm technique can solve every problem due to the peculiarity and complexity of each problem. According to Mahesh (2021), the type of technique depends on the following factors; specific features of the problem, optimal model form and the number of variables involved. The ML algorithms can be grouped into various categories, including deep learning; however, the four main categories of machine learning techniques, according to Mohammed et al. (2016), include supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning.

Supervised Learning: Using sample input-output pairs, supervised learning is a common machine learning task that involves learning a function that transforms input to output (Han et al., 2011; Alpaydin, 2010). This method is task driven since it infers a function using labelled training data and a set of training examples. When a set of inputs is to be used to achieve specific identified goals, this learning method is employed (Sarker et al., 2020). Among the most popular algorithms for supervised tasks are sentiment analysis, logistic regression, linear regression, decision trees, random forests (which combine classification and regression), K-Nearest Neighbour (KNN), Naïve Bayes Classifier, Support Vector Machine (SVM), and classification.

Unsupervised learning: Here, unlabelled data (where the input features do not have matching labels on the output) are provided and analysed without human interference (data-driven process) or prior knowledge (Han et al., 2011; Goodfellow et al., 2016). This is often used to identify trends, patterns and structures in the data. Examples of unsupervised learning tasks

BODHIVRUKSHA JOURNAL OF DIVERSE DISCIPLINE (BJDD)
E-ISSN :
An Open Access, Peer-Reviewed, Multidisciplinary Scholarly Journal
Bi-monthly | Multilingual | Academic Research
Email: editor@bjddjournal.org Website: www.bjddjournal.org

are autoencoders, density estimation, principal component analysis (PCA), anomaly detection, dimension reduction, feature learning, finding association rules and clustering (K-means).

Semi-supervised learning: This is the layering of supervised and unsupervised learning since it works with both labelled and unlabelled data (Han et al., 2011; Sarker et al., 2020). Semi-supervised learning's main goal is to guarantee better prediction results than using the model's labelled data alone. Semi-supervised learning can be used for fraud detection, data labelling, machine translation, and text classification.

Reinforcement learning: Reinforcement learning is an environment-driven approach where the algorithm improves efficiency by automatically evaluating the behaviour in a particular context or environment (Kaelbling et al, 1996). Rewards and penalties form the basis of the models. Robotics, manufacturing, supply chain logistics, gaming, autonomous driving, and control systems like artificial neural networks are among its applications (Sutton & Barto, 2018).

Empirical Insights into the Application of Machine Learning in Education

The use of algorithms in analysing students' performance to meet students' needs has transformed the educational sector towards enhancing personalised learning. Hence, Holmes et al. (2019) stated that the use of ML promotes guided support and provision of resources in their learning processes. This guided support must be identified earlier (Alhazmi et al., 2023; Adeyemi, 2020) to ensure the early intervention of the teachers towards improving students' overall learning outcomes. The use of ML algorithms can help in improving the academic success of students by giving insights into the best variable contributing more to it (Alyahyan & Düstegör, 2020); promoting economic and social development (Chan, 2016); providing significant insights into students' performance and learning patterns (Waheed et al., 2020; Yu et al., 2020); and analysing different academic and non-academic criteria such as previous grades, attendance records, socioeconomic background, and student behaviour (Batool et al., 2023; Ahmed et al., 2021). These studies show how relevant and applicable ML is to education because it not only provides insights but also solutions to complex problems. A study by Sedigheh et al. (2023) averred that lecturers with prior experience in technology like AI along with ML acknowledged the positive advantages of using these technologies as facilitators of education, as they help in educational content production, assessment, guided learning experiences and feedback, which improves student engagement and efficiency in grading. The utilisation of machine learning in education has helped to advance the standard of learning along with its instructional approaches. Therefore, it has transformed different teaching methods by creating solutions through personalised learning enhanced through the combination of data and adaptive technologies.

Practical Applications of Machine Learning in Higher Education

The practical applications of ML in higher education are as follows:

1. **Personalised learning:** Through the use of various adaptive learning platforms and AI powered tutoring systems which utilise ML algorithms, students' comprehension gaps and learning progress are noted. This will enable the teacher to provide personalised support, leading to improved educational outcomes.
2. **Collaborative learning:** ML algorithms can help in identifying the communication patterns of students by analysing their group contributions and interactions. This will help in facilitating effective collaboration and promote

BODHIVRUKSHA JOURNAL OF DIVERSE DISCIPLINE (BJDD)
E-ISSN :
An Open Access, Peer-Reviewed, Multidisciplinary Scholarly Journal
Bi-monthly | Multilingual | Academic Research
Email: editor@bjddjournal.org Website: www.bjddjournal.org

interpersonal skills and collaborative problem-solving skills when teachers create well-balanced groups.

3. **Enhanced Feedback:** The utilization of ML in learning aids to provide the expertise in addition to limitations of every student for the all-round development of the students. Automated grading systems are known to lessen grading bias, provide timely feedback to students, and give more time for interactions between the students and their teachers.
4. **Accurate Assessment:** Machine learning can be used to evaluate students' examinations, quizzes and assignments using the automated grading systems. This not only decreases the work of instructors and human bias but also identifies areas of improvement and adjustments.
5. **Predicting students' performance/Improved learning outcomes:** By noting the areas of strength and weaknesses through the prediction of ML, the students are encouraged to work hard to reduce those weaknesses towards improved learning outcomes. This can be by suggesting educational materials, learning methods, additional practice tests and meaningful learning tools for each student.
6. **Predictive Analytics/Decision-making for the future:** The use of predictive analytics in education helps in making academic decisions on things that will occur in the future. This will make both the educators and students take caution and precise measures towards preventing the occurrence.
7. **Prediction of students' career paths:** The use of ML can help track students' aptitudes, interests and abilities; based on it, a fair prediction can be made regarding each student's career path in which they can excel.

Barriers to Implementing Machine Learning in Higher Education

The major challenges associated with machine learning are highlighted below.

1. **Ethical considerations:** Lack of ethics in managing students' data while using ML can lead to lack of trust, legal issues and harm to the students.
2. **Expensive:** It is expensive to procure the needed equipment and programmes for the students and educators. Moreover, maintenance of such equipment is also costly.
3. **Inadequate resources:** The use of machine learning calls for more computational resources and technical experts, without which institutions may struggle to develop an effective ML solution.
4. **Low adoption rate:** Teachers and students may find it difficult to accept the use of ML due to their fixation on the traditional system.
5. The use of ML takes away personal interaction from the students. This invariably affects their capacity to make friends among their peers and teachers.
6. Machine learning in education hinders the social skills of the students, which may affect them in their future workplace.
7. Computers still find it difficult to assess essay questions because they do not have a specific technical requirement like the multiple choices.
8. Instructors still need to plan and grade essay questions using the old (conventional) ways.

BODHIVRUKSHA JOURNAL OF DIVERSE DISCIPLINE (BJDD)
E-ISSN :
An Open Access, Peer-Reviewed, Multidisciplinary Scholarly Journal
Bi-monthly | Multilingual | Academic Research
Email: editor@bjddjournal.org Website: www.bjddjournal.org

Conclusion and Implications for South African Higher Education

In this chapter we have stressed that the digitalisation of the educational system of the world using ML along with AI may serve as a catalyst for future transformation. This is because it minimises effort and learning gaps between students and teachers and offers several new chances to maintain the management of the educational system. Machine learning algorithms are set to transform higher education all over the world by maximising assessments, encouraging collaboration, predicting student performance, enhancing feedback, predicting students' career paths and eventually boosting learning outcomes. By harnessing the power of machine algorithms, higher institutions in South Africa and the world at large can carter to the diverse needs of each student towards better social and economic development. However, this cannot be achieved without taking cognisance of the challenges as highlighted in this chapter. The implication of this is to increase the awareness and understanding of ML techniques as an emerging technology for better decision-making of educational stakeholders. Also, data analysis should be made a compulsory course in all the institutions of learning to significantly transform the educational system in light of a technology-driven education. Educators and students should be empowered to close the divide between cutting-edge data analysis methods and the conventional educational research.

Policy and Practice Recommendations for South African Institutions

The following recommendations were made keeping South Africa's higher institutions in mind.

1. Institutions and government should ensure that privacy and transparency are addressed in handling student data. This will help strike a balance between human expertise and automated systems towards responsible use of data.
2. Machine learning should be used as a blended learning approach to encourage human interaction and mentorship which are pivotal in every learning process. Therefore, ML should be seen as a tool to enhance instructors' contributions in higher education.
3. Resources should be provided to ensure the successful integration of machine learning in the universities. This will help in the development and upgrading of ICT infrastructure in the universities through collaboration between government, university administrators and private stakeholders.
4. Professional workshops and capacity-building programmes should be provided by the institutions to develop more experts in machine learning. This can be achieved by partnering with intentional institutions and technology companies.

References

1. Adeyemi, O. A. (2020). Integrating artificial intelligence into STEM education in Nigerian secondary schools. *Journal of Educational Technology Research*, 15(2), 112–130.
2. Ahmed, D. M., Abdulazeez, A. M., Zeebaree, D. Q., & Ahmed, F. Y. (2021). Predicting university's students performance based on machine learning techniques. In *2021 IEEE International Conference on Automatic Control & Intelligent Systems (I2CACIS)*, pp. 276–281. IEEE.
3. Alhazmi, A. K., Alhammadi, F., Zain, A. A., Kaed, E., & Ahmed, B. (2023). AI's role and application in education: Systematic review. In: Nagar, A.K., Singh Jat, D., Mishra, D.K., Joshi, A. (eds) *Intelligent sustainable*

systems. Lecture notes in networks and systems, 578, pp. 1–14, Springer. https://doi.org/10.1007/978-981-19-7660-5_1

4. Alpaydin, E. (2010). *Introduction to machine learning*. The MIT.
5. Alyahyan, E., & Düstegör, D. (2020). Predicting academic success in higher education: Literature review and best practices. *International Journal of Educational Technology in Higher Education*, 17, 3. https://doi.org/10.1186/s41239-020-0177-7
6. Batool, S., Rashid, J., Nisar, M. W., Kim, J., Kwon, H.-Y., & Hussain, A. (2023). Educational data mining to predict students' academic performance: A survey study. *Education and Information Technologies*, 28(1), 905–971. doi: 10.1007/s10639-022-11152-y
7. Chan, R. Y. (2016). Understanding the purpose of higher education: An analysis of the economic and social benefits for completing a college degree. *Journal of Education Policy, Planning and Administration*, 6(5), 1–40.
8. Department of Education. (2004). *White paper of e-education. Transforming learning and teaching through information communication technologies*. https://www.gov.za/sites/default/files/gcis_document/201409/267341.pdf
9. Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning* (1st ed.). MIT Press.
10. Han, J., Pei, J., & Kamber, M. (2011). *Data mining: Concepts and techniques*. Elsevier.
11. Hilbert, S., Coors, S., Kraus, E. B., Bischl, B., Frei, M., Lindl, A., Wild, J., Krauss, S., Goretzko, D., & Stachl, C. (2021). Machine learning for the educational sciences. *Review of Education*, 9(3), 1–39. https://doi.org/10.1002/rev3.3310
12. Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.
13. Jagwani, A. (2019). A review of machine learning in education. *Journal of Emerging Technologies and Innovative Research*, 6(5), 385–386. https://www.jetir.org/view?paper=JETIR1905658
14. Kaelbling, L. P., Littman, M. L., & Moore, A. W. (1996). Reinforcement learning: A survey. *Journal of Artificial Intelligence Research*, 4, 237–285. https://doi.org/10.1613/jair.301
15. Mahesh, B. (2021). Machine learning algorithms — A review. *International Journal of Engineering and Advanced Technology*, 10(6), 2109–2113. https://doi.org/10.35940/ijeat.F1543.1196S621
16. Mohammed, M., Khan, M. B., & Bashier, E. B. M. (2016). *Machine learning: Algorithms and applications* (1st ed.). CRC Press. https://doi.org/10.1201/9781315371658
17. Okaforcha, C. C. (2024). Benefits and challenges of integrating machine learning for effective teaching in universities in Anambra State. *International Journal of Advanced Academic Research*, 10(11), 19–29. doi: 10.5281/zenodo.14193266
18. Sarker, I. H., Kayes, A. S. M., Badsha, S., Alqahtani, H., Watters, P., & Ng, A. (2020). Cybersecurity data science: An overview from machine learning perspective. *Journal of Big Data*, 7(41), 1–29. https://doi.org/10.1186/s40537-020-00318-5
19. Sedigheh, S. K., Sojida, S., & Mehrnaz, F. (2023). Lecturers' perceptions of using artificial intelligence in tertiary education in Uzbekistan. In *International Conference on*

Future Networks and Distributed Systems (ICFNDS '23), December 21–22, 2023, Dubai, United Arab Emirates. ACM, New York, NY, USA, pp. 570–578. https://doi.org/10.1145/3644713.3644797

20. Waheed, H., Hassan, S.-U., Aljohani, N. R., Hardman, J., Alelyani, S., & Nawaz, R. (2020). Predicting academic performance of students from VLE big data using deep learning models. *Computers in Human Behavior*, 104, 106189. https://doi.org/10.1016/j.chb.2019.106189

Yu, R., Li, Q., Fischer, C., Doroudi, S., & Xu, D. (2020). Towards accurate and fair prediction of college success: Evaluating different sources of student data. In: *Proceedings of The 13th International Conference on Educational Data Mining (EDM 2020)*, Anna N. Rafferty, Jacob Whitehill, Violetta Cavalli-Sforza, and Cristobal Romero (eds.), pp. 292–301.