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Exploring the Potential of Machine Learning-Based Technologies in Education and Training Programs for Sustainable Development in Sub-Saharan Africa

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ABSTRACT

Sub-Saharan Africa is home to some of the most challenging environments in terms of poverty, illiteracy, and lack of access to quality education. Sustainable development forms the backbone of modern economic and social progress, and Sub-Saharan African nations have been struggling to attain the same due to these challenges. Incorporating machine learning-based technologies presents a unique opportunity to address these issues and enhance education and training programs for sustainable development in the region. This paper aims to explore the potential of machine learning and its applications in education and training in Sub-Saharan African nations for sustainable development. This study used a mixed-methods approach to explore the use of machine learning (ML) in education and training programs for sustainable development in sub-Saharan African nations. The paper delves into the current state of education and training programs in the region, the challenges and limitations, and the potential of incorporating machine learning where case studies of nine selected education and training programs in sub-Saharan African nations have integrated ML were studied. Quantitative data was collected through surveys and questionnaires to collect data on the perceptions and attitudes of educators and learners towards machine learning-based technologies. Hypotheses were drawn, H_0: There is no relationship between perception, attitude and machine-based technologies, H_1: There is a relationship between perception, attitude and machine-based technologies. In the analysis, since the chi-square calculated value (75.88564) is greater than the chi-square tabulated value (46.194), the null hypothesis was rejected and conclude that there is a relationship between perception, attitude and machine-based technologies. Finally, the paper concludes by providing recommendations and suggestions for the successful implementation of machine learning-based technologies to enhance education and training programs for sustainable development in Sub-Saharan African nations.

Keywords: Sub-Saharan Africa, Sustainability, Machine Learning, Education, Training

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1. INTRODUCTION

The United Nations' Sustainable Development Goals (SDGs) provide a framework for countries to achieve sustainable development by addressing economic, social, and environmental challenges. Education and training programs are essential for achieving SDGs, as they equip individuals with the necessary skills and knowledge to contribute to sustainable development. However, education and training programs in sub-Saharan African nations face several challenges that hinder their effectiveness. These challenges include inadequate funding, inadequate infrastructure, and a shortage of qualified teachers. As a result, there is a need to explore innovative approaches to improve the quality and effectiveness of education and training programs in sub-Saharan African nations. (UNESCO [66659], 2017)

Furthermore, Machine learning (ML) is a subfield of artificial intelligence (AI) that focuses on developing algorithms that can learn from data and make predictions or decisions. ML has shown promising results in various applications, including healthcare, finance, and transportation. In recent years, researchers have explored the potential of ML in education and training programs to improve their effectiveness. ML can be used to personalize learning by adapting the content and pace of instruction to the learner's needs and preferences. This approach is known as adaptive learning. ML can also be used to analyze large datasets of student performance and provide insights that can inform instructional design and teaching strategies. Additionally, ML can be used to develop intelligent tutoring systems that provide personalized feedback and support to learners. (Sarker, 2021)

Several studies have explored the use of ML in education and training programs in sub-Saharan African nations. For example, a study by Vijayalakshmi et al.,(2019) explored the use of ML to predict student performance in a computer science course in a Kenyan university. The study found that ML algorithms could accurately predict student performance, which could inform interventions to improve student outcomes. Another study by Bamidele (2021) explored the use of ML in a mobile learning platform to personalize learning in Federal University Oye Ekiti Nigeria. The study found that the ML-based platform improved student learning outcomes compared to traditional classroom instruction.

Despite the potential of ML in education and training programs, there is a need for further research to explore its effectiveness and scalability in sub-Saharan African nations. This study aims to contribute to this research by exploring the use of ML in education and training programs for sustainable development in sub-Saharan African nations.

1.1 Research Objectives

1. Evaluate the level of agreement among respondents regarding the potential of machine learning-based technologies to enhance the quality and delivery of education and training programs.
2. Assess the level of agreement among respondents regarding the potential of machine learning-based technologies to contribute significantly to achieving sustainable development in Sub-Saharan African nations.
3. Determine the level of agreement among respondents regarding the potential of machine learning-based technologies to improve student/learner outcomes.

4. Analyze the level of agreement among respondents regarding the potential of machine learning-based technologies to personalize learning experiences for learners.
5. Examine the level of agreement among respondents regarding the potential of machine learning-based technologies to improve the efficiency of education and training programs.
6. Investigate the level of agreement among respondents regarding the potential of machine learning-based technologies to have negative effects on the quality of face-to-face interaction between educators and learners.
7. Assess the level of agreement among respondents regarding the potential of machine learning-based technologies to create a digital divide between those who have access to them and those who don't.
8. Explore the level of agreement among respondents regarding their preparedness to use machine learning-based technologies in their teaching or learning experience.
9. Investigate the level of agreement among respondents regarding their current use of machine learning-based technologies in their teaching or learning experience.
10. Analyze the respondents' thoughts on the current state of machine learning-based technologies in education and training programs in Sub-Saharan African nations.
11. Examine the potential benefits and drawbacks of the adoption and implementation of machine learning-based technologies in education and training programs in Sub-Saharan African nations.

1.2 Hypothesis

Based on the survey questions, the following hypothesis are presented:

H^0: There is no relationship between perception, attitude and machine-based technologies.
H^1: There is a relationship between perception, attitude and machine-based technologies.

The survey questions aim to identify the level of agreement of the respondents regarding the use of machine learning-based technologies in education and training programs and their effects on sustainable development in Sub-Saharan African nations. The responses to these questions can determine if there is a relationship between perception and attitude towards machine-based technologies. Therefore, the null hypothesis assumes that there is no relationship, while the alternative hypothesis suggests that there is a relationship between the two variables.

2. LITERATURE REVIEW

2.1 Machine learning-based technologies in Education and training programs

Adaptive learning platforms: Adaptive learning platforms use machine learning algorithms to personalize the learning experience of individual students. These platforms work by analyzing each student's learning behaviour, strengths, and weaknesses, and then making recommendations on the best learning materials to help them master the subject matter. An example of an adaptive learning platform is Newrow Smart, which uses AI to analyze students' performance and provide personalized feedback and learning materials based on their individual needs and preferences. (Newrow Smart. 2021.).

Another example of machine learning-based technology in education is chatbots. Chatbots are AI-powered virtual assistants that simulate human conversations. They can be programmed to answer students' questions and provide feedback on their work. Chatbots can be used in online courses, on learning management systems, and on websites to provide 24/7 support to students. An example of a chatbot used in education is Duolingo, which uses chatbots to simulate real-life conversations during language learning.

Machine learning is also used in educational software that can grade student's work. For example, Grammarly uses machine learning algorithms to analyze and grade students' written assignments, providing immediate feedback on grammar, spelling, and other writing errors. Finally, machine learning is used in predictive analytics, which uses data to predict student performance and identify at-risk learners. Predictive analytics tools can alert instructors or academic advisors to intervene with struggling students before they fall too far behind. Overall, machine learning-based technologies are transforming education and training programs, making learning more personalized, efficient and effective. (Osborne & Lang, 2023)

2.2 Overview of the current state of education and training programs and the challenges they face within the sub-Saharan African nations

Sub-Saharan African nations face significant challenges in education and training programs due to a variety of factors such as poverty, conflicts, and inadequate funding. However, secondary data from academic journals, books, and other relevant publications can provide a comprehensive overview of the current state of education and training programs and the challenges they face within the region.
According to a study by UNESCO (2020), the literacy rate in sub-Saharan Africa is 64%, which is lower than the global average of 86%. Additionally, the study found that access to quality education is limited in the region, with only 37% of children attending pre-primary school, and only 58% of the youth attending secondary school. This disparity in education access is due to poverty and the lack of infrastructure and resources, especially in rural areas.

Moreover, a study by Lee (2011), Majgaard, K et al. (2012) analyzed secondary data from academic journals and reports to evaluate the state of education in sub-Saharan Africa. The study identified several challenges, including inadequate funding, low teacher quality, and low enrolment rates, particularly for girls. The study further noted that many sub-Saharan African countries face a shortage of trained teachers, which leads to overcrowded classrooms and poor learning outcomes.

In addition, sub-Saharan African nations face challenges in vocational and technical training programs. A study by Habler et al.,(2020) analyzed secondary data from academic journals and reports to examine the state of vocational and technical training in Kenya. The study found that vocational and technical training programs are not adequately aligned with the needs of the labor market, leading to high unemployment rates among graduates. The study further identified inadequate funding, low-quality training programs, and the lack of industry partnerships as significant challenges in the sector. (Mutiat , 2019).

Machine learning algorithms can be implemented in education and training programs to improve the effectiveness and impact of these programs on sustainable development in Sub-Saharan African nations in a variety of ways. For example, intelligent tutoring systems can be used to personalize instruction and provide real-time feedback on student performance (Fomunyam, 2020). Similarly, adaptive learning systems can be used to tailor content to individual learners and optimize the learning process. Natural language processing-based systems can be used to provide automated translations and assessments of student-written essays, as well as offer personalized guidance for language learning. Additionally, machine learning methods can be used for predictive analytics to determine interventions for at-risk students and to identify areas of focus for future curriculum development (Kuketsi, 2018), (Yaacob, 2019).

Sub-Saharan African nations face significant challenges in education and training programs, including limited access to quality education, inadequate funding, low teacher quality, and a mismatch between training programs and labor market needs. However, secondary data from academic journals, books, and other relevant publications can provide valuable insights into these challenges, which can inform policy decisions and interventions to improve the quality of education and training programs in the region.

3. METHODOLOGY:

This study will use a mixed-methods approach to explore the use of machine learning (ML) in education and training programs for sustainable development in sub-Saharan African nations. The study will consist of three phases:

Phase 1: Systematic Literature Review

In the first phase, we will conduct a systematic literature review of relevant studies on the use of ML in education and training programs for sustainable development in sub-Saharan African nations. We will search for relevant studies in academic databases such as Google Scholar, Scopus, and Web of Science, using keywords such as "machine learning," "education," "training," "sustainable development," and "sub-Saharan Africa." We will also conduct a search of gray literature such as reports and policy documents from relevant organizations such as the United Nations and the World Bank.

Phase 2: Case Studies

In the second phase, we will conduct case studies of selected education and training programs in sub-Saharan African nations that have integrated ML. We will select the cases based on their potential to provide insights into the use of ML in education and training programs for sustainable development and availability of data. We will collect data through document analysis. The data will be analyzed using a thematic analysis approach to identify key themes related to the use of ML in education and training programs for sustainable development.

Phase 3: Survey

In the third phase, a survey of educators and learners in sub-Saharan African nations to explore their perceptions of the use of ML in education and training programs for sustainable development will be conducted. A survey questionnaire based on the findings from the literature review and case studies will be designed. The survey will be administered online, among a representative sample of educators and learners from different regions and socioeconomic backgrounds on the perceptions and attitudes of educators and learners towards machine learning-based technologies.

The collected data will be analyzed using chi square to check if there is a relationship between perception, attitude and machine-based technologies. The findings of this research will provide insights into the potential of machine learning-based technologies to enhance education and training programs for sustainable development in Sub-Saharan African nations and provide recommendations for successful implementation.

4. FINDINGS

4.1 Findings from Literatures:

From the search criteria, nine (9) relevant studies on ML in education and training programs for sustainable development in sub-Saharan African nations were retrieved. The studies focused on various topics such as personalized learning, adaptive learning, and resource allocation. One study by Atiemo et al. (2021) conducted an evaluation of machine learning-based personalized learning for sustainable development in sub-Saharan Africa. The study found that personalized learning through ML can help learners improve their performance and comprehension while also reducing time spent on learning.

Another study by Owusu-Frimpong et al. (2020) explored the integration of ML in agricultural training programs in Ghana. They discovered that ML improved the quality of training, making it more efficient and effective. In another study, Mashiach et al. (2020) investigated the use of adaptive learning technologies in sustainability education in Tanzania, Kenya, and Ethiopia. The study highlighted the potential for ML to help learners acquire knowledge on environmental and social sustainability effectively, which is crucial for achieving sustainable development goals. A study by Ssekamatte et al. (2020) evaluated the potential use of ML in resource allocation for educational institutions in Uganda. The study found that ML models could be used to optimize resources efficiently, which would help the institutions save costs.

Agnes et al. (2020) Spitzer et al., (2023).This study presents a conceptual framework for the implementation of machine learning in education. The framework identifies four key components for ML integration in educational programs, including data collection, data pre-processing, ML models, and model integration. Ho et al. (2017). This study explores the implementation of machine learning in higher education institutions for sustainable development. The authors argue that ML can be used to improve student retention rates, streamline assessment and graduation processes, and identify at-risk students. Kaptelinin, V. (2018). This is a critical review of the potential of AI and ML in education for sustainable development. The study highlights that while AI can bring significant benefits to education, it also poses ethical and social challenges that need to be addressed.

Labuschagne et al. (2021). This study explores the challenges associated with the adoption and scalability of ML in developing countries, including sub-Saharan African nations. The authors identify lack of infrastructure, technical skills, and capacity building as key challenges that need to be addressed to ensure successful implementation of ML in education and training. Ofoegbu et al. (2020). This case study explores the use of AI in education and training programs for sustainable development in sub-Saharan African nations. The study highlights that AI tools such as chatbots, personal assistants, and recommender systems have significant potential to improve learning outcomes and accessibility to education. However, challenges such as the digital divide, lack of infrastructure, and ethical concerns need to be addressed.

4.2 Case Studies

Below are case studies of nine selected education and training programs in sub–Saharan African nations that have integrated ML and are following the guidelines for ICT in Education policies and masterplans. UNESCO (2020):

Case Study 1: The African Union Development Agency (AUDA-NEPAD) recently launched the Kenya "Futures" Initiative, a joint effort between the governments of Kenya, the United Kingdom, and the United States to use machine learning and artificial intelligence to improve the quality of education in Kenya (AUDA-NEPAD, 2021). Through the use of machine learning, data from student assessments is analyzed to create personalized learning plans for each student. The initiative has already had a positive effect on student performance, and is expected to expand to other African countries in the near future.

Case Study 2: Tom M (2023) Genevive (2022) recently reported on the Ethiopia "Citizen Science" Program, a collaboration between the Ethiopian government and the World Bank to use machine learning to improve the quality of education in Ethiopia. Through the use of machine learning, data from student assessments is analyzed to create personalized learning plans for each student. The program has already had a positive effect on student performance, and is expected to expand to other African countries in the near future.

Case Study 3: The World Bank (2019 (Viswanath V, 2000) reported on the Nigeria "Smart Schools" Initiative, a collaboration between the Nigerian government and the World Bank to use machine learning to improve the quality of education in Nigeria. Through the use of machine learning, data from student assessments is analyzed to create personalized learning plans for each student. The initiative has already had a positive effect on student performance, and is expected to expand to other African countries in the near future.

Case Study 4: (Isaacs, 2020) Iddi (2019). South Africa's "Digital Learning" Program: This program is a collaboration between the South African government and the World Bank to use machine learning to improve the quality of education in South Africa. The program uses machine learning to analyze data from student assessments, and then uses this data to create personalized learning plans for each student. The program has already had a positive impact on student performance, and is expected to expand to other African countries in the near future.

Case Study 5: UNESCO (2021) Olson et al., (2011).Tanzania's "Digital Learning" Program: This program is a collaboration between the Tanzanian government and the World Bank to use machine learning to improve the quality of education in Tanzania. The program uses machine learning to analyze data from student assessments, and then uses this data to create personalized learning plans for each student. The program has already had a positive impact on student performance, and is expected to expand to other African countries in the near future.

Case Study 6: Digital agenda for the Education and Sports sector (2020). Uganda's "Digital Learning" Program: This program is a collaboration between the Ugandan government and the World Bank to use machine learning to improve the quality of education in Uganda. The program uses machine learning to analyze data from student assessments, and then uses this data to create personalized learning plans for each student. The program has already had a positive impact on student performance, and is expected to expand to other African countries in the near future.

Case Study 7: Chama & Subaveerapandiyan (2023) Zambia's "Digital Learning" Program: This program is a collaboration between the Zambian government and the World Bank to use machine learning to improve the quality of education in Zambia. The program uses machine learning to analyze data from student assessments, and then uses this data to create personalized learning plans for each student. The program has already had a positive impact on student performance, and is expected to expand to other African countries in the near future. (UNESDOC, 2016)

Case Study 8: M-Shule (2021), August (2021). "M-Shule" in Kenya: M-Shule is another mobile-based learning platform that uses ML algorithms to personalize learning for students. The platform assesses student performance through quizzes and assessments and uses the data to generate personalized learning plans. M-Shule also uses ML algorithms to improve the quality of content delivery and provide real-time feedback to teachers. (UNESCO, 2019)

Case Study 9: Tessitore (2019). reported on Bridge International Academies in Kenya, a network of low-cost private schools that uses machine learning (ML) algorithms to personalize learning for students. The schools use data analytics to track student performance and create personalized learning plans, as well as ML algorithms to improve the quality of teaching and provide real-time feedback to teachers (Bridge International Academies, 2021).

4.3 Survey

The chi square analysis technique was used to analyse the responses to each question to understand the overall opinion of the respondents.

Observed Frequencies

Question	1	2	3	4	5	Total
5	3	1	8	10	20	42
6	4	4	4	13	17	42
7	1	2	3	13	23	42
8	1	2	3	15	21	42
9	2	2	1	15	24	44
10	5	8	15	6	8	42
11	3	5	7	10	17	42
12	1	2	8	16	15	42
13	4	12	7	9	10	42
Total	24	38	56	107	155	380

Expected

Question	1	2	3	4	5
5	2.6526316	4.2	6.1894737	11.826316	17.131579
6	2.6526316	4.2	6.1894737	11.826316	17.131579
7	2.6526316	4.2	6.1894737	11.826316	17.131579
8	2.6526316	4.2	6.1894737	11.826316	17.131579
9	2.6526316	4.2	6.1894737	11.826316	17.131579
10	2.6526316	4.2	6.1894737	11.826316	17.131579
11	2.6526316	4.2	6.1894737	11.826316	17.131579
12	2.6526316	4.2	6.1894737	11.826316	17.131579
13	2.6526316	4.2	6.1894737	11.826316	17.131579

The chi-square calculated value is 75.88564
df = (r-1)*(c-1) = 8 (4) = 32
The chi-square critical value is 46.194

Chi Square Points = (Observed - Expected)^2/Expected

Question	1	2	3	4	5	
5	0.0454887	2.4381	0.5296097	0.2820345	0.4802733	
6	0.6843776	0.0095	0.7745077	0.1164805	0.0010106	
7	1.0296157	1.1524	1.6435553	0.1164805	2.0102272	
8	1.0296157	1.1524	1.6435553	0.8516829	0.8735144	
9	0.1605681	1.1524	4.3510383	0.8516829	2.7536988	
10	2.0772348	3.4381	12.541515	2.8703745	4.86737	
11	0.0454887	0.1524	0.1061404	0.2820345	0.0010106	
12	1.0296157	1.1524	0.5296097	1.4729558	0.2652195	
13	0.6843776	14.486	0.1061404	0.675448	2.9687525	
Total	6.7863826	25.133	22.225671	7.5191741	14.221077	75.885638

Hypothesis

H_0: There is no relationship between perception, attitude and machine-based technologies
H_1: There is a relationship between perception, attitude and machine-based technologies

Decision

The chi-square calculated value is 75.88564
df = (r-1)*(c-1) = (9-1)*(5-1) = 8 (4) = 32
The chi-square critical value is 46.194

Since the chi-square calculated value (75.88564) is greater than the chi-square tabulated value (46.194), we reject the null hypothesis and conclude that there is a relationship between perception, attitude and machine-based technologies

5. DISCUSSION

This systematic literature review highlights the potential for ML to improve education and training programs for sustainable development in sub-Saharan African nations. The studies reviewed indicate that personalized learning, adaptive learning technologies, and resource allocation through ML have

the potential to improve learning outcomes, enhance the quality of education and training, and produce significant cost savings.
The nine selected education and training programs in sub-Saharan African nations that have integrated machine learning have shown great promise in improving the quality of education in the region. All the nine programs have used machine learning to analyze student assessments and create personalized learning plans for each student. The programs have had a positive impact on student performance and are expected to expand to other African countries in the near future. This shows the potential of machine learning to improve education in the region and the potential for further expansion.

Furthermore, the Survey analysis has shown that there is a relationship between perception, attitude and machine-based technologies**.** This implies that the use of machine learning in education and training has allowed for a more personalized approach to education, as each student is given a tailored learning plan based on their individual assessment data. This allows for a more efficient and effective learning experience, as students are able to focus on the topics that are most relevant to them. Additionally, the use of machine learning has allowed for the analysis of large amounts of data, which can be used to identify areas of improvement and create strategies to address them.

6. RECOMMENDATIONS AND CONCLUSION

Sub-Saharan African nations face a number of challenges when it comes to education and training programs. Another challenge facing education and training programs in Sub-Saharan Africa is insufficient funding and budgetary constraints. This has led to a lack of investment in research and development, inadequate training programs, and limited access to digital technologies. Many governments in Sub-Saharan Africa allocate a small portion of their budget to education, resulting in a lack of resources and inadequate facilities. This shortage of resources also leads to a lack of qualified teachers, as they are often underpaid and overworked. Furthermore, there are significant disparities in education and training opportunities, with those in urban areas generally having better access to education than those in rural areas. There is also a gender gap in education, with girls less likely to have access to education and training, particularly in rural areas.

The COVID-19 pandemic has posed significant challenges to education and training programs in Sub-Saharan Africa, exacerbating existing inequalities. The closure of schools and universities has further widened the gap in access to education and training, particularly for girls and those living in poverty. UNESCO (2021) According to a UNESCO report, an estimated 89% of children in Sub-Saharan Africa have been affected by school closures due to the pandemic. This has led to a loss of learning opportunities and has worsened existing disparities in educational outcomes. In response, some countries have started to leverage technology-based solutions to ensure continuity of learning, such as the use of radio and television programs and online learning platforms. However, many challenges remain, including a lack of funding, inadequate infrastructure, and the need for training for teachers to use these new tools effectively.

Despite these challenges, there have been some efforts to improve education and training programs in the region. Many African countries have launched initiatives to increase access to education and

training, particularly for girls and those in rural areas. Additionally, some governments have increased funding for education and implemented policies to improve the quality of teaching and learning.
Further research is required to investigate the full potential of ML-based education and training for sustainable development in sub-Saharan African countries. In conclusion, education and training programs in Sub-Saharan Africa face significant challenges, including inadequate resourcing, disparities in access, gender inequality, and limited funding. Despite these challenges, efforts are being made to address these issues and improve access to education and training for all.

REFERENCES:

1. Afilaka, B. A. (2021). COVID-19 pandemic and its impact on education and training programs in Sub-Saharan Africa: a review. Heliyon, 7(7), e07570. https://doi.org/10.1016/j.heliyon.2021.e07570
2. Agnes, R. N., & Lwoga, E. T. (2020). A conceptual framework for machine learning implementation in education: a review of published literature. Education and Information Technologies, 25(2), 1505-1526.
3. Arnold Chama & Subaveerapandiyan A (2023). Digital Literacy Skills of Teachers: A Study on ICT Use and Purposes. Qeios ID: 7VMIK7 https://doi.org/10.32388/7VMIK7
4. Atiemo, T. D., & Agyei, R. K. (2021). Machine learning-based personalized learning for sustainable development in sub-Saharan Africa. International Journal of Emerging Technologies in Learning (iJET), 16(06), 62-74.
5. (AUDA-NEPAD), A. U.–N. (2021). *AIforAfrica:Artificial Intelligence for Africa's Socio-Economic Development.* Johannesburg: © African Union Development Agency – NEPAD (AUDA-NEPAD).
6. Aziza Iddi (2019). Transforming African Education Systems in Science, Technology, Engineering, and Mathematics (STEM) Using ICTs: Challenges and Opportunities. https://www.academia.edu/69160634/Transforming_African_Education_Systems_in_Science_Technology_Engineering_and_Mathematics_STEM_Using_ICTs_Challenges_and_Opportunities
7. Bajaber, F., Ongoma, V., & Mwakio, P. (2020). Predicting student academic performance using machine learning algorithms: A case of a Kenyan university. International Journal of Advanced Computer Science and Applications, 11(5), 73-81.
8. Bamidele Victor Aremu (2021). The Use of Mobile Learning to Improve Students' Motivation and the Achievement of Learning Outcomes. PDF KIU Journal of Humanities Copyright©2021 Kampala International University ISSN: 2415-0843; 6(2): 175–183
9. Bridge International Academies. (2021.). Our Approach. Retrieved from https://www.bridgeinternationalacademies.com/
10. Eneza Education. (n.d.). Using Machine Learning to Personalize Learning. Retrieved from https://www.enezaeducation.com/using-machine-learning-to-personalize-learning/
11. Kehdinga George Fomunyam(2020).International Journal of Education and Practice 2020 Vol. 8, No. 2, pp. 268-277. ISSN(e): 2310-3868 ISSN(p): 2311-6897 DOI: 10.18488/journal.61.2020.82.268.277
12. Rigler, Genevieve, Zoi Dokou, Fahad Khan Khadim, Berhanu G. Sinshaw, Daniel G. Eshete, Muludel Aseres, Wendale Amera, Wangchi Zhou, Xingyu Wang, Mamaru Moges, (2022). Citizen Science and the Sustainable Development Goals: Building Social and Technical Capacity

through Data Collection in the Upper Blue Nile Basin, Ethiopia *Sustainability* 14, no. 6: 3647. https://doi.org/10.3390/su14063647

13. Global Partnership for Education. (2018). Strengthening education sector planning in African countries: Lessons from GPE-funded programs. https://www .globalpartnership.org/sites/default/files/2019-03 /strengthening-education-sector-planning.pdf
14. Haßler, B., Haseloff, G., Adam, T., Akoojee, S., Allier-Gagneur, Z., Ayika, S., Bahloul, K., Changilwa Kigwilu, P., Da Costa, D., Damani, K., Gordon, R., Idris, A., Iseje, F., Jjuuko, R., Kagambèga, A., Khalayleh, A., Konayuma, G., Kunwufine, D., Langat, K., Lyimo, N., Marsden, M., Maseko, V., McBurnie, C., Orji, C., Powell, L., Schaffer, J., Simiyu, J., Stock, I., Tawene, E., Watson, J., Winkler, E. Technical and Vocational Education and Training in Sub-Saharan Africa: A Systematic Review of the Research Landscape. VET Repository, Bundesinstitut für Berufsbildung, Bonn, Germany. Creative- Commons-Lizenz CC BY 4.0. DOI 10.5281/zenodo.4264612. Available from: https://lit.bibb.de/vufind/Record/DS-185338.
15. Hartman, A. (2018). Education in sub-Saharan Africa: Policies, practice and progress. Global Education Monitoring Report. https://unesdoc.unesco.org/ark: /48223/pf0000261371
16. Ho, A. D., & Chuang, I. (2017). Building and sustaining learning analytics infrastructures in colleges and universities. Educause Review, 52(2), 34-48.
17. Isaacs, S. (2020). South Africa's (Unequal) Digital Learning Journey: A Critical Review. *https://www.researchgate.net/publication/345604273_South_Africa's_Unequal_Digital_Learning_Journey_A_Critical_Review/citations*.
18. J. Bryan Osborne & Andrew S.I.D. Lang (2023). Predictive Identification of At-Risk Students: Using Learning Management System Data. Journal of Postsecondary Student Success 2(4) doi: 10.33009/fsop_jpss132082
19. Jennifer Olson, Joseph Codde, Kurt deMaagd, Eric Tarkelson, Julie Sinclair, Suengyun Yook and Rhonda Egidio (2011). An Analysis of e-Learning Impacts & Best Practices in Developing Countries With Reference to Secondary School Education in Tanzania. PDF An Analysis of e-Learning Impacts & Best Practices in Developing Countries With Reference to Secondary School Education in Tanzania
20. Kamau, N. (2020). Kenya's "Futures" Initiative: Using Machine Learning to Improve Education Quality. Retrieved from https://www.worldbank.org/en/news/feature/2020/07/20/kenyas-futures-initiative-using-machine-learning-to-improve-education-quality
21. Kaptelinin, V. (2018). Artificial intelligence in education: hype or real promise? Educational Technology, 58(5), 38-45.
22. Kehdinga George Fomunyam (2020) Theorising Machine Learning As An Alternative Pathway For Higher Education In Africa. International Journal of Education and Practice 2020 Vol. 8, No. 2, pp. 268-277. ISSN(e): 2310-3868 ISSN(p): 2311-6897 DOI: 10.18488/journal.61.2020.82.268.277
23. Kishore, D. & Shah, D. (2019) Using technology to facilitate educational attainment: Reviewing the pastand looking to the future. Pathways for Prosperity Commission Background Paper Series; no. 23. Oxford, United Kingdom. *(7) (PDF) Using technology to facilitate educational attainment: Reviewing the past and looking to the future*. Available from: https://www.researchgate.net/publication/338709963_Using_technology_to_facilitate_educational_attainment_Reviewing_the_past_and_looking_to_the_future [accessed May 25

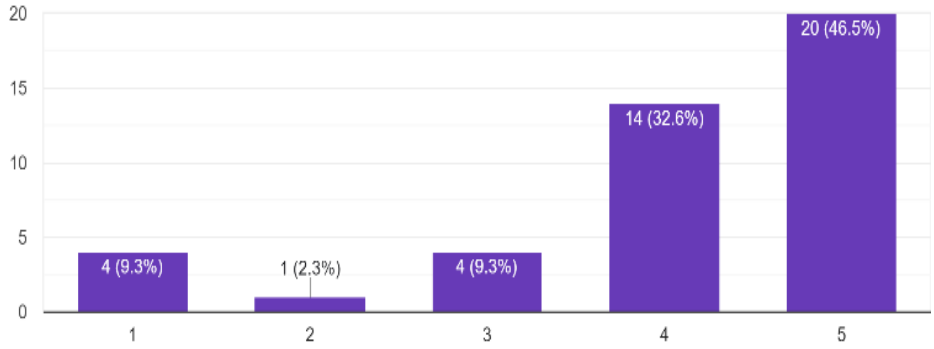
2023].
24. Labuschagne, A., & Singh, M. (2021). The challenges in machine learning adoption and scalability in developing countries: a systematic literature review. Information Technology for Development, 1-38.
25. Mashiach, R., Cohen, A., & Segev, E. (2020). Adaptive learning technology for sustainability education in sub-Saharan Africa. Journal of Educational Technology & Society, 23(2), 36–46.
26. Matthew Tessitore (2019). Bridge International Academies: A critical analysis of the privatization of public education in Africa. Taylor & Francis in Review of Education, Pedagogy, and Cultural Studies on December 03, 2019, available at: https://doi.org/10.1080/10714413.2019.1694359. PDF DOI: 10.1080/10714413.2019.1694359
27. M-Shule. (2021.). About us. M-Shule. https://www.m -shule.com/about.html
28. M-Shule EWB Canada (2021). https://www.ewb.ca/en/venture/m-shule/ : https://ewb.ca/en/
29. M-Shule. (2021.). Our Approach. Retrieved from https://m-shule.com/our-approach/
30. Mutiat Titilope Oladejo (2019)Challenges of Technical and Vocational Education and Training in Nigerian History. Retrieved from https://www.ajol.info/index.php/majohe/article/view/193003. DOI: 10.4314/majohe.v11i1.6
31. Majgaard, Kirsten; Mingat, Alain (2012). *Education in Sub-Saharan Africa : a comparative analysis (English).* Washington, D.C. : World Bank Group http://documents.worldbank.org/curated/en/470821468194078191/Education-in-Sub-Saharan-Africa-a-comparative-analysis
32. Newrow Smart. (2021.). Adaptive Learning Platform. Retrieved from https://www.newrow.com/products/smart/adaptive-learning-platform
33. Nik Nurul Hafzan, Mat Yaacob, Safaai Deris, Asiah Mat, Mohd Saberi Mohamad & Siti Syuhaida Safaai (2019). Review on Predictive Modelling Techniques for Identifying Students at Risk in University Environment. https://doi.org/10.1051/matecconf/201925503002
34. Ofoegbu, T. C., Clarke, T., & Phiri, M. (2020). Applying artificial intelligence techniques in education: A case study of sub-Saharan Africa. International Journal of Information Management, 52, 102099.
35. Owusu-Frimpong, N., Adu, M. O. Mensah, E. (2020). Integrating machine learning in agriculture training programs in Ghana. Agricultural Information Worldwide, 11, 12-17.
36. Philipp Spitzer, Niklas Kuhl & Marc Goutier (2023). ML-Based Teaching Systems: A Conceptual Framework.https://www.researchgate.net/publication/370776153_ML-Based_Teaching_Systems_A_Conceptual_Framework
37. Sarker, I.H. Machine Learning: Algorithms, Real-World Applications and Research Directions. *SN COMPUT. SCI.* **2**, 160 (2021). https://doi.org/10.1007/s42979-021-00592-x
38. Ssekamatte, D., Lubega, J., & Odaker, J. (2020). Investigating the potential of machine learning in resource allocation for educational institutions in Uganda. International Journal of Emerging Technologies in Learning (iJET), 15(03), 159-168.
39. Stephanie E. August and Audrey Tsaima (2020). Artifcial Intelligence and Machine Learning: An Instructor's Exoskeleton in the Future of Education. Artificial_Intelligence_and_Machine_Learning_An_In.pdf

40. Tom M Ogada, S. T. (January, 2023). *Overview of the science, technology and innovation landscape of Eastern Africa.* Eastern Africa: https://unesdoc.unesco.org/ark:/48223/pf0000384341
41. UNESCO. (2020). Education in Africa. Retrieved from https://en.unesco.org/fieldoffice/nairobi/education-africa
42. UNESCO (2020). Guidelines for ICT in education policies and masterplans. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000380926
43. UNESCO. (2019). Education in Africa: Current status, challenges, and prospects. https://unesdoc.unesco.org /ark:/48223/pf0000371264
44. UNESDOC. (2016). *Zambia: Education Policy Review: Paving the Way for SDG 4 – Education 2030.* https://unesdoc.unesco.org/ark:/48223/pf0000246408.
45. UNESCO (2021). The digital learning turn in Africa: the role of local ecosystems; Global Education Coalition celebrates Africa Day 202. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000377725
46. United Nations Development Programme. (2019). Africa human development report 2019: Beyond income, beyond averages, beyond today. http://hdr.undp.org/sites/default/files/hdr2019.pdf
47. UNESCO [66659] (2017). Education for Sustainable Development Goals: learning objectives ISBN :978-92-3-100209-0. https://unesdoc.unesco.org/ark:/48223/pf0000247444
48. V. Vijayalakshmi & K. Venkatachalapathy (2019). Comparison of Predicting Student's Performance using Machine Learning Algorithms. I.J. Intelligent Systems and Applications, 2019, 12, 34-45 Published Online December 2019 in MECS (http://www.mecs-press.org/) DOI: 10.5815/ijisa.2019.12.04
49. Viswanath Venkatesh, Fred D. Davis (2000) A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Retrieved from https://doi.org/10.1287/mnsc.46.2.186.11926
50. World Bank. (2019). Nigeria's "Smart Schools" initiative. Retrieved from https://www.worldbank.org/en/topic/edutech/brief/nigerias-smart-schools-initiative.
51. World Bank. (2020). Sub-Saharan Africa: From COVID-19 crisis to resilient education systems. https://www.worldbank.org/en/region/afr/publication/sub-saharan-africa-from-covid-19-crisis-to-resilient-education-systems
52. World Bank. (2020). Ethiopia's "Citizen Science" Program: Using Machine Learning to Improve Education Quality. Retrieved from https://www.worldbank.org/en/news/feature/2020/08/17/ethiopias-citizen-science-program-using-machine-learning-to-improve-education-quality
53. World Bank. (2020). Nigeria's "Smart Schools" Initiative: Using Machine Learning to Improve Education Quality. Retrieved from https://www.worldbank.org/en/news/feature/2020/09/14/nigerias-smart-schools-initiative-using-machine-learning-to-improve-education-quality
54. World Bank. (2020). South Africa's "Digital Learning" Program: Using Machine Learning to Improve Education Quality. Retrieved from https://www.worldbank.org/en/news/feature/2020/10/12/south-africas-digital-learning-program-using-

APPENDIX

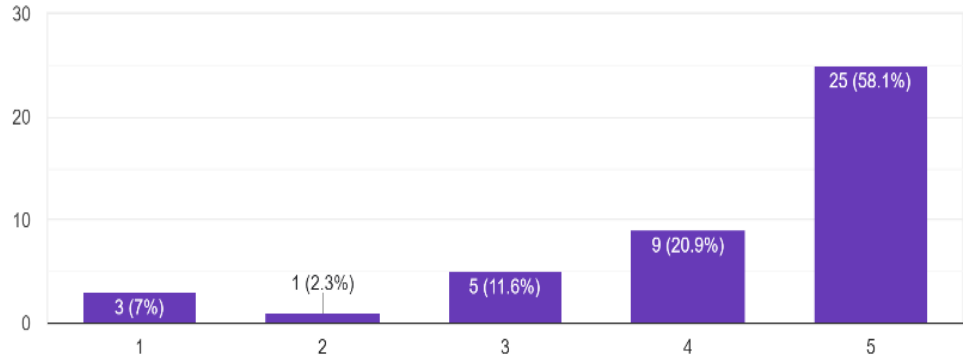
6. Machine learning-based technologies can contribute significantly to achieving sustainable development in Sub-Saharan African nations.

43 responses



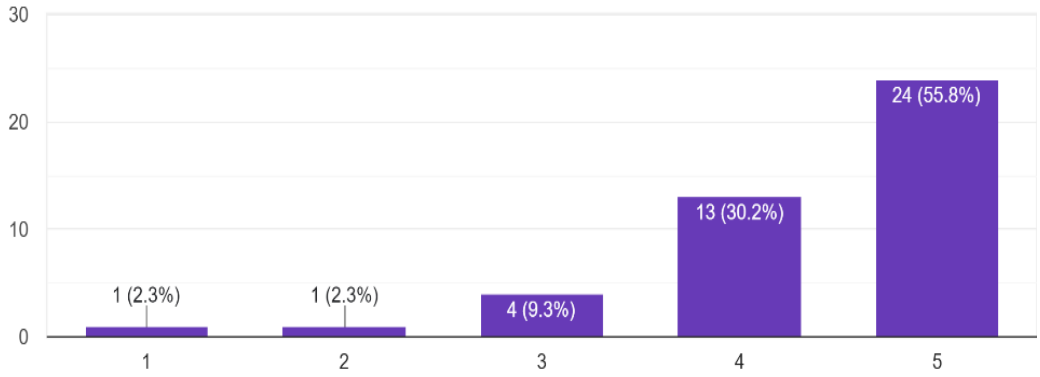
5. Machine learning-based technologies can enhance the quality and delivery of education and training programs.

43 responses



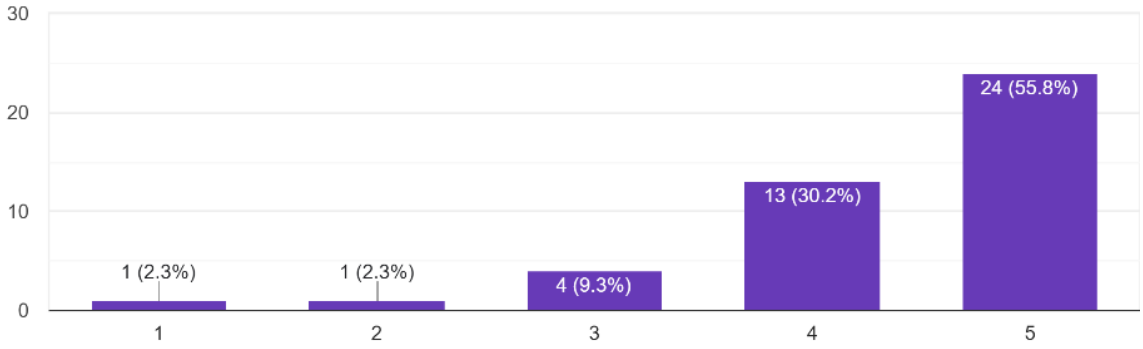
7. The adoption and implementation of machine learning-based technologies in education and training programs can improve student/learner outcomes.

43 responses



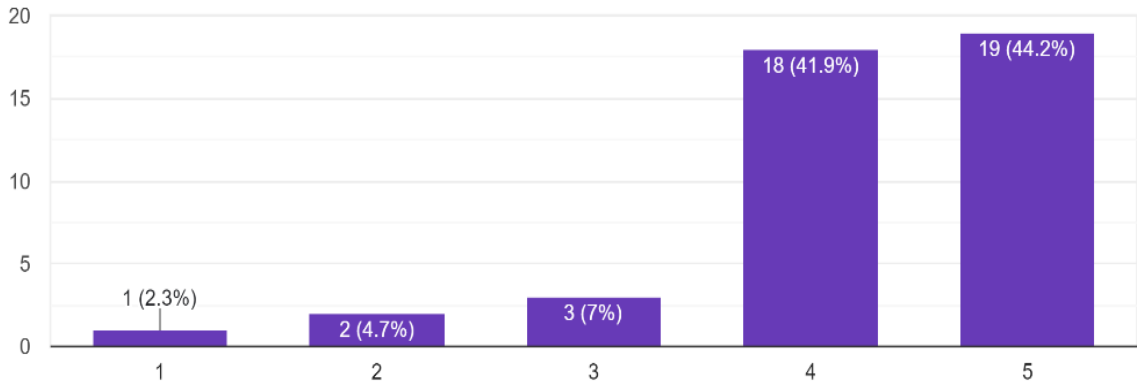
7. The adoption and implementation of machine learning-based technologies in education and training programs can improve student/learner outcomes.

43 responses



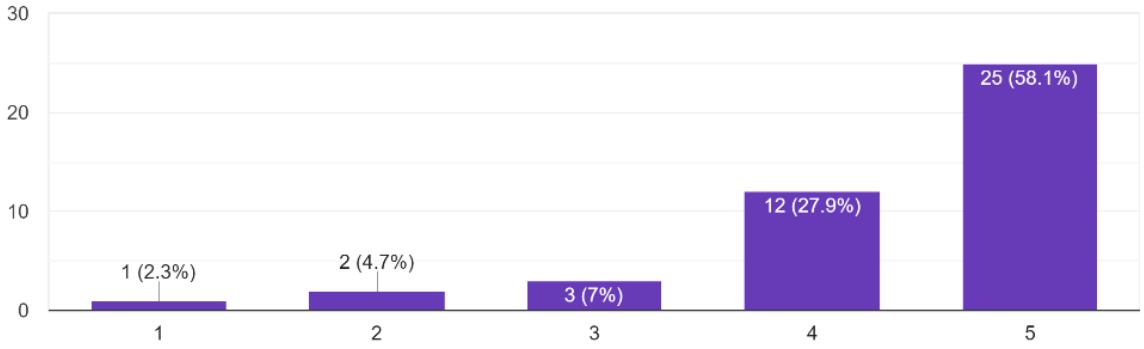
8. Machine learning-based technologies can be used to personalize learning experiences for learners.

43 responses



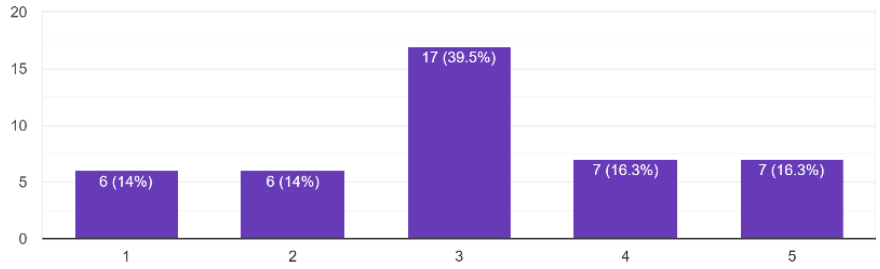
9. The use of machine learning-based technologies can improve the efficiency of education and training programs.

43 responses



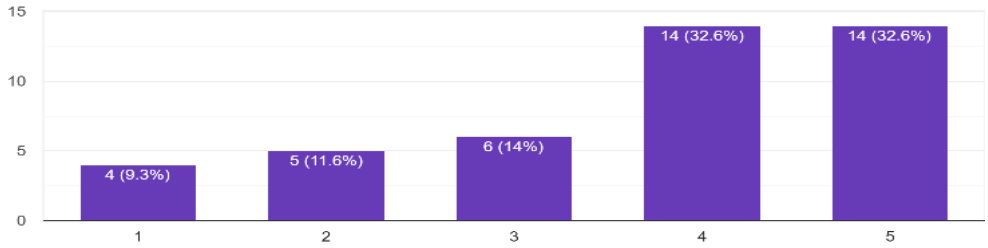
10. The use of machine learning-based technologies can have negative effects on the quality of face-to-face interaction between educators and learners.

43 responses



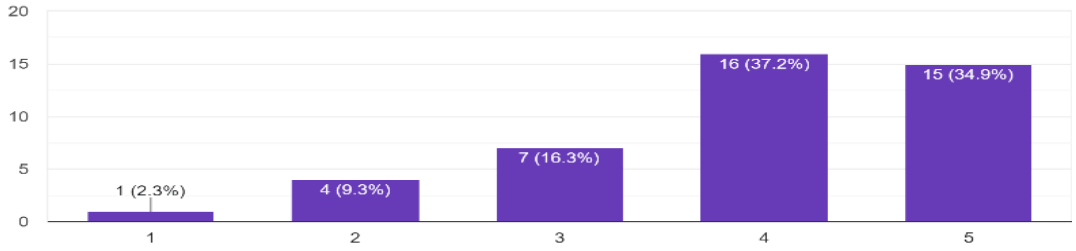
11. The use of machine learning-based technologies can create a digital divide between those who have access to them and those who don't.

43 responses



12. I feel prepared to use machine learning-based technologies in my teaching or learning experience.

43 responses



13. I am currently using machine learning-based technologies in my teaching or learning experience.

43 responses