Artificial Intelligence in African Schools: Towards a Contextualized Approach

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***Abstract*—Artificial Intelligence (AI) for K-12 education has been considered a global initiative. However, evidence of Africa's inclusion in globalization across schools is lacking in the literature. Besides, resources, including materials and content, are developed across Hong Kong, Japan, Europe, and the USA. These suggest that contextualized resources are effective for AI implementation in schools. Since appropriate pedagogical approaches, sound instructional methods, materials, tools, and activities familiar to the student for instruction lead to effective learning, we embark on a literature survey to unravel the approaches and kind of AI resources utilized across contexts. A systematic literature review methodology was used in this paper to understand the trends of teaching AI at the K-12 educational level. Scientific databases such as IEEE, ACM, Web of Science, and Scopus were searched to gather relevant literature in tandem with our research aim. Out of the 451 articles that were retrieved, only 54 fit well into the inclusion criteria and were reviewed for further analysis. This study revealed several existing approaches and resources used to teach AI in schools.**

Keywords—artificial intelligence, K-12 Education, Contextualization, Africa

I. INTRODUCTION

Artificial Intelligence (AI) for K-12 education has been considered a global initiative. However, evidence of Africa's inclusion in the globalization of AI across schools is lacking [1], [2], [3]. To develop AI competencies so that all citizens can understand how to interact with AI systems, AI has to be included in the curriculum. Accordingly, researchers developed AI literacy frameworks such as AI Competencies and Design Considerations [4], the Five Big AI Ideas [5], and the Machine Learning Education Framework [6], which served as references for AI curriculum development. However, several curricula have been designed to introduce AI in schools across regions to create an AI-ready society. These curricula, as evident in literature, are mostly researcher-designed materials for specific grade levels, age groups, and context [7], [8], [9]. While the concerted effort on resources development for K-12 AI education in the United States, Europe, and Asia keeps growing, there is no evidence of such in Africa. According to a recent report on the mapping of AI curricula by UNESCO, only eleven countries have government-endorsed K-12 AI curricula, while four countries have governmental K-12 AI curricula in development. The report clearly shows that none of these identified countries are from Africa.

Why is AI for K-12 important in Africa?

According to [10], if the dearth of significant AI research and development in Africa persist, AI applications deployed in Africa tend to emanate from other continent and thus lack contextual relevance, specifically as regards to cultural and infrastructural factors [11]. This concern can be linked to the 2020 global Government Artificial Intelligence Readiness Index ranks Africa among the lowest-scoring regions [12]. The report credited Mauritius as the only Sub-Saharan African country with a formalized national AI strategy for implementation of AI while Kenya is in the process of development. Numerous countries have also initiated task forces and authorize them to generate a national AI strategy. For example, Nigeria launched the Centre for Artificial Intelligence and Robotics (NCAIR) in November 2020, a research facility that is centered on AI, Robotics, Drones, Internet of Things, and other emerging technologies with the aim to transform the Nigerian digital economy.

Reports and other anecdotal information confirm the limited research and development activities focusing on AI in Africa. However, there is growing awareness in the continent that establishing robust African AI policymaking capacity also requires the development of a critical mass of AI skills [10]. Accordingly, in her 2021 International Forum on AI and Education, UNESCO dedicated a session for Africa tagged "Promoting the use of AI in Africa: Build the partnership." This forum opened up discussion around collaboration among universities, research centers, and public institutions in Africa to promote AI and AI literacy.

While the unique context of Africa will influence the depth and breadth of the AI impact in the continent, AI has the potential to be as impactful in Africa as it is in other regions of the world [10]. AI education, an emerging K-12 STEM initiative, should be considered through an African lens. Africa, the second largest and second-most-populous continent globally, boasts of the youngest population amongst all the continents. A younger population translates to a larger upcoming workforce and more innovation and economic growth opportunities. It is then imperative that these sets of demography be equipped with AI skills required to equip them for places of work where human-AI teaming is the standard[3].

The introduction of artificial intelligence (AI) to K-12 education has further widened the gap of access to quality and relevant Science, Technology, Engineering, Mathematics (STEM) education between developed and developing countries, particularly Africa. Especially that teaching and learning of computer science is still low and plagued with challenges in Africa's foundational levels of education [13], [14]. Regardless of these issues, AI applications are now part of our daily lives, and teaching this concept will soon be introduced to African schools since it is a global initiative. It is now the time to find ways to teach AI concepts to students such that it will be less intimidating as the new subject requires novel approaches.

Why contextualization?

AI resources, including materials and content, are developed across regions such as Hongkong [15], Japan [16], and the USA [7], among others. These suggest that contextualized resources are effective for AI implementation in schools. This study examines the research landscape of AI education as demonstrated in different contexts to guide the conceptualization of AI literacy in African schools. Moreover, the study also investigates the approaches as developed in existing studies and seeks whether they are adaptable to fit the African context or otherwise. Since introducing materials, tools, and activities familiar to the student for instruction leads to effective learning [17], we highlight how contextual indices could influence the AI teaching and learning. Specific research questions that guide the study are:

- What kinds of pedagogical approaches are utilized to teach AI?
- What kinds of instructional materials and tools are used to teach AI?

II. METHODOLOGY

A systematic literature review covering the range of AI and machine learning (ML) in K-12 was presented in this study. ML, an application of AI, is considered in the search because the teaching of the concept is also growing in K-12. The study surveyed published articles across contexts. Wohlin [18] describe Systematic literature evaluation as a means of synthesizing data to aid researchers in understanding the primary status of a particular research area in which a study is carried out. This includes literature mappings and reviews.

A. Search Strategy

This research began by gathering literature on AI relevant to our study from four different multidisciplinary databases [19]. We considered all metadata during the data collection. Relevant articles on studies regarding AI, AI curriculum, teaching, and AI learning at the K-12 level were collected in our search. Furthermore, the search keywords used are artificial intelligence, machine learning, Contextualize, School, Children, curriculum, resources, tools, and K-12. We conducted our search in four different databases, which include IEEE Xplore, ACM, Web of Science, and Scopus. The databases warehouse the published articles in the education field, science, technology engineering, and mathematics (STEM), and computer science, which is why they were selected for the search. The exact keyword was applied in each database to conduct the research in the advanced search. Table I shows the keyword utilized. All metadata aspects of literature were targeted during the search. Article metadata contains the relevant information about the article, such as the article keywords, title and abstracts are all part of metadata. A search string combination example is (teach OR education OR course OR learn) AND (Contextualize) AND (machine learning OR artificial intelligence) AND (k-12 OR school OR kids OR children OR teen) AND (curriculum OR resources OR tools). Modifications were carried out on the search strings to suit the search pattern of the databases when needed. A criteria list was used to select the articles relevant to our study.

TABLE I. KEYWORDS

Main Concept	Synonyms
Teach	Education, course, learn
Contextualize	Contextual
K-12	School kids, children, teenagers
Curriculum	Resources, tools

Our concern about the low yield of appropriate documents led us to review several relevant papers for the selected bibliography manually.

B. Paper Screening

The paper screening process was carried out by employing some inclusion and exclusion criteria. The selection process commenced scanning through all metadata to download the article for more screening. Skimming was conducted on the keywords, title, and abstracts to ensure that the selected articles aligned with our study. Below are the criteria for inclusion and exclusion:

- Inclusion Criteria

1) *Articles that focuses on teaching artificial intelligence, contextualization, K-12, and curriculum.*
2) *Articles published in a conference or peer-reviewed journal.*
3) *Articles demonstrating tools, design, or artifacts in teaching AI in a contextualized context.*
4) *Articles that demonstrate pedagogical approaches that are utilized to teach AI.*
5) *Articles that present contextual instructional materials and tools used in teaching AI.*

- Exclusion Criteria

1) *Articles not written in English and articles not focused on keywords were excluded.*
2) *Resources or materials such as audio/video files, PPT files, etc., were excluded.*
3) *Non-journal and non-conference articles.*
4) *Articles that do not present the implementation of AIin contextualized terms.*
5) *Articles that discuss AI without contextualized implementation.*

After the inclusion and exclusion criteria has been applied, our final screening yielded 54 data. The data were subsequently analyzed, and the results are presented in the next section. Our analysis suggests that research into teaching AI in K-12 is mainly in the United States, Hong Kong, and

Europe. Most of the AI courses are targeted at secondary school students in a formal setting.

II. Result

To examine the different approaches and resources in respect to AI teaching and learning among K-12 learners, a literature survey was performed to understand the phenomenon regarding how scholars and educators have demonstrated AI literacy. This approach aims to unravel insights that can guide the fundamental indices for introducing AI education in Africa. This section presents the findings that address the research questions formulated in the study. First, the results related to the pedagogical approach employed to introduce AI in a k-12 setting. Second, we present the instructional materials and tools used in teaching AI in different contexts equally.

RQ1. What kind of pedagogical approaches are utilized to teach AI?

The study investigated the teaching methods and instructional approaches to answer the research question of what pedagogical approaches are utilized to teach AI. As revealed in Table II, the analysis revealed several pedagogical approaches used in different contexts as presented. Predominantly, participatory learning, design-oriented, and collaborative learning are commonly used as teaching methods to introduce AI to k-12 learners. We found out that gamified and unplugged activities are also part of the instructional approaches.

RQ2. What kinds of instructional materials, tools, and resources are used to teach AI

As shown in Table II, we deduced that instructional materials or type of media included YouTube videos, PowerPoint slides, sticky notes, and whitepaper and textbook. The instructional tools, which are primarily web-based, include Machine learning for Kids, Google Teachable Machine, Python, JavaScript, HTML5, Cognimates, ecraft2Learn, mBlock5.0’s Scratch, Unity 3D.

Topics covered included introduction to AI and ML, Data clustering, Neural network, problem-solving, search, planning, introduction to computer vision, K-means, KNN classifiers, Naive Bayes simple clustering, Feedforward Neural Network, Random Forest, Linear regression, deep learning, decision tree, CNN, PoseNet,

III. Discussion

This study investigated the existing literature to unravel how AI education for K-12 has been demonstrated in different contexts to provide insights into the context of AI education in Africa. The study adopted a systematic review and analysis of the relevant articles to address the research questions. First, several approaches, designs, and materials for AI education in K-12 found in the literature were presented. Additionally, tools and interventions deployed for teaching AI in K-12 were also unraveled.

Several pedagogical approaches have been used to demonstrate AI education across the literature. For example, this study revealed that collaborative learning, design-oriented approach, and participatory design remain the commonest pedagogies used in teaching AI in K-12. These approaches have been widely adopted by scholars, which shows potential evidence to foster AI and STEM education across different contexts [1], [20], [21], [22]. The use of a collaborative learning approach to deploy AI education in the K-12 context has been emphasized by recent studies [1], [23]. According to [24], [14], collaborative learning is an approach that has been used to bring teachers and learners together to solve a problem, complete a task, or create a product—making contextual AI educational material and instruction would impact learners' and teachers' conceptualization, design, and implementation process. In African context, AI K-12 education is almost inexistence, and learners may feel more comfortable if they are involved with the teachers to create an intervention for learning.

Furthermore, participatory design and problem-based approach were used to prepare students to engage in AI education actively. According to [25], [26], participatory design is a relevant approach for gathering and organizing requirements from stakeholders. Analyzing how countries formally introduce AI to K-12 students, scholars in the United States and Norway use methods such as game-based learning problems and inquiry-based learning. Moreover, emphasis on allowing K-12 learners to contribute to their learning and describe their own experiences has been stressed [27]. Based on the study of [28], there is a call for radical change in how AI is taught to kids since kids are highly interested in robotics.

On the other hand, there is a broad conception that it is pretty challenging to teach the basic concepts of AI. In the African context, where teaching AI to K-12 students is relatively new, the Design-Based Research curriculum of teaching AI faces many challenges. However, using African artifacts for training AI models built by Native K-12 kids could mitigate these perceived challenges.

In addition, problem-based learning (PBL) and game-based learning (GBL) are the prevalent pedagogical methods of teaching AI in K-12 settings [1], [29]. Teaching students AI algorithms with games can improve their creative thinking skills required to transform general ideas into practical solutions. However, unlike collaborative learning, the GBL model is not widely adopted due to the lack of empirical evidence and the stigma associated with ‘Play,’ which brings about comparative pleasure. Although the GBL approach can motivate students by enhancing their learning experiences, AI games could include dragging and ordering code fragments to train a model. In Africa, contextual games used for recreation and other purposes can be adapted into teaching AI concepts.

Moreover, African children are fascinated with games, and there are several games children can play to gain knowledge. Some games are gender-based, while others are not. For example, girls love playing “Tinko Tinko,” where two girls face each other and clap each other's hands in a memorized fashion. Other popular children's games in Nigeria include” Fire on the Mountain,” where two teams of children run in opposite directions and try to increase their team number. Introducing the GBL method of teaching AI will arouse the interest of young learners in Africa who already want to play and have a higher attention span when playing games. In comparison with other methods of teaching K-12, the GBL could be more suitable for African kids because of the communal nature of African communities, allowing kids to build their model for training AI algorithms in a gamified environment, spurring interest and excitement amongst them.

Regarding the instructional material used in teaching AI in a different context, this study revealed that conventional instructional materials such as YouTube videos, paper-based sticky notes, and PowerPoints are used by some studies [1], [30], [31], [32]. These materials can be adapted for AI education in K-12 in Africa since they are affordable and accessible. Furthermore, some of the predominant tools used in teaching AI concepts to young learners are Teachable Machine, Cognimates, ecraft2Learn, Machine Learning for Kids, mBlock5.0, MIT App Inventor, ML4Kids, Pix2Pix, Google Teachable Machine, Quick Draw, and AI for Oceans. These tools are mostly free and are available as open-source for researchers' use. However, there is a limit to how these tools can be customized to suit the context of Africa.

IV. Conclusion

This study introduces the need for contextualized resources to teach AI in African schools and highlights the impact of such initiatives on students. It is expected that the design and implementation of such materials will bring about effective learning of the new concept in schools. AI impact in African community is not clear, whether negative or positive. There is the need to maximize the learning ability of AI using African artifacts such as talking drums, and it appears that training AI models using non-African artifacts will not allow accurate predictions of African artifacts. Therefore, we now research ways of building an AI model contextualized to African society. In Africa, we need social improvement. With more research into contextualizing AI for Africa, we can develop more systems that consider African artifacts and promote effective AI literacy.

The key limitation of our study is that it does not focus on a specific country which may lead to generalization risk across the African continent with fifty-four (54) countries. The authors understand that the continent is vast, with different cultural, social, and political outlooks within its constituent countries. Nonetheless, this paper discusses the need to have contextualized AI resources for the African States, including curriculum, tools, and materials, to ensure effective AI learning and promote local AI innovations. Part of the future study would investigate how human intelligence influence the contextualization of AI in African schools. The next step is to develop a framework for contextualizing K-12 AI education in the African context.

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Table II. Result of Analyzed literatures

Reference	Teaching method	Instructional approach	Topics Covered	Type of AI/ML Algorithm	Tools/Framework	Type of Data	Instructional Materials	Learning Outcome
[30]	Game-based learning, problem-based learning, inquiry-based learning	Collaborative approach, life science adventures, group, data collection, modelling	AI methods: image recognition, machine learning, planning and automated decision making	N/A	Primary AI, block-based programming	Images	sticky note, images	negotiation, decision-making
[33]	N/A	36-week open-source AI curriculum, online and unplugged activities, workshop, quiz, modelling, prototyping	Introduction to Computer Vision, Developing intelligent interfaces to communicate with human users, Computer vision systems to see the environment, Speech and audio systems to hear the environment	chromakey, blob detection, and image filters, feature extraction, neural network	Touretzky's Five Big Ideas on AI Education, Cognimates, ecraft2Learn, Machine Learning for Kids and MIT's Ethics Curriculum, mBlock5.0's Teachable Machine	interactive digital material, interviews	Programmable tangibles and robotics, Web-based tools, in-class evaluation forms and Kahoot quizzes, CLEAR Laboratory's BabyLegs project, Rock, Paper, Scissors game from Machine Learning for Kids, Google forms,	help students see the interdisciplinary connections, and better understand how science and innovation work in conjunction
[31]	Value-Sensitive Design approach, Participatory design; User cantered design, peer-to-peer collaboration	multi-session co-design workshops,	what and why AI was important, How Does Data Affect Government Policy? Learn Vocabulary with an AI, and Build an AI-powered Pronunciation Application	N/A	questionnaire, Zoom, Slack, and Miro, s Teachable Machine, MIT App Inventor, ML4Kids, BERT Q&A and Zhorai, Pix2Pix, Google, Quick Draw, and AI for Oceans	audio recordings, questionnaires	N/A	K12 teachers need additional scaffolding in AI tools and curriculum to facilitate ethics and data discussions
[34]	Designed oriented pedagogy Collaborative learning	workshop,	N/A	Aspect ratio	web-based ML tool for image recognition. HTML5 and JavaScript, questionnaire,	Images	PowerPoint slides and a simple web app, camera	students adapted to programming task in JavaScript and Pascal
[2]	self-learning, collaborative learning and peer teaching	riddles and games	N/A	blind search, informed search, search games trees and ML algorithms	DrRacket functional programming language	N/A	N/A	N/A
[36]	Collaborative learning, hands-on learning	comparative visualization	design space of data visualization hands-on exploration collaborative learning	k-nearest	SmileyCuster, glyph-based data visualization and superposition comparative visualization	survey, interviews, screen and video recordings.	Computer	change in learning ML, methods and sense-making of patterns
[20]	Constructive Design Research (CDR) process	Iterative design process, prototyping,	what should students learn about ML? how do we design learning tools and -activities that support students in engaging with ML? what are opportunities and challenges for a CE approach to understanding ML?	k-nearest, Feedforward Neural Network (FNN)	Jupyter Notebook, VotestratesML, Google collaboratory	Images, observations, field notes, sound recording, voting data	N/A	N/A
[27]	Design-based research	workshop	N/A	N/A	Google Teachable Machine	Sound, image, pose	Whitepaper,	Students create design ideas applicable to everyday lives.
[38]	design-based research, experimental learning	experimenting, hands-on workshop	N/A	N/A	Pedagogical content knowledge (PCK)	Semi-structured interview	N/A	N/A
[28]	N/A	workshop	data clustering, artificial neural networks learning	Artificial Neural Network, k-means	scratch	Questionnaire,	N/A	N/A
[21]	Objectivist, constructivist	summer school	bagging, clustering, unsupervised learning, ML and human learning, applications of ML	Random forest, k-means	N/A	Two dimensions of oranges and lemons	N/A	N/A
[37]	instructional approach, exploratory learning approach	workshop	definition and comparison of AI, ML, and DL; types of ML problems in supervised and unsupervised learning. Explainable AI.	KNN classifiers, linear regression, Naive Bayes, simple clustering algorithms	2D game-based educational tool, Unity 3D	N/A	N/A	N/A
[40]	N/A	workshop	Introduction to ML, Training and test sets, Labels,	Linear regression, linear and binary search, logistics regression, neural network, deep learning	Cola	N/A	N/A	N/A
[41]	Design based research	workshop, Experiential learning theory	Introduction to scratch, climbing the DIKNW pyramid	Random Forest, Fuzzy Hoeffding Decision Tree, J48, Fuzzy unordered Rule induction algorithm	Scratch, ExpliClas	Spanish basketball league data	NLG pipeline	N/A
[32]	N/A	constructionism	N/A	N/A	Machine Learning for Kids, scratch, Mitsuku chatbot, IBM Watson AL model API	Images	presentation slides, videos, activity worksheets	increased motivation, peer teaching, increased belief state in the potential of AL
[42]	N/A	workshop	N/A	N/A	Scratch, Machine Learning for Kids, MIT App Inventor, Arduino, CodeINTEF, Lego Mindstorms Ev3	images	N/A	N/A
[39]	Review paper on curriculums	N/A	Data clustering, Neural Network learning	Artificial Neural Network and k-means	Scratch	Questionnaire,	N/A	convey sophisticated concepts of AI, paving alternative ways to learn ML for the unsophisticated public
[45]	constructionist pedagogy	Instructional design	problem solving, search, planning, graphs, data structures, automata, agent systems, ML	reinforcement learning, decision trees, neural networks, search algorithm	N/A	N/A	paper-and-pencil or programming exercise, robot construction, discussions, group work and homework.	N/A
[16]	learningML tool	N/A	introduction to AI, Scratch and AI, AI Ethics	N/A	Cognomates, Scratch, machine learning for kids		N/A	N/A
[23]	Design - oriented pedagogy, data-driven design,	workshop, co-design process	Introduction to AI, practicing the ML process, constructing a rule-driven ML system	ANN	code.org, Mitsuku , WebEx, Programmbale Learning Environment, ARCS model	Interview	N/A	N/A
[43]	Participatory learning,	learning by teaching a computer	N/A	N/A	LearningML,	N/A	N/A	N/A
[44]	Meta-design, co-design process	workshop	N/A	N/A	GTM,	Images, sound, pose	white paper,	students learnt essential 21-century skills, data-driven reasoning and design,
[15]	N/A	36-week open-source AI curriculum for middle school, online and unplugged activities, workshop, quiz, modelling, prototyping	computer vision, robotics, NLP, and computational biology;	Naive Bayes, k-nearest neighbours algorithm, Dijkstra's algorithm	python	N/A	N/A	N/A