

Volume 1, Issue 1

Research Article

Date of Submission: 10 July, 2025

Date of Acceptance: 05 August, 2025

Date of Publication: 21 August, 2025

Prognostication Opportunity of Future STEM Education and 4IR for Africa: Uphill Massif

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Citation: Bedada, T. B., Dame, D. D. (2025). Prognostication Opportunity of Future STEM Education and 4IR for Africa: Uphill Massif. *Hematol J Blood Sci Disord*, 1(1), 01-11.

Abstract

The digital revolution is the widespread diffusion of information and communication technologies and the transformation towards an entirely digitized society. The digital revolution can radically develop and change Africa like what the first industrial revolution did to western countries in the 19th century. Most, if not all, African countries are still looking for solutions to the education, socioeconomic, and political problems that their inhabitants face. The study's main goals were to identify the challenges and potential trends in African countries in implementing STEM education and 4IR on the continent, as well as to provide a strategy and method for implementing 4IR and STEM education. The study used the archival research study process to investigate the searched articles to answer the research questions. The findings reveal that there are some trends that were implemented in Africa, such as Experimento and STEM power, that need to be implemented within the continent in a cooperative way. There is also a forum [PASET Forum (2019)] that is prepared by the African countries to discuss the hot issues of the world 4IR. Besides these trends, the study also finds out the challenges such as human skills, infrastructure, and resources [budget] and, to some extent, fear of job loss those African countries are facing and will be facing within the continent.

Keywords: Africa, Archival Research Study, STEM Education, 4IR, Trends and Challenges of Africa

Introduction

Many developed nations have adjusted while others are beginning to adjust the education provided in institutions of learning and training in preparation for the Fourth Industrial Revolution (4IR). Reterritorialising education in Africa in the Fourth Industrial Revolution is to introduce Science, Technology, Engineering, and Mathematics (STEM) education to students of higher education in Africa. With the emergence of the Fourth Industrial Revolution (4IR), rapid developments in science and technology have greatly affected everyday life. In the education sector, developments such as the Internet of Things (IoT) have influenced curricula and introduced educators to new teaching methods with the combination of well-developed model of teaching and learning [e.g. ASSURE model and Cycle Model developed by and promoted by indigenous knowledge [1,2]. In this context, 4IR is expected to actualize smart education environments that can improve the quality and accessibility of education. Corresponding to 4IR, we have education 4.0 that developed for adjusting traditional curricula familiar with IoT. This calls for an increased emphasis on mathematical skills such as critical thinking, problem solving, communication, collaboration, and innovative thinking [3]. The mathematical skills such as critical thinking, problem solving, communication, collaboration, and innovative thinking can be improved by using technology within the classroom [4]. This concept goes with the internalization of curriculum/lesson plan (please see stages of cycle model) that need to be deterritorialized [loss of territory] and which can be ensured by student engagement [5]. In addition to this, one of the force tasks of doing this is the role of teacher and students [scaffolding stages of cycle model]. Moreover, the teacher training courses need to shaped to improve practices and education in the teaching and learning relationship by delocalization and spatialization classroom in which students are become reflective and protagonists of their cognitive and intellectual growth [6]. For this to happen it needs a collaboratives room/site/center of innovation known as STEM curricula. STEM is curriculum reform-based education process that educating students in four specific disciplines science, technology, engineering, and mathematics per an interdisciplinary and applied approach sometimes includes arts [7]. Says that Climbing Mountains, Building Bridges is a rich theme for exploring some of the "challenges, obstacles, links, and connections" facing mathematics education within the current

STEM [8]. To the above concepts end, 4IR and STEM education have relationships in such a way that 4IR is the stages while the STEM education is the curriculum reforms can be reformed depending on the stages of 4IR accordingly to produce cultivated society [7]. Artificial intelligence (AI) culture to the cultivation of Augmented Humanity (AH) and as a result now adays within 4IR society 5.0 were cultivated.

Statement of Problem of the Study

Everyone is concerned about aspects of 4IR, but no one bears ultimate responsibility at this time [9]. STEM professionals would readily identify themselves as scientists, engineers, or mathematicians but rarely as technologists [10]. However, within the area of 21st century the technology is the word that tied to the society to answer the human made or nature created problems in the community of 4IR. The Fourth Industrial Revolution (4IR) is outgrowing including the introduction to artificial intelligence, advanced robotics, block-chain, drones, internet of things, wearable technologies, cloud computing technologies, 3D printing, Big Data, machine learning, and software-enabled industrial platforms and outliving the Third Industrial Revolution, and it has implications for higher education in Africa and in general the global world continues to prepare itself for the Fourth Industrial Revolution (4IR) due to the envisaged effects of the 4IR on individuals, nations, and the global world. The 4IR is the current and developing environment in which disruptive technologies and trends are changing the way we live and work. 4IR comes with high digitization and formulate the causes of 4IR to happen by stating that rapid increase and exposure of people to radical techno-economic solutions can resolve their daily challenges [11]. Some of the features of the 4IR include mobile supercomputing, intelligent robots, self-driving cars, neuro-technological brain enhancements, and genetic editing. Higher education in Africa is in danger of being left behind if serious consideration is not given to the 4IR (for instance the occurrences of Covid-19), and the digitization that it comes to; with more specifically, Ethiopia. Moreover, STEM education in Africa is falling behind when compared with the rest of the world [5,12]. The African Development Bank has reported that less than 25% of African higher education students pursue STEM-related career fields, with more students pursuing social sciences and humanities. With the appearance of Covid-19, most of the universities in the world shut down their teaching and learning most largely in African countries to reduce the distribution of the diseases. The universities involved in online teaching and learning processes are the best universities that answer for reducing the Covid-19 distribution as they run their teaching and learning process online within the Covid-19 period. For, instance the University of South Africa (UNISA). The fourth industrial revolution entails the integration of technology, humanity, and biology [13]. However, review literature reveals that schools that do teach the four STEM disciplines often do so in a disjointed manner, failing to integrate STEM in a unified way [14]. advice by saying that for the purpose of avoiding confusion on the process of teaching STEM education, it is possible to teach one of the elements of STEM referred as STEM education and can teach students by integrating the elements of it together and named it as I-STEM [10]. This study is motivated by this gap, it aims to bring to light challenges faced by Africa and offer some insights to guide the development of credible corridors for policy makers and researchers for developing African countries and forecast how to develop tools to mitigate future anticipated challenges of Africa.

Objectives of the Study

The objectives of the study were coined within the following concepts.

- a. To investigate the trends of Africa on the implementation of STEM education and 4IR in their education system at higher education.
- b. To elaborate on the challenges to Africa that hinder to implementation of STEM education and 4IR in their education system at higher education.
- c. To suggest the future supposed gate/path/ of Africa to be familiar with the STEM education and 4IR in the education system at higher education.

Research Questions

- a. What are the trends of Africa with the implementation of both STEM education and 4IR in their education system at higher education?
- b. What are the challenges and opportunities for Africa to implement STEM education and 4IR in their education system at higher education?
- c. What is the future supposed gate/path/ of Africa to implement STEM education and 4IR in the education system (forecasting of the matter)?

Significance of the Study

This insight paper gives a potent voice to the causality challenge and calls for the necessary moral obligations of academia, government, and industry to engage in the efforts required to address the challenge that occurred in Africa in particular Ethiopia forecast the future educational system in the eye of 4IR and STEM education.

Review Literature

The reviewed literature this divided into three categories to answers the research questions of the study. These are searching about 1) Trends of implementation of STEM education and 4IR in the education system in Africa 2) Challenges to African countries that hinder to implement of STEM education and 4IR in their education system 3) future of African countries to implement STEM education and 4IR in their education system.

Trends of Implementation of STEM Education and 4IR in the Education System in Africa

In this section, we need to define the term revolution and paradigm. The two terms are defined by the known scholar Thomas Kuhn to mean gradual changes of science and world views respectively in the world [15]. Kuhn argued that a scientific revolution is a non-cumulative developmental episode in which an older paradigm is replaced in whole or in part by an incompatible new one. The world has gone through several industrial revolutions over the past decades and every industrial revolution has come with implications on the country's education of society [16]. 4IR has become the driving force for integrating technology in the classroom teaching and learning process for improving higher education worldwide. Revolutions occur not only in science but in all areas of the human experience. In science education and related fields, the potentially revolutionary times concerning various proposals for STEM (science, technology, engineering, and mathematics) education were emerged and will emerge also. STEM education is the basis of the appearances of 4IR and can be considered as a site [11,17]. As to Ethiopia, it is named as the center.

To this effect, in South Africa, one university was found to have made significant progress in training 4IR skills for industrial engineers [18]. In the same fashion, in Rwanda, engineering education has provided skilled personnel for industry and solutions for local development problems and the Swedish university boosts the human power (considered as the benchmark) and quality of STEM education in African countries are poor [19]. Hence, to us, as STEM education is the base for 4IR and STEM is not a new concept as the ideas promoted since 1990, 4IR is also poor in African countries and the indicator of this assertion is that Africa has started its digital transformation by the end of the 1990s where it has begun by the mobile or telecommunications revolution [19,20].

As to the 4IR, STEM education does have some revolutionary character [10]. To this end, new proposals were given as "blend" a subject like art into STEM, resulting in STEAM; or add medicine to form STEMM; or law, making STEMLE; or infuse STEM with reading, creating the hybrid STREAM [21,10]. They also fear the problem arises because of teaching students by merging engineering and sciences in the classroom while they reviewed their literature, however, concludes as the "links between science elements of mathematics, engineering, and, perhaps to a lesser extent, technology may be helpful" (p.825). Moreover, in developed countries for instance "various US cities, schools labeled as failing are being repurposed as selective STEM-intensive academies to build a STEM education infrastructure" [22]. STEM is an educational methodology that is now accompanied by the STEAM the combination of STEM and arts [in terms of student's creativity within the classroom and outsides of the classroom modification [4,7,21]. However, some scholar starts with a question to define STEM as "Is STEM a new teaching approach or a philosophy?" According to the author Maybe both because we still do not have precise methods about how to practice STEM and clear definitions which are accepted universally on STEM education [23]. States that together with having students ask questions like how tools, equipment's, or anything that we use work and what kind of benefits technology brings into our lives to make them work and providing motivations which will keep their curiosity alive means STEM is being practiced properly [23]. Depending on the literature, STEM is coined in the 4IR. Moreover, it known that engineering is directly involved in making innovations and solving problems. In addition, the scholar states that STEM is a holistic educational approach that includes science, technology, engineering and mathematics, has been increasing and very important for countries to compete and stand out in the new world order and economy in 21st century [24]. In contrast to this scholar, STEM is educational approach only in United States of America (USA) and in many countries it is educational curriculum reform [25].

Many countries are increasing their attention on STEM in schools and the workforce, with its important significance across numerous industries becoming explicitly recognized [8]. Having a problem of understanding and implementing STEM education in the classroom some organization tries to establish a center known as Experimento and STEM power and prepare Forum [PASET Forum]. Here, I am interested to discuss the trends of the three ideas such as Experimento and STEM power and preparing Forum [PASET Forum].



Figure 1: Countries Implemented Experimento in Africa and Continent in the World

Experimento is based on the principle of inquiry-based learning, which sees children and young people actively shaping their learning processes: They come up with questions, apply a range of methods to arrive at solutions, reflect on what they've discovered, and summarize the results – all on their own. The young researchers learn that their actions lead to success – a valuable, motivational lesson that boosts a child's belief in his or her capabilities. It also means that learning is not limited to the classroom and encourages applying lessons to everyday life, reassessing information, and coming up with new ideas outside of school.

The education program Experimento is about more than acquiring science and technology knowledge and specifically incorporated values into the program as it was conceptualized with Ludwig-Maximilians-Universität (LMU) in Munich. Multi-tiered, age-appropriate value-building STEM lessons should focus on personal and social values, such as cognitive ability, problem-solving skills, cooperation, and the ability to act. Societal values such as conscientiousness and engagement on behalf of nature, the environment, and a sustainable future are encouraged.

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Discussion on the 5th PASET FORUM Africa country intends to do the following actions to accomplish 4IR(PASET Forum, 2019): -

a. From the Ethiopian government

- There has been an expansion of the TVET sector and growth in higher education institutes in Ethiopia.
- An enabling ICT policy with institutional arrangements to implement is important to have an ICT-driven country as well as a knowledge-based economy.
- Ethiopia is currently well connected in terms of coverage and several sectors are adopting digital technologies from agriculture to finance. However, TVET schools and some universities still have poor connectivity.
- There is a national depository system for educational materials as well as digital libraries in some universities. Several digital courses (e.g., from author observation Mathematical software for Mathematics students was added, etc.) have been added to curricula and all students take a course in emerging technologies (for freshman Ethiopian university students) to prepare the youth. Universities also have incubation centers.

To sum up, the speaker from Ethiopia on PASET FORUM did not say anything about 4IR directly. Ethiopia is limited in its ability to implement and develop the fourth knowledge wave [26].

b. From the Guinea government

- There is political commitment to keep up with the 4IR.
- Guinea has formed the Guinea Technology Valley that emulates Silicon Valley.
- Guinea is promoting a technology-led education system hence several reforms are ongoing: key sectors like agriculture and mining are being focused on for digital transformation; fiber optic is being laid out across the country; training programs are being initiated in various sectors; curricula have been adapted to match companies' needs; all high schools have electronic communications, and there are virtual libraries in some universities.
- Challenges in the country include access to wide-scale internet, human resource issues, and funding

c. From the Tanzania Government

- Several initiatives such as an ICT policy and corresponding pillars for infrastructure, human capital development etc. have been introduced.
- The government has laid 7500 km of fibre optics and an additional 20,000 km will be built to cover the last mile solution.
- Curricula are being revised to reflect the needs of the 4IR, such as IoT, AI as well as 3D technologies in TVET. e-Libraries have been established from primary to higher learning institutions.
- Connectivity has been improved in higher learning institutions using the Ubuntu service.
- Challenges that the country faces include human capital capacity and funding. The way forward involves increased collaboration, charting new ways to get funding and reviewing the policy roadmap for the 4IR.

d. From the Rwanda government

- Human skills are critical to leverage the 4IR and Rwanda has placed a great deal of effort in this area considering the country's history where education was segregationally based on ethnic backgrounds.
- Education and training are considered as the main driver for Rwanda's development. Several policies and initiatives

have been put in place including initiatives to promote new pedagogy and assessment required by the 4IR, promotion of Science, Technology, Engineering and Mathematics (STEM) programs and enhancement of English language proficiency.

- University of Rwanda has been reformed and merged to raise academic quality as well as to avoid duplication of resources. The same merging policy has also been enacted in TVET colleges which have been merged into Rwanda Polytechnic.
- Rwanda has been getting ready for the 4IR since 2000.
- The journey started with the formation of an ICT policy and institutional arrangements, hard core infrastructure such as fibre optics, use of secured and shared infrastructure, and finally implementing the Smart Rwanda master plan. Currently, the Rwanda Coding Academy has been launched to address readiness for the 4IR.
- Rwanda has established a regulatory framework as an enabler for digital transformation. There is a need for smart and dynamic regulations and guidelines. With the 4IR, change is rapid and hence, there is a need for continuous revision.
- Efforts are being made to provide flexible guidelines in cybersecurity and data privacy.
- Rwanda is active at the international level in standardization issues related to the 4IR.
- There are special provisions for companies in critical sectors such as transport by issuing licences.

In general, the countries involved on PASET Forum talked about the understandings of 4IR, on the challenges and opportunities in the past, past in the present, future, and future in the present directly except Ethiopia.

Challenges and Opportunities to Africa Countries that Hinders to Implement STEM Education and 4IR in their Education System

Challenges to African Countries

Accessibility of 4IR technologies has been a typical challenge in many African countries. The access issues are often related to the quality of the connectivity infrastructure as well as the cost of devices and connectivity services such as the internet. Extremes in the access to technology, typical for those in towns and cities compared to the rural majority have resulted in the digital divide.

With the development and deployment of new technology, the 4IR has its own set of risks. According to [27], it is unknown how the 4IR will manifest, but one certain thing is that a response to it must be coherent and inclusive of all interested parties in the nation's institutions, ranging from business and public sectors to educational and public society [27]. Careful planning is needed to mitigate these risks. Moreover, new risk management systems and processes will have to be implemented. This implies that the new technologies have the potential to change life positively. However, the world should not overlook the dangers and the negative impacts of these new technological advancements. According to [18], one of the hazards of 4IR for education is inequality and income distribution among South Africans, and they also forecast that STEM curriculum should be reconsidered as a new method in 4IR [18].

Many African countries have limitations to develop even though they have 'latent comparative advantages' because of no infrastructure for 4IR [26]. Africa's continued challenges with availability and affordability of bandwidth and noted that this is the time for Africa to catalyse its transformation through the utilization of 4IR technologies, which will entail reforming the education system, and strong leadership and commitment [28].

One of the elements of 4IR is IoTs which deals with is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. Ethiopia, on the other hand, currently only has the infrastructure to use basic to intermediate cloud computing applications (internet) (e.g., email, web browsing, and video conferencing) [29]. The more challenges of Ethiopia's on the industry are unreliable electricity supply, logistical bottlenecks, and contraband. In general, the majority of African countries' ICT is at an embryonic stage [30]. poor reading and literacy skills, poor reasoning and logic skills, and inadequate use of technology assets are the challenges that occurred within higher education of South Africa [31]. The issues faced in South African higher education include weak reading and literacy abilities, poor reasoning and logic skills, and insufficient utilization of digital assets [31].

South Africa has a significant skills shortage, due to failings in its education system, limiting the supply of managers, of poor-quality infrastructure, reflecting weak governance and state capture researchers and workers needed for 4IR [32]. Developing countries have not been able to take full advantage of the first three industrial revolutions because of the factors such as location, government structure, and lack of technical expertise and infrastructure [33]. It has a poor record in policy formulation and implementation, especially across departments, with notable delays in cybersecurity and data protection. The lack of STEM education in Ethiopia is the problem of implementation strategies, lack of a national scheme, uneven implementation, and variations in the creation of STEM education centers [34].

The examination focuses on the disruption of societal values and restructuring of the economy, poor infrastructural development, lack of skills capacity to integrate new technologies, fear of losing jobs, poverty, and inequalities that threaten the success of the implementation of 4IR [35,31].

Rapid and significant technological advancements have the potential to improve human lives, but they also raise fears about the future, especially for job seekers [9,36]. One of the biggest fears related to the new technologies is that robots and artificial intelligence will replace the human factor in work leading to “technological unemployment” [36]. This is not the first time that technological advancement has been viewed as a danger to people’s jobs.

Opportunities to Ethiopia

Since Prime Minister Abiy Ahmed (Ph.D.) came to power in Ethiopia, the government introduced a home-grown economic growth policy at the center of which is private ownership through privatization of state-owned enterprises such as railway projects, sugar development plants, industrial parks, hotels, and other manufacturing industries. The decision was made also to partially allow minimum shares on state-owned companies such as Ethiopian Airlines, Ethio-Telecom, electricity generation projects, and the Ethiopian Shipping and Logistics Services Enterprise. The current availability and political will for trying new approaches mean that there is currently much interest in and expenditure on technology for education. Ethiopia is one of such countries that need technology for education in the time as government want to lead countries to prosperity. For instance, recently October 1/2020 inaugurated Artificially Intelligence (AI) Center which is one of 4IR has signed Memorandums of Understanding with five institutions(such as Zewditu Memorial Hospital, Addis Ababa Institute of Technology, Addis Ababa Science and Technology University, National Meteorology Agency, and Oromia Cooperative Bank) to cooperate on artificial intelligence products and services developments that will enhance the health, education, agriculture, transport sectors as well as public protection and safety with AI products and services. It is clearly identified without research that the environmental disaster by itself forces the world to use the technology. Even though Ethiopia is one of the countries that are facing with many problems on the implementation of 4IR, the Ministry of Education (MOE) has begun projects to improve and introduce technology to alleviate chronic problems faced in the educational sector. As to the Ethiopian government, 4IR is the revolution that can solve a society’s problems, for example in the educational sector. The following figure indicates how the project aims to transform Ethiopian educational sectors.

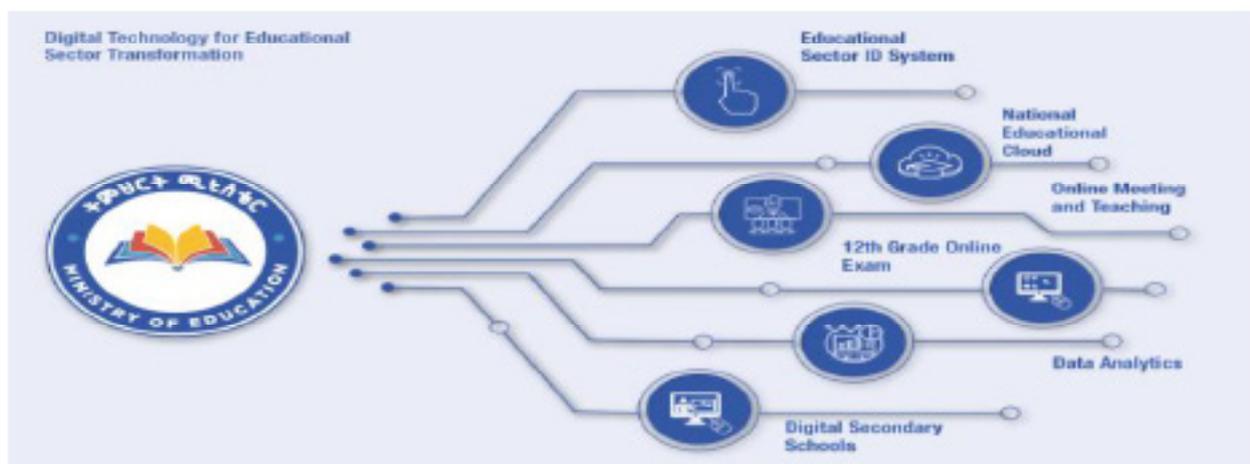


Figure 2: Ethiopia Digital Technology for Educational Sector Transformation (adopted from MOE, Ethiopia Web Pages)

In addition to this, the Ethiopian government identified the problem of a country’s education system and developed a new education system known as the Ethiopian educational road map which aims to cultivate a society of the 21st century [37].

Future and Future in the Presence of African Countries to Implement STEM Education and 4IR in their Education System (Forecasting Matter)

The best method to grow an industry or society utilizing technology is to use their technology and experience [26]. The African Union’s Agenda 2063 aspires for inclusive growth and sustainable education programs that can ensure skills revolution accentuating innovation, science, and technology. That is why the African Union Continental Education Strategy for Africa (CESA) aims to transform Africa’s education and training systems to generate sustainable knowledge, competencies, skills, innovation, and creativity suitable for Africa’s socio-economic development. As such, African countries are revitalising and expanding access to quality education, harnessing the capacity of training systems, harmonising education management and integration, and strengthening the science, technology, engineering, and mathematics (STEM) curricula. This includes disseminating scientific knowledge and promoting the culture of science within African society.

4IR for Emergency in the Education Sector

Given its effect in other sectors, particularly in the manufacturing and service industries with the appearance of Covid-19, there is little doubt about 4IR’s contributions to the education sector, including recruitment, teaching, and learning [38]. When it comes to 4IR’s contribution to teaching and learning, the interactive side of technology is more important,

while current solutions like Blackboard, LCD, Projector can help. In South Africa, during the lockdown, a variety of 4IR tools were unleashed from primary education to higher and tertiary education where educational activities switched to remote (online) learning [39]. These observations reflect that South Africa generally has some pockets of excellence to drive the education sector into the 4IR, which has the potential to increase access. Compared to South Africa, Ethiopia is a country that faced many problems in the education sector as the country is not ready for employing 4IR [40]. The government recommends teachers and students use telegrams during the occurrence of the Covid-19. In general, to my understanding, as Africans are new to the implementation of 4IR and starting to implant STEM education in the education center because of the challenges indicated in section 6.2.1, the continent should prepare to take revenge for the problems the world brings to them.

Theoretical Underpinning

Research on user acceptance of new computing innovations has resulted in various theoretical models for explaining individuals' intention to use technological innovations. These frameworks theoretically originate from information systems, psychology, and sociology. I used a few frameworks such as the Unified Theory of Acceptance and Use of Technology framework, and the use of identification of the environment in the cycle model in this study [41]. Some of the frameworks that have been used to study people's adoption and use of technology include the Theory of Diffusion of Innovations, the Technology Acceptance Model (Davis, 1989), and the Unified Theory of Acceptance and Use of Technology [41-43]. To address the absence of a theory to guide effective integration of technology in education, the Technological Pedagogical Content Knowledge (TPACK) framework was developed by [44]. To this effect, the cycle model was developed by that considers the environment itself on the first hand for integration of technology into the classroom teaching and learning. According to the model whatever the types of technology that are comfortable for the learning and teaching process, the identification of the environment should be there [1]. Hence, for instance, in developed countries, the implementation of STEM education and 4IR is easier than in developing countries [2].

Research Methodology

Research Design

This research study follows an archival research study process. Archival research is a review of existing research studies from a specific period that meet particular criteria [45]. In this paper, I use an archival study to investigate a relatively new area of research and to propose underlying themes for future research on 4IR and STEM education.

Review of Existing Research: Criteria and Procedure

The study purposively selected the sub-Saharan countries those running STEM power currently such as Ethiopia, South Sudan, Kenya, Tanzania, Somaliland, Cameroon, Ghana, South Africa, and Zimbabwe of these more attention was given to both Ethiopia and South Africa as the authors of the articles are from the two countries and four countries were also selected from PASET forum (2019) such as Ethiopia, Guinea, Tanzania, and Rwanda. The researchers directly search the articles published by the author of the countries on google scholar (scholars' publication) and google (published by the government in the year of 2021 calendar) platform on their education system by using the specified database.

For each participant of the study the researchers have used implementation of STEM education and 4IR, challenges and opportunities of implementation of STEM education and 4IR; and future of STEM education and 4IR as key term searching engines for each selected country. A desktop literature study approach was followed to assess the data for answering the research questions of the articles. Journal articles were sourced from online academic databases including Mendeley, African Journals Online, Google Scholar, Unisa library, and Direct Google were systematically searched to identify primary studies.

Analysis and Quality Assurance

This is a guiding paper to further research into the implications of the 4IR and STEM education and it is against this background that its analysis is to be of exceptional quality. The analyses of articles sourced for this study are to be analysed based on archival research practices [45]. The typical bases for analysis are the length of the article and its relevancy. The quality assurance procedure follows a step-by-step procedure that includes: (1) sourcing relevant articles to (4IR and STEM education), (2) reviewing each of the articles, (3) qualifying or disqualifying article(s) as part of analysis (4) validating key information of the chosen (qualified) article and (5) tabulating the analysis based on all articles that passed the quality assurance of this research study.

Discussion and Findings

Curricula: Trends to be Implemented in Africa

The level of education of a nation determines the level of development that is experienced. The study finds from the review literature on the trends of the implementation of STEM education and 4IR in schools in Africa. The trends are Experimento and STEM power and prepare Forum [e.g., PASET Forum] in which African countries are working together to implement STEM education and 4IR or which lessons can be learned from each other in the continent. Some university in Africa starts training to skill up their students with the concept of 4IR [18]. This trend should be expanded throughout the continent to compete with western countries, especially in Ethiopia.

Challenges of Africa to Implement STEM Education and 4IR:(SIB Challenges)

The study finds three major challenges as factors of STEM education and 4IR implementation in the continent. These three broad factors are human skills, infrastructures, and Resources[budget] or in short SIB factors which align with the findings of [18]. According to some academics, the number of job seekers not only in Africa as a globe has increased as human labor is replaced by machines, and some jobs are offshored because of robotization, autonomous driving, dematerialization which may be considered as a factor [26].

Themes	Factors
Human skills 	<ul style="list-style-type: none"> ✚ Supply of managers ✚ Weak of governance ✚ Capture research ✚ Governance structure ✚ Technical experts ✚ Implementation strategy ✚ Pedagogical adaptation ✚ Teacher development
Infrastructures 	<ul style="list-style-type: none"> ✚ Location [e.g., Africans and Western countries] ✚ Supply electricity
Budget	<ul style="list-style-type: none"> ✚ Inequality

Future and "Future in the Present" of Africa for the Implementation of STEM Education and 4IR: Forecasting

A) identifies three distinct features of the Fourth Industrial Revolution: velocity, scope, and systems impact. Velocity refers to the speed at which 4IR technologies are spreading and evolving [27]. These technologies have the potential to increase the speed, efficiency, and sustainability of the production of goods and services including in Africa. Strengthening national competitiveness (The Russian Federation said "artificial intelligence is the future not only of Russia but of all of mankind. There are huge opportunities, but also threats that are difficult to foresee economic perspective, today. Whoever becomes the leader in this sphere will become the ruler of the world"). Economic perspective, in the early 1990s, Michael E. Porter, a professor from Harvard University, pointed out that "a nation's competitiveness depends on the capacity of its industry to innovate and upgrade". This point well supports that national competitiveness is highly correlated with national innovation capability. AI, as a leading frontier technology, can potentially be accelerating the pace of innovation, enhance the productivity of a country, and strengthen national competitiveness. In general, the study presented the author insights in three main time-frame 1) Future (Long-Term Vision), 2) Forecasting Models and Methods to Support This Vision and 3) Future in the Present" (Emerging Realities & Immediate Trends)

A) Future (Long-Term Vision)

This refers to the ideal or intended state of STEM and 4IR implementation in Africa over the next 10–30 years.

1. Universal Access to Quality STEM Education

- A. Integration of STEM into national curricula from early childhood to tertiary levels.
- B. Gender-equitable access, especially for girls and marginalized communities.
- C. Competency-based and inquiry-driven learning environments.

2. AI-Driven and Tech-Infused Education Systems

- A. Widespread use of AI, robotics, and IoT in classrooms.
- B. Personalized learning paths through adaptive learning platforms.
- C. AI-enhanced teacher professional development.

3. Pan-African Research and Innovation Hubs

- A. Regional centers of excellence in STEM and 4IR research (e.g., smart agriculture, climate tech, bioinformatics).
- B. Strong university-industry-government linkages for technology transfer and innovation.

4. Digital Sovereignty and Infrastructure Expansion

- A. Africa-led platforms for EdTech, cloud computing, and data security
- B. Massive investments in broadband connectivity, even in rural areas
- C. Creation of African standards for digital education and 4IR ethics.

5. Future-Ready Workforce

- A. Alignment of STEM education with labor market demands in 4IR sectors: robotics, biotech, renewable energy, fintech.
- B. Reskilling and lifelong learning systems for adults in a constantly changing economy.

B) Future in the Present" (Emerging Realities & Immediate Trends)

This reflects current trends and transitional stages that signal the shaping of Africa's future in STEM and 4IR.

- A. National STEM and 4IR Strategies
- B. Countries like South Africa, Ethiopia have launched national 4IR strategies or AI policies.
- C. Investments in coding academies, STEM high schools, and digital universities.

Partnerships and Regional Collaboration

- A. Initiatives such as PASET (Partnership for skills in Applied Sciences, Engineering and Technology), African Union's Agenda 2063, and Next Einstein Initiative.
- B. Collaborations with China, the EU, and USA on digital and AI education initiatives.

EdTech and Blended Learning Adoption

- A. Rapid use of online platforms (Google Classroom, Moodle, WhatsApp learning).
- B. Increased uptake of tools like GeoGebra, Arduino, Scratch, and VR/AR for interactive STEM teaching.

Grassroots Innovation and Entrepreneurship

- A. Innovation hubs (e.g., iHub Nairobi, Ethiopia's Sheba Valley) fostering young techpreneurs.
- B. Youth-led STEM clubs, maker spaces, and AI hackathons emerging in secondary schools.

Challenges Being Actively Addressed

- A. Policies are being adapted to bridge the digital divide.
- B. Teacher training for digital pedagogies and 4IR literacy is increasing.
- C. Donor and government-led programs now target girls' participation in STEM.
- B) Forecasting Models and Methods to Support This Vision
 - A. Delphi Method: Engaging African STEM experts to co-create scenarios for the continent's digital future either by using Blended learning or Integrating AI in Blended learning
 - B. Futures Wheel: Mapping direct and indirect consequences of emerging technologies in African education.
 - C. Scenario Planning: Preparing for high-connectivity vs low-connectivity futures in rural Africa.
 - D. Trend Extrapolation: Using data from EdTech adoption, mobile penetration, and STEM enrolment.

Conclusion

As STEM education in 4IR is a new paradigm by technology and knowledge, its impact will give on everybody and everywhere. However, it is not easy alone for almost underdeveloped countries of Africa to prepare the strategy and implement it because of too wide even they understand and want.

Most, if not all, African countries are still looking for solutions to the education systems, socioeconomic, and political problems that their inhabitants face. Since the inception of the fourth industrial revolution, technology has restructured and intensely dictated the world's fundamental teaching and learning methods through digital technology. STEM education within the fourth industrial revolution era has become the main driving force in improving higher education worldwide. In higher education, it is believed that the rapid advancement of technology has created an efficient teaching and learning environment in the twenty-first century by developing a center of incubation. Having this as the starting idea, the main aims of the study were to elevate the challenges and find out the possible trends of African countries to implement STEM education and 4IR in the continent. This research is to provide strategy and method for implementation of 4IR of Africa country through analysis and review of methodology and characteristics of several materials and research papers. The study used the archival research study process to investigate the searched articles to answers the research questions aligning with the theoretical underpinning of the study that helps to forecast the action to be taken to implement STEM education and 4IR in Africa to conceptualise and contextualise the 4IR and STEM education. The findings reveal that some trends were implemented in Africa such as Experimento and STEM power. I took this as the best trend for African countries to implement within the continent cooperatively. There is also a forum [PASET Forum (2019)] that was prepared by the African counties to discuss the hot issues of the world 4IR. Besides these trends, the study finds out the challenges that the African countries are faced and will be facing within the continent. These challenges are human skills, infrastructures, and Resources[budget] and to some extent Fear of Loss of Job.

Recommendation

As STEM education is based on 4IR, it is better to bring the knowledge of 4IR to STEM education centers in Africa. The study recommends that African governments should adopt modern technology to grow their economies while minimising risks that can be triggered by this advanced technological revolution. Institutionalize STEM and 4IR in National Education Policies: Governments should embed STEM education and 4IR principles into national education policies and strategic frameworks. This includes aligning curriculum reforms with digital economy goals such as "Digital Ethiopia 2025" and the "5 Million Coders" initiative. Expand Digital Infrastructure and Access: Invest in equitable digital infrastructure across urban and rural universities, ensuring reliable internet access, electricity, and digital devices to support blended and online learning environments. Strengthen Faculty Training in Digital Pedagogy: Develop national-level continuous professional development (CPD) programs for higher education instructors focused on STEM content delivery, digital literacy, AI tools, and blended learning methodologies. Establish Public-Private-Community Partnerships (PPCPs): Foster multi-stakeholder partnerships to mobilize resources, share innovation, and scale successful STEM and

4IR models such as STEM-power and Experimento across institutions. Monitor and Evaluate Implementation through Data-Driven Systems: Develop national monitoring and evaluation frameworks to track progress in STEM and 4IR integration, using data analytics to inform policy adjustments and evidence-based decision-making. Promote Equity and Inclusion in Digital Transformation: Ensure that all reforms address the needs of marginalized populations, including women, students with disabilities, and rural learners, through targeted support and inclusive program design.

Declarations

Availability of Data and Materials

The data and materials used in the current study are available in the articles

Competing Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Acknowledgements: All views and results of this study are only that of author.

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