A NOVEL PEDAGOGICAL TOOL FOR CHILDHOOD EDUCATION IN STEM AND STEAM TOWARDS ACHIEVING SUSTAINABLE DEVELOPMENT GOALS IN AFRICA

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Abstract

The integrating of Science, Technology, Engineering and Mathematics (STEM) and Science, Technology, Engineering, Art and Mathematics (STEAM) in Early Childhood Education in developing countries has proved to be a workable strategy in enhancing inclusive and equitable quality education and lifelong opportunities for all (SDG 4) towards achieving Sustainable Development Agenda by the year 2030.This paper presents a critical review of early childhood education in Africa, its impacts, benefits, challenges and plausible remedies. Theoretical frameworks in use were x-rayed with basic characteristics and types of pedagogical tools highlighted. A firsthand experience of non-formal, community-linked and integrated approaches, STEM Play cycle and Culturo-Techno-Contextual Approach (CTCA) to STEM and STEAM education at childhood stage was carried out in Ekiti State, a rural –urban setting in densely populated Nigeria for this case study research. The role of culture and influence of environment in learning were showcased.

Keywords: Children, Non-formal, STEM/STEAM, Education, Community

Introduction

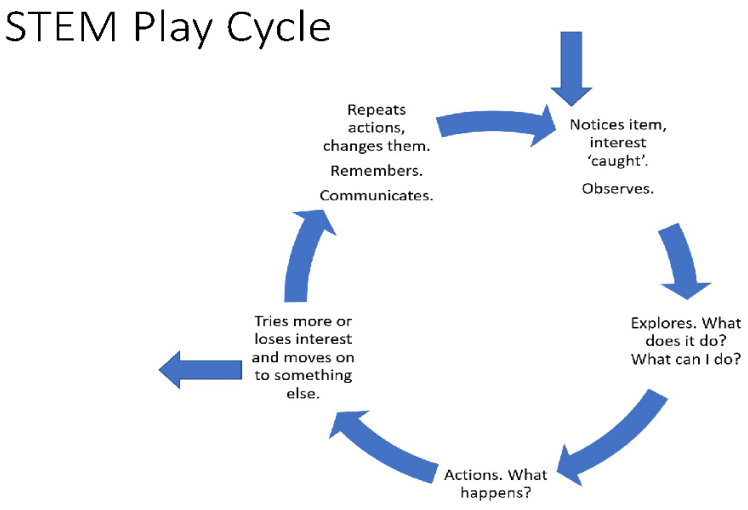
The success rate of achieving sustainable development goals is hinged on 'Ensuring inclusive and equitable quality education and promotes lifelong learning opportunities for All' (SDG 4) which can only be attained by innovative pedagogical methods of imparting knowledge in STEM and STEAM education at early years.

STEM (Science, Technology, Engineering and Mathematics) education can be developed at all stages of education, from pre-school to the tertiary levels given a favorable learning environment. The integration of Arts (STEAM) in STEM education brought about creativity, innovation, critical thinking, and problem-solving skills with the use of appropriate tools.

STEAM education seems potentially rich to foster creative and innovation in teaching and learning processes of education for sustainable national development. (Kim and Bolger2017). At the onset of STEM learning, home sets the pace for children early in life to be conscious of the activities within their surroundings, hence the need for innovative approaches and strategies to guide against ignorance, promote the culture of science and enable children to be interested in science and technology through a non-formal approach (Ogunlade, 2005) and STEM Play cycle (Tunnicliffe, 2021) for sustainable development. STEM Play cycle creates curiosity and develops skills for investigation and observation in children.

The STEM Play cycle starts with the interest of the children caught, followed by observations, explorations, actions, sustenance, and communication as shown in Figure 1.

Figure 1. *The STEM Play Cycle (Tunnicliffe,2021)*



STEM and STEAM education can be built by shifting the emphasis from rigid, formal methods of teaching to more interesting, creative, and innovative approaches to science teaching and learning processes that revolve round the day-to-day activities.

STEM and STEAM Education towards Sustainable Development

There is a direct correlation between STEM (Science, Technology, Engineering and Mathematics) and STEAM (Science, Technology, Engineering Arts and Mathematics) in Early Childhood Education; therefore, workable strategies need to be adopted to sustain children's interest for sustainable development. For example, a wide variety of activities that challenge children's thinking, observing, and generalizing using a non-formal approach supports STEM and STEAM learning such activities are revolving round home setting and schooling system that require mental functioning and encourage learning.

Outdoor learning and field trips that are centered on nature, animals, plants, seasons, and weather stimulate concept learning and integration of knowledge of the environment. Home Science include mothers-children's interactions, cooking projects as related to children's eating habits; Use of blocks as a medium for continuous learning; Water play in teaching STEM concepts of volume, measuring and numeracy numbers are of great benefit.

Early Childhood Education in Africa

Early Childhood Education (ECE) is a starting point for a child's development. It is taken as the key foundation of educational system in any country. (Obiweluozor, 2015). ECE is centred on the vital developmental platforms, abilities, and ideas that children pick up at this time in their lives, from social and emotional development to the emergence of reading, numeracy, and critical thinking.

Africa has a population of over one billion people and comprising of 54 countries but plagued with myriads of challenges, ranging from food insecurity, poverty, increasing population, impact of climate change and poor policy implementation (Hassan, 2023). Early childhood education plays an important role at the basic levels of learning in sciences and arts but unfortunately it is affected by socioeconomic challenges in Africa. Early childhood education which is the first tier of educational level (pre-primary schooling) is poorly developed despite its importance and significance in preparing children for conventional schooling. (Obiweluozor, 2015).

According to Curries (2001) and McCoy *et al* (2018), pre-primary development is significant and is a major contribution to school readiness of children, prevention of repetition and strengthening of school performance among children. The Organization for Economic Co-operation Development (OECD, 2006) considers the growth of high-quality Early Childhood Care and Education to be a crucial economic indicator for evaluating the health and future posture of a nation, in addition to preparing children for an all-round development. However, only 27% of children are reported to attend Early Childhood Education in Africa compared to 61% in another developed continent (Badiel, 2011). This accounts for a poor turnout in Early Childhood Education with resultant aggravated poverty.

Categories of Early Childhood Education in Africa

There are three categories of Early Childhood Education comprising of public, private and community services. These are usually established in cities, rural and remote areas. They are operated under different types of institutions such as Local, State and Federal within specified age range.

For community services, early childhood education is operated as Crèches (0-2years), Koranic schools, Community huts and pre- primary schools that are financed and managed by the national or international non- governmental organizations.

Pre- primary school and day-care centres do exist under the private services while the public services run day nurseries (3-6years) and Elementary classes (5-6years) managed by the Ministry of Education (Lawrence and Sharrock 2021).

Importance of Early Childhood Education in Africa

Education is one of the fundamental pillars as far as a country's developmental process is concerned; however, the lack of access to early education in Africa has affected the progress of African continent.

In Africa there are so many places where access to early childhood education is limited for the citizen due to poverty, corruption and bad leadership, the menace of poor education has contributed to the growth of violence, crime and unemployment In Africa there are so many places where access to early childhood education is limited for the citizen due to poverty, corruption and bad leadership, the menace of poor education has contributed to the growth of violence, crime and unemployment (Mellah *et al* 2022). Quality Early Childhood Education is one of the most powerful agents for change and sustainable development of a country, hence ECE aims to push, inspire, and nurture children during their early years which offer them the best opportunity for a healthy development.

Learning at the early stage positively influences the development of the cognitive, psychomotor, and affective domains in children. Furthermore, ECE lays the groundwork for continual cognitive development. According to a report by UNICEF (2019), 90% of children's brain develops before age 5.Learning cognitive and stimulation at this age help to provide solid foundation for other schooling activities and hence the belief that early childhood education will provide the needed human resources for future development (UNICEF, 2019).Recent studies have revealed that between birth and three years of age, the human brain generates most of its neurons and is most susceptible to learning. In fact, the development of active brain circuits depends on the assimilation of incoming information. (Shonkoff & Phillips, 2000). A child's physical, intellectual, emotional, and social development and the early years of life are critical because early learning occur between birth and age six along with the growth of mental and physical capacities.

Benefits of Early Childhood Education in Africa

The benefits of Early Childhood Education include:

1. Proved social skills through interactive play and communication with their school mate in a conductive pre -school play environment.
2. Eagerness to learn through exposure to novel/unconventional activities such as singing, play let rhymes.
3. Encouraging holistic development through building the child's cognitive, physical, social and emotion sufficient with counting and sorting (mathematics)
4. Boost self-confidence through interaction with other children and teachers displaying a level of boldness in articulation and positive mindset.
5. Enhanced attention span through painting, drawing, and playing with toys.

Challenges of Early Childhood Education in Africa

The extremely low rate of early childhood education in Africa where 1 in 4 children aged 3-5 attend some form of pre- school in Africa (Kabiru, 2017)are due to the following challenges: workplace burnout due to stress, staff shortage, low motivation for teachers and caregivers, inadequately trained teachers and caregivers, lack of learning materials, mental health concerns, lack of resources, safety issues, low level of compensation and ever-evolving technologies, lack of parental involvement, and lastly inadequate communication (Akinrotirni & Olowe, 2016). In addition, there are operational gaps in early childhood education centers due to lack of supervision and inspection of the pre-primary schools. Furthermore, there is no provision in teacher education programs for specialization in early childhood education and thereby the standard and quality of education are compromised.

Learning Barriers Confronting Early Childhood Education

There are some barriers confronting children learning in STEM and STEAM, these are cognitive, physical, mental, emotional, cultural, language, social and environmental as follows:

- ***Cognitive Learning Barrier (CLB):*** This limits the development and functions of children in social and practical skills that are needed in the classroom environment. Children's memory, problem solving skills, attention, reading, verbal, numerical and visual comprehension are affected.
- ***Emotional Learning Barrier (ELB):*** This is related to the emotions of children such as enjoyment, anger, fear, anxiety, boredom, pride, hope, or shame (Goetz & Perry, 2002). The most common emotional learning barriers occur due to peer pressure, fear of failure, judgment, rejection, emotional sensitivity, adjustment to change and embarrassment (Nash and Schlosser 2014).

- ***Environmental Learning Barrier (EnLB):*** These are the obstacles in the immediate surroundings of a child that can negatively influence their learning and behavior such as classroom management, size, time, space, resources available teacher- student ratio (DaRosa et al., 2011; Moore & Hansen, 2012). Environmental barriers could result in negative behavior, indifferences, lack of consecration in classroom discussion or weak connection between the student and teacher.
- ***Cultural Learning Barrier (CuLB):*** This barrier to learning occurs due to the influence of culture on children which in turn affects their perspectives to learning (Vulcan, 2018). According to Nunez *et al* (2017), the most common cultural barriers that can affect children are communication that is related to language, the meaning, interpretation of words, signs, and the motives of the conversation.
- ***Language Barriers (LB):*** Children facing language barriers are unable to have strong connection to the teacher, peers, community, and themselves. They find it difficult to freely express their thoughts, emotions, and feelings (Imberti, 2007).
- ***Mental Health Barriers (MB):*** Mental health barriers to learning STEM in children is their perception and coping threshold to stress, decision making, and capacity to participate with their family, community, and peers (Lean, Colucc & Fullan, 2010).
- ***Physical Learning Barriers (PLB):*** The physical learning barriers are visual and auditory impairments or speech and communication difficulties.
- ***Social Learning Barriers***: This is connected to the social development of children and the social skills that a child gains in STEM such as language, numerical skills, interpersonal skills, understanding of social cues and behaviors of others. Lack of development of social skills leads to lack of personal development that might result in learning difficulties in children (Damirchi, 2013)

Theoretical Frameworks

Over the years, there has been a variety of pedagogical tools in use to disseminate Science, Technology, Engineering and Mathematics (STEM) concepts. The onset and growing awareness of digital technological approach in teaching/learning process requires an emergence of innovative pedagogical tools such as non-formal approach (Ogunlade,2005), STEM play cycle (Tunicliffe,2021) and Culturo-Techno-Contextual Approach CTCA (Okebukola *et al*2022). Oladejo *et al* (2023) reported the efficacy of Culturo-Techno-Contextual Approach (CTCA) in reducing learning anxiety and promoting meaningful learning of chemistry among students.

This paper presents pedagogical tools for early childhood education in STEM and STEAM towards achieving Sustainable Development Goals through community- based approach, STEM Play cycle and using CTCA, as a method of learning by children at infancy. It was proposed that this may address challenges and barriers posed by traditional methods of integrating STEM and STEAM concepts in early years by their teachers. Incorporating STEM in early years through building blocks and identifying shapes has improved vocabularies, reading, numeracy and critical

thinking of children. STEM Play cycle creates curiosity and develops skills for investigation and observation in children as shown in Figures 2, 3, 4, 5 and 6.

Figure 2. *Children building blocks. Photo used with parental permission.*

Figure 3. *Children in critical thinking mode. Photo used with parental permission.*

Figure 4. *Children with investigation and observation skills in a home garden. Photo used with parental permission.*

Figure 5. *Culturo-Techno-Contextual approach to STEM. Photo used with parental permission.*

Figure 6. *Teaching /learning STEM using play cycle at a workshop. Photo used with parental permission.*

Non- Formal Approach to Teaching and Learning of STEM and STEAM Education

The conventional schooling system (formal approach) is not adequate for effective childhood education in STEM and STEAM, hence the need to complement it without -of- school activities (non-formal approach) especially for children. The diverse and dynamic nature of scientific knowledge poses several challenges as to the effective ways of disseminating its basic principles to learners especially of tender age. One non-formal approach for children is termed Children Science Clinic. Children Science Clinic is an annual workshop, aimed at getting children at tender age to learn and 'live' science. The motto of the project is "Catching them Young for Science". The 'Clinic' is intended to stimulate and create awareness in children in a world of growing scientific networks (Ogunlade, 1999).

This approach creates healthy scientific and technological cultures that influence education for entrepreneurship purposes. Children Science 'Clinic' with its novel approach and innovations affecting existing orientation, organizational structures, logistics and the inherent rigidities of formal educational systems in Nigeria.

According to Combs (1989), Non formal Education (NFE) is a bewildering variety of educational activities, consciously organized and operated outside the structure of the formal education system. They are generally free of rules, regulations, and conventions, designed to serve the interests and learning needs of children. To address children's education in the 21st century, Children Science Clinic adopts integrated programs in which learning of context with culture, evolving technology, and appropriate pedagogical tools to achieve broader developmental objectives of non-formal education. The goal of the program is to popularize Science and Technology among children and to enable them to play an active role in the process of development and acquire new knowledge to improve social and economic life of society.

Pedagogy As a Tool for STEM And STEAM Education

Pedagogy is the method and practice of teaching, especially in relation to academic subjects or theoretical concepts (Li, G., 2012). Pedagogy can refer to all levels of teaching from pre-primary, nursery and primary to higher education. it is the relationship between learning techniques and culture. This factor puts emphasis upon the point that pedagogy contributes in an efficient manner in enriching the culture of the educational institutions at all levels. It is determined through the norms and beliefs of the educators regarding how learning should take place. The procedures need to be effectual, meaningful, and worthwhile. The strategies that are put into operation should render a significant contribution in facilitating the achievement of academic goals (Johnson *et al* 2014). Pedagogical tools encourage teamwork for children to develop mutual understanding and work in co-ordination and integration with each other through significant learning strategies.

Pedagogical Approaches

There are 5 different Pedagogical approaches, these are:

1. ***Constructivist Approach:*** The constructivist approach is based on the concept of learners creating their own understanding of the world around them and this understanding is based on the experiences through their everyday lives as they grow (Pritchard and Woollard, 2012). This approach is handy for allowing learners to take a more active role in the learning process as it encourages them to use their previous knowledge as a foundation for understanding new concepts as opposed to passively receiving information.
2. ***Collaborative Approach****:* The collaborative approach is the idea that learners work together to gain a greater understanding of the information. The strength of this approach is that learners can capitalize on each other's understanding of the information, and even their unique skills and resources (Laal and Laal, 2012). This process allows for learners to create an environment where people can interact with each other by sharing experiences and knowledge. This can be done in a variety of ways, including exchanging ideas and information, evaluating, or monitoring somebody else's work.
3. ***Reflective Approach***: The reflective approach focuses primarily on analyzing what the teacher and learners are doing in the classroom. It encourages thinking about teaching practices and figuring out ways to improve them to make learning processes more effective for learners. This can be done through processes such as self-evaluation and self-reflection.
4. ***Integrative Approach:*** The integrative approach differs from the other teaching approaches in the sense that it tries to provide learners with an environment where they can make connections between the current topic they are learning about and other topics they will come across at different stages of the curriculum (Roegiers, 2016). This means that it tends to focus on specific connections between different bits of information rather than facts in isolation. While this approach is more commonly used in higher education,

it can still be quite useful at other stages of education too as it can help learners gain a broader understanding of the world around them by linking together bits of related information. Studies have shown that this kind of approach can help learners stay engaged on the topics they are learning about.

5. ***Inquiry-based Approach:*** The inquiry-based approach is a unique approach of encouraging learners to engage in exploration, investigation, research, and study (Rabih, 2007). It begins with presenting questions, scenarios or problems that require critical thinking to solve problems, which is vastly different from other approaches where facts are presented in a simple manner. This approach requires more than just simply giving the correct answers to questions and encourages more thoughtful and engaged participation from learners (Pedasta *et al, 2017)*. This makes it incredibly effective when teaching science, as many science topics are more easily learned through an understanding of processes rather than isolated facts.

Table 1. Process skills used in STEM/STEAM science activities by children.

Circus Items / Process Skills	1	2	3	4
Raising Questions	Children Interaction Plants & Animal Kingdom.	Health time ABC of Dental Hygiene.	Science Essay Competition. Science has done better to man than art.	My rights as a road user.
Prediction	The language of Science is Mathematics.	Science puzzle.	Science Career Compass.	Weather Control.
Observing	One world in danger.	Weather Observations.	Use of the System (Eye watch).	Classification of plants and Animal Kingdom.
Hypothesizing	Paper Pencil Activity.	Group activities.	The world around us.	Composition of water.
Measuring and Calculating	Reality of Mathematics.	Weather Recording.	Nutritional Assessment.	Buying and Selling in the market**.**

Manipulating Materials	Conversion and Transfer of Energy.	Excursion to Science based Industries.	My little world of computer.	I belong to Computer age.
Devising and Planning	Air has weight.	Science games e.g., snakes & ladder.	Causes and Prevention of fire.	Prevention is better than cure Malaria, HIV/AIDS.
Designing and Making	Take home project e.g First Aid box.	Making a telephone, Stethoscope etc.	Conditions Necessary for seed germination.	Science is Photographic.
Communicating	The reality of Mathematics to children Areas of plane geometry. Triangle, Rectangle.	Mind your language even in Science.	The language of Science is Mathematics.	Telecommunication, keeping your messages secret.
Finding patterns relationships	Take trip round the world in 30 mins.	Science Crossword puzzle.	Food square.	Blood types & Groups.

Conclusion and Recommendations

Developing countries are striving to come up with newer techniques suitable for their environment and culture to attain the target of SDGs, thereby creating a platform for teaching and learning process of STEM and STEAM education. In this 21st century learners need to acquire strong STEM/STEAM abilities to be competitive at work and in the environment. Thus, development of profound knowledge and skill sets in teamwork, rational thinking, investigative and creative work in all areas of life is essential. The development of STEM in Nigeria has been able to shift the emphasis from a rigid, formal method of teaching to a more interesting inquiry-based, community-integrated approach to science teaching and learning process which revolves around the day-to-day activities of the people. Integrating STEM and STEAM concepts in early years will awaken the hidden potentials of the young children thereby providing them with an exciting avenue to explore, ask questions, and observe activities. An environment where the educators and children are free to express themselves was created. In addition, the environment should include outdoor spaces for early childhood education where children can embark on active inquiry, investigation

and problem-solving which can help teaching and learning of STEM and STEAM concepts. Finally, this paper recommends capacity training workshops, funding, effective monitoring and evaluation processes, and support for the well-being of early childhood educators.

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