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Article

Contemporary approaches to science and engineering pedagogy: A perspective from Nigerian engineering education

Kingsley Eghonghon Ukhurebor[1,*], Grace Egenti[2,3], Imudia Uduehi[2,4], Ikenna Odezuligbo[5], Nihad Saliu Achekuogene[6], Adeyinka Oluwabusayo Abiodun[2,3], Benjamin Sunday Eragbe[1], Adedoyin Abiodun Talabi[2], Grace Jokthan[2], Johnson Opateye[2], Udochukwu Chidiebere Nwankwo[2], Benjamin Maxwell Eneche[2]

[1] Department of Physics, Edo State University Uzairue, Auchi 312001, Edo State, Nigeria
[2] Africa Centre of Excellence on Technology Enhanced Learning (ACETEL), National Open University of Nigeria, Abuja 900001, Nigeria
[3] Department of Computer Science, National Open University of Nigeria (NOUN), Abuja 900001, Nigeria
[4] Nigerian Building and Road Research Institute, Abuja 900001, Nigeria
[5] Department of Physics, Creighton University, Nebraska State 68178, United States
[6] Department of Mechanical Engineering, Edo State University, Uzairue, Auchi 312001, Edo State, Nigeria
*** Corresponding author:** Kingsley Eghonghon Ukhurebor, ukeghonghon@gmail.com, ukhurebor.kingsley@edouniversity.edu.ng

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Abstract: Ensuring access to quality education and career training is a crucial challenge, especially in developing nations. Vocational, scientific, technological, and engineering education are essential for active participation in any community and play a significant role in shaping life perspectives. The ability to sustain competitiveness depends on receiving high-quality vocational, scientific, technological, or engineering education and professional growth. These factors are vital for the long-term growth of prosperous economies and nation-building. Hence, this perspective review attempts to provide information on some contemporary pedagogies in science, technology, engineering, and mathematics (STEM) and science, technology, engineering, arts, and mathematics (STEAM) vis-à-vis scientific and engineering education in Nigeria. The study zooms into the challenges and possible solutions that will promote and enhance pedagogies in scientific and engineering education in Nigeria. The study adopted a perspective review approach in overviewing prior accessible studies (literatures) as well as a methodological framework. It is believed that this perspective review study will serve as a way forward for other developing nations.

Keywords: developing nations; pedagogy; scientific and engineering education; STEM and STEAM education; technology

1. Introduction

The significance of science, technology, engineering, and mathematics (STEM) education in the development of any society cannot be overstated. According to Gutierrez-Bucheli et al. (2022); Ndunagu et al. (2023); and Ukhurebor, Efanodor-Obeten, et al. (2024), STEM education is crucial for fostering creativity and developing innovative solutions necessary for sustainable development in higher education. The primary goal of STEM education is to approach real-life problems with an interpretative mindset, utilizing technology to promote critical thinking and problem-solving skills. This educational approach empowers learners to become researchers, encourages collaboration, transforms mindsets, and contributes to building a stronger society (Amadasun et al., 2024; Hussaini et al., 2023; Ndunagu et al., 2023; Sinan, Nwoacha, et al., 2024; United Nations, 2022). Education in STEM is generally technologically driven in advanced countries, and the number of STEM graduates continue to grow in these developed countries as opposed to developing

countries. These differences have further reduced the economic development gap between developed and developing countries. The low STEM skill output affects science, technology, and innovations, and this arguably leads to inequitable implementation of STEM education in Nigeria, especially the engineering aspects. Hence, there is a need to adopt some contemporary approaches to engineering pedagogy in Nigeria. According to Love and Hughe (2022), developing the content knowledge and pedagogical skills of pre-service educators is essential to delivering high-quality STEM education. In engineering education, one of the most urgently needed study fields has been identified as pedagogical content knowledge (PCK). There is, however, a paucity of studies on PCK in engineering education settings. Thus, Love and Hughe (2022) in their study looked into whether certain courses for teacher preparation and unofficial learning opportunities affected the engineering curriculum and methods that high school teachers taught. According to the "International Technology and Engineering Educators Association (ITEEA, 2020), "high-level professional development is required if teachers of engineering are to effectively integrate methods and information from all STEM disciplines as required by national science, technology, and engineering standards documents (ITEEA, 2020). Multidisciplinary preparation experiences can help teachers of engineering teach science and engineering materials and processes more effectively (Love and Wells, 2018; Love and Hughe, 2022). Consequently, Love and Hughe (2022) suggested that there is a need to particularly draw attention to the wide range of perspectives that should be taken into account when training teachers to teach engineering concepts integrated into STEM curricula that span several disciplines. In addition, researchers, teacher educators, school districts, administrators, and educators can benefit from the formal and informal experiences that were found to be strongly associated with greater levels of teaching engineering materials and practices. To this end, this perspective review highlights some of the contemporary approaches to engineering pedagogy vis-à-vis STEM and science, technology, engineering, arts, and mathematics (STEAM) from a Nigerian scientific and engineering education perspective. The challenges and possible solutions that will promote and enhance pedagogies in engineering education in Nigeria will be highlighted.

2. Overview of STEAM education

STEAM education is a method of teaching that guides students' inquiry, discussion, and critical thinking by using these subjects as entry points. STEAM education seeks to pique children's curiosity and cultivate a lifetime love of the arts and sciences from an early age. All of the STEAM fields—science, technology, engineering, math, and the arts—involve creative processes and don't rely solely on one approach to research and analysis. It is crucial to teach kids current, in-demand skills that will enable students to develop into innovators in an international environment that continues to evolve, both for the student's future and for the benefit of the nation (STEAM Club, 2021).

Students who acquire STEAM education are far more inclined to take thoughtful risks, participate in experiential learning, persevere in addressing problems, value teamwork, and go through the stages of creativity. These are the 21st-century leaders,

innovators, teachers, and students. This multidisciplinary approach is transforming cooking in developing nations and improving air quality in the process. It has also contributed to the creation of products such as the iPhone and the original laptop computer (STEAM Club, 2021).

As rightly reported by the U.S. Department of Education, it's more essential than ever that the young people of our country have the necessary knowledge and skills to solve challenges, make connections between information, and have the ability to collect and analyze evidence to make decisions, referring to the constantly evolving and increasingly intricate world. The foundation of STEM and STEAM education is the development of these abilities (STEAM Club, 2021).

Over the past few decades, research has shown that STEAM which is the introduction of arts and design in the delivery of STEM (Harris and Bruin, 2018), exhibited a higher capacity to address our developmental needs and those of the future generation as illustrated in **Figure 1** as adapted from the "Institute for Arts Integration and STEAM (IAIS, 2024)".

Figure 1. The various aspects of STEAM education.
As adapted from IAIS (2024).

According to some studies, STEAM is a potential strategy for raising teacher effectiveness and student accomplishment (Harris and de Bruin, 2018; IAIS, 2024). In a 2016 study, researchers examined how STEAM instruction affected students' understanding of physical science in grades 3 through 5 at urban elementary schools (Harris and de Bruin, 2018). According to research, students' science achievement improved when they got just nine hours of STEAM teaching (Brouillette and Graham, 2016). According to a different 2014 study, integrating STEAM and literacy can improve students' cognitive development, boost their reading and math proficiency, and enable them to critically analyse both their own and their peers' work (Cunnington et al., 2014). A 2014 study on the connection between student proficiency in reading

and mathematics and theatre arts lends more credence to this. According to the findings, students who received theatre arts integration in their language arts curricula frequently did better in both language arts and mathematics than their peers in the control group (Inoa et al., 2014). Furthermore, secondary teachers' reflections "revealed inter-, trans-, and cross-disciplinary learning shaped by teacher collaboration, dialogue, and classroom organization that fosters critical and creative thinking" (Harris and de Bruin, 2018).

In education, we have operated under the assumption that our goal is to prepare students for a "good job" for far longer than necessary. However, how does that appear? Students are being prepared for occupations that are not even feasible. We have reached a point in time where creating learning environments that are flexible, dynamic, and pertinent is not just feasible but essential. None of us walk outside and declare, "The sky is blue, so that's art", or "That's a tree, so that's science". In and of itself, our world is a stunning, intricate, and multifaceted fabric of knowledge. Why do we think that at a place called school, we have the power or the right to confine it behind classroom doors and masonry walls? One effective strategy to help our children get off the "school merry-go-round" and vary their usual pattern of study is to integrate concepts, themes, standards, and assessments. It uses the actions we take when we let the actual world in and incorporates those similar activities into our teaching and learning cycles. At last, we can take down the classroom doors and brick walls to reach the core of education (IAIS, 2024).

2.1. Movement from STEM to STEAM

One aspect of STEAM is STEM. The practical application of science, technology, engineering, and mathematics through art and design is the main focus of STEAM education. Another way of looking at this is that STEAM teachers can assist students in making connections between art practices and design aspects and the concepts that they acquire in these important disciplines (STEM). In the end, students should have the confidence to question, reflect, enquire, and create (STEAM Club, 2021).

Over the past few years, the STEM to STEAM revolution has gained traction and is gaining momentum as a constructive approach to genuinely address the demands of the 21st-century industry. STEM education leaves out several essential elements that many parents, educators, and organizations have stressed are necessary for young people to succeed in the now and the swiftly near future (Harris and de Bruin, 2018; IAIS, 2024).

The necessity for more STEM "programs" in our educational institutions has been widely declared. The reasoning is straightforward: a workforce skilled in growing fields like science, technology, engineering, and mathematics will ride the wave of economic growth in the future. The crucial process of creativity and innovation is absent from these projects, even though they are a fantastic place to start when exploring these four academic fields (Harris and de Bruin, 2018). While there may be greater opportunities for hands-on learning for students in STEM programs, these options are restricted to science, technology, engineering, and mathematics. Our economy demands application, creativity, and innovation far more than it does

knowledge of these subjects. These essential elements are not fostered by STEM alone (IAIS, 2024).

Integrating STEM principles into the arts is how STEAM brings the benefits of STEM to a whole new level. STEM is elevated to a new level by STEAM, which gives students access to a wide range of learning opportunities by integrating their studies in these vital subjects with artistic practices, elements, design concepts, and standards. Limitations have been eliminated by STEAM and are replaced with incredulity, critique, inquiry, and innovative thinking (Harris and de Bruin, 2018; IAIS, 2024).

2.2. The STEAM model

While the STEAM path can be exciting, it can also pose challenges if one does not fully understand the meaning and use of STEAM. Similar to STEM, STEAM cannot reach its full potential without a few essential elements (IAIS, 2024):

a) STEAM is an integrated approach to education that necessitates a deliberate relationship between assessments, standards, and the planning and execution of lessons.
b) Two or more STEAM standards should be taught and assessed in and through one another to get a true STEAM experience.
c) Inquiry and collaborative teamwork, as well as a focus on learning via processes are the foundations of the STEAM method.
d) A true STEAM project should make use of and influence the veracity of the arts itself.

Educational institutions have to take into account several factors to achieve these aims of STEAM (IAIS, 2024):

a) Cooperative planning with a variety of educators on each team.
b) Modifying the schedule to take into account a new method of instruction.
c) All employees should receive professional development in STEAM techniques and principles.
d) Designing curricula and assessments using STEAM schema mapping.
e) Harmonisation and deconstruction of evaluations and standards seamless methods and procedures for implementing lessons.

2.3. How to apply STEAM: Procedure and outcome

No matter what subject you teach, there are actually six phases (steps) to building a STEAM-centred classroom: "(Focus, Detail, Discovery, Application, Presentation, and Link)" as shown in **Figure 2** as adapted from IAIS (2024). Working through the material and the artistic standards in each phase, you are addressing a major issue or crucial query. The best thing about this technique is that it can be used to support the actual learning process in your STEAM classroom as well as aid in lesson planning. Details of these phases are contained in the IAIS (2024).

Figure 2. The phases (steps) to building a STEAM-centred classroom.
As adapted from IAIS (2024).

2.4. STEM to STEAM in Nigeria

As previously mentioned, the role of STEM education in our national development cannot be overemphasized (Harris and de Bruin, 2018). This fact has long been recognized by the Nigerian government through the funding and promotion of STEM education. However, it has been observed that despite the massive financial support in implementing STEM education policy, Nigeria is yet to reap corresponding positive technological development. In view of this, of recent the "Nigerian Young Academy (NYA)" in collaboration with the "Nigerian Academy of Science (NAS)", the "Nigerian Academy of Letters (NAL)", and the "Joint Admission and Matriculation Board (JAMB)", are carrying out a STEAM education project which is funded by JAMB. The project started with the advocacy visit to key stakeholders of education at national level that included the Minister of Education, the Executive Secretary of the "National Universities Commission (NUC)", the "Universal Basic Education Commission (UBEC)", etc. to sensitize them about STEAM education and the need to have a national policy on STEAM education and its implementation. This was followed by a policy review workshop and policy implementation workshop in Abuja. The program was cascaded to six states, with one state selected from the six geopolitical zones namely; Ebonyi State from the South-East, Rivers State from the South-South, Ondo from the South-West, Nasarawa from the North-Central, Adamawa from the North-East and Sokoto from North West. As of today, this project has covered all the selected states, except for Sokoto state, whose project implementation is scheduled to hold before the end of 2024.

The Africa Centre of Excellence on New Pedagogies in Engineering Education (ACENPEE), Ahmadu Bello University, Zaria, Nigeria recently organized a workshop focused on reducing gender bias in STEAM education. The aim was to raise awareness among female students about the importance of reducing gender bias in STEAM education and to encourage their active engagement in this field, as they are currently

underrepresented. The workshop created a learning environment that promoted collaboration among female students, diversity, and inclusive learning through both onsite and online platforms. It was supported by female scholars in various fields of STEAM who facilitated the workshop by covering topics such as enhancing gender equality in STEAM, turning gender underrepresentation into an innovative opportunity, and leveraging the feminine gender in research. The workshop not only helped bridge the gender gap but also fostered a diverse and innovative STEAM workforce for the future. Results from the learners' satisfaction survey showed a high level of interest and contentment among the participants. The survey results also indicated that sensitization and creating awareness successfully communicated gender issues to female students who were previously unaware of them. The workshop served as a source of motivation for the participants to pursue their career goals, regardless of any obstacles.

According to STEM Club (2021), the following are the roles STEM education has in Nigeria:

a) Active learning for the pupils. Students are empowered to participate in the teaching process when they create STEAM projects that demonstrate STEM ideas. Research indicates that students learn more and retain what they learn when they engage in experiential, creative learning.
b) To assist pupils in acquiring the abilities necessary for success in the future. It is now essential that students leave for college and/or enter employment with a set of well-rounded skills that enable them to adapt to a changing and fast-paced environment, regardless of the exact function or industry.
c) Feel free to share original and imaginative thoughts.
d) Students can learn subjects in various professions by using real-life tangible materials with the aid of STEAM. Every STEAM subject has real-world applications.
e) Using a creative approach, education may once again be enjoyable. A K–5 STEAM curriculum improves students' learning and test scores while making learning enjoyable for them by utilising art projects as an initial starting point for STEM instruction. Students who are actively involved in their studies acquire and retain more knowledge.

The following are companies/clubs that offer STEM/STEAM training in Nigeria, as highlighted by STEM Club (2021):

a) Olabisi Ozo-Onyali, has been running STEAM education in various schools for a few years now under the auspices of Attainables Entertainment Limited (STEAM empowerment foundation and The STEAM club).
b) TechQuest, Founded in 2015, is a non-profit organisation that offers STEM (science, technology, engineering, and mathematics) education to students between the ages of 6 and 16. By providing people, organisations, and educational institutions with the knowledge, materials, and instruments required for STEM education, the aim is to enhance conventional classroom instruction by offering a thorough introduction to STEM subjects in an engaging and cooperative learning environment.

c) Africa STEM and Video Game Research: STEMifying African K–12 kids with STEM experience is a technology, video game, and engineering curriculum provider.
d) STEMers: The organisation wants to promote, uphold, and support young individuals in Nigeria's interests in the STEM disciplines.
e) EDUFUN TECHNIK: A learning organisation that specialises in developing educational programs for kids and young adults to assist them in planning and learning through play, practice, hands-on learning, and learner/student-centred methods of instruction while enabling them to fully engage with technology and, in particular, STEM education through the STEM LAB.

3. ACENPEE revolutionizing the STEM/STEAM fields using new pedagogies

The coronavirus (COVID-19) has lately had an impact on research and academia in STEM/STEAM, and the recent shutdown of laboratories has had a major impact on actual classrooms and laboratory experiments (Abiodun et al., 2024; Nneji et al., 2022; Sinan, Nwoacha, et al., 2024; Ukhurebor, Efanodor-Obeten, et al., 2024; Ukhurebor et al., 2021). This has prompted creative solutions to address this issue. To tackle the challenges associated with instructing science and engineering courses that hold substantial appeal for students in Nigerian educational institutions, a novel teaching and learning pedagogy known as CACPLA- Communicate, Active, Collaborate, Problem-based Solving, Learning, and Assessment (Obada et al., 2023), was developed by ACENPEE, Ahmadu Bello University, Zaria, Nigeria. ACENPEE's mission is "to provide a world-class teaching and learning environment that stimulates and promotes innovation in techno-pedagogical skills and competencies for engineering education and practice. CACPLA is a transitional pedagogy, and the approach incorporates blended learning (**Figure 3** as adapted from Obada et al., (2023)).

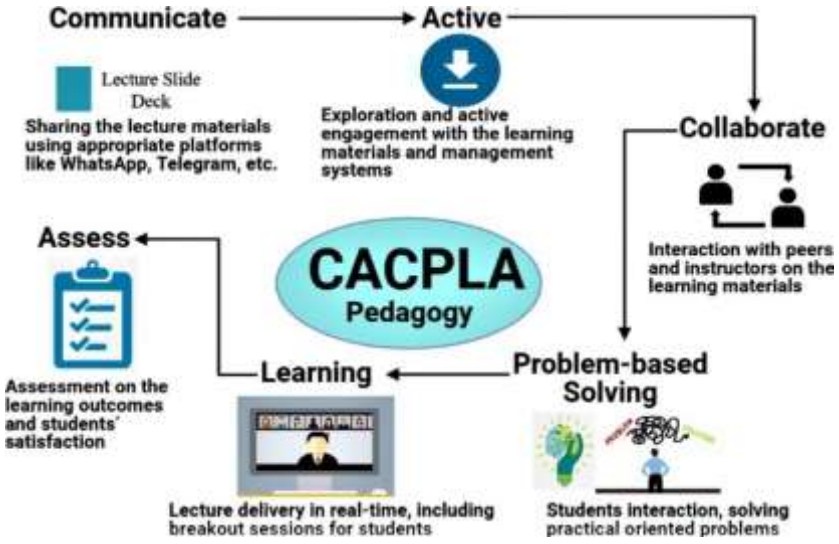

Figure 3. The major components of the CACPLA pedagogy.
As adapted from Obada et al. (2023).

In the study by Obada et al. (2023), they demonstrated how an innovative approach could initiate a gradual shift in various engineering disciplines from traditional classroom settings to fully online training which would be helpful to advance the teaching of STEM/STEAM subjects in Nigeria and globally. The study involved 253 students from third and final-year classes in an experimental group. The instructional materials and environment were carefully planned, and the impact of critical thinking before and after lectures on the student's overall performance was assessed. To gather data, two questionnaires were created: one for technical inquiries and the other for receptiveness. According to the findings of a student poll, the teaching approach was positively received, helping students understand the concept of bioengineering within the context of materials chemistry and mechanical measurements. The results showed that 80% of the students found the blended learning (CACPLA) approach adequate to meet the study's learning objectives. The study suggests that the CACPLA approach, which utilizes platforms like Zoom and Google Meet, can effectively replace traditional teaching methods and advance techno-pedagogical practices in STEM/STEAM subjects. The pedagogy has been highlighted as a quick and cost-effective solution due to the accessibility and convenience of these online platforms.

4. Conclusion

The importance of STEAM education is increasingly relevant. By incorporating arts and design into traditional STEM subjects, STEAM has demonstrated its effectiveness in addressing the developmental needs of today and the future. There is a growing need for innovative teaching methods in science and engineering, and more broadly the STEAM fields, and the CACPLA, developed ACENPEE, align with modern technology. However, more work still needs to be done to enhance pedagogies in science and engineering education, not only in Nigeria but globally, as this is essential for technological advancement, economic growth, and national sustainability.

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