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Article

The role of continuous engineering and scientific education for sustainable development in Sub-Saharan Africa: Insights from Nigeria

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Abstract: The developmental and advancement of engineering vis-à-vis scientific and technological research and development (R&D) has contributed immensely to sustainable development (SD) initiatives, but our future survival and development are hampered by this developmental and advancement mechanism. The threat posed by current engineering vis-à-vis scientific and technological practices is obvious, calling for a paradigm change that ensures engineering as well as scientific and technological practices are focused on SD initiatives. In order to promote sound practices that result in SD across all economic sectors, it is currently necessary to concentrate on ongoing sustainable engineering vis-à-vis scientific and technological education. Hence, this perspective review article will attempt to provide insight from Sub-Saharan Africa (Nigeria to be specific) about how engineering vis-à-vis scientific and technological R&D should incorporate green technologies in order to ensure sustainability in the creation of innovations and practices and to promote SD and a green economy. Furthermore, the study highlights the importance as well as prospects and advancements of engineering vis-à-vis scientific and technological education from the in Sub-Saharan Africa context.

Keywords: engineering and scientific education; engineering practices; environment; green economy; research and development; science and technology; sustainable development

1. Introduction

According to Dunmade (2016), engineering is the practical application of mathematical, scientific and technological concepts for tasks such as process and product design, manufacturing, and operation, while taking into consideration the limitations imposed by the environment, the economy, and other sociological factors. Additionally, Chukwu and Amonye (2022), described engineering as the "application of laws governing forces and materials of nature through research, design, management, and construction for the benefit of mankind." In other words, it is the application of scientific and technological knowledge for the effective use of natural resources to generate prosperity (Chukwu and Amonye, 2022). In order to harness and transform natural resources into fair solutions to the problems at hand, engineers learn tools and procedures in the classroom (Chukwu and Amonye, 2022). Engineering is more than just automating or digitising the globe to increase national power and make living easier (Chukwu and Amonye, 2022; Ukhurebor et al., 2024). The goal of engineering as a profession should be to better society overall. In order to serve society, engineers must acquire a body of specific knowledge, capacity to solve problems, and sound judgement as part of their professional development (Chukwu and Amonye, 2022). The goal of these engineering education areas is to produce engineers who are capable in the real world, have strong intellectual backgrounds, and take ethical responsibility for their work (Chukwu and Amonye, 2022; Obada et al., 2023). Engineering education is a core aspect of "science, technology, engineering, and mathematics (STEM)" education (Chowdhury et al., 2019; Elme et al., 2022; Hsu et al., 2023; Margot and Kettler, 2019; Martín-Páez et al., 2019; Sari et al., 2020). STEM education is important for any society's progress in many different kinds of aspects (Gutierrez-Bucheli et al., 2022; Ndunagu et al., 2023; Ukhurebor et al., 2024a). According to Iboronke (2021), STEM education is essential for fostering the innovative thinking and creative problem-solving that higher education requires for sustainable growth. Consequently, every professional engineer is expected to not only reach a given level of both technological and intellectual proficiency, but in the same way to develop a practical perception that combines knowledge and abilities in a model that best advances a certain goal for the benefit of humanity (Chukwu and Amonye, 2022; Obada et al., 2023; Sheppard et al., 2006).

Modern existence is made possible by the intricate technological frameworks that engineers have skillfully created (Chukwu and Amonye, 2022). Penitently, we were not effective as well at foreseeing and mitigating the unfavorable effects of our works. Being creative entails accountability (Chukwu and Amonye, 2022). Engineers must assume primary responsibility for tackling the pressing issues of climate change by means of efficiency in energy use and renewable energy since they have developed ever-more-efficient methods of removing fossil fuels from the Earth and burning them for human advantage. Since engineers created and constructed automobiles, highways, and roads, they must deal with the environmental and societal issues of traffic jams, urban sprawl, pollutants, and growing costs of fuel. Even though fresh water is rare in many locations, we have constructed water distribution networks that supply homes with an endless supply. Currently, engineers must assist people in finding ways to minimize water waste. Technological systems developed by engineers have revolutionized both the environment and civilization. While we should be happy with our accomplishments, we also need to accept our shortcomings (Bell, 2013; Chukwu and Amonye, 2022).

In every civilization, knowledge is essential. Any society's well-being and resilience depend on its members' ability to learn about one another. This universal principle is attested to by all celestial religions. Higher education institutions, such as universities, are seen as hubs for the creation, dissemination, and application of knowledge for the good of humanity (Gutiérrez-Carreón et al., 2020; Holly et al., 2021; Wu et al., 2020). We work tirelessly to expand and enhance knowledge in order to better the lives of people everywhere. Universities serve as exemplars of discipline, new ideas and values, peace, and optimism for individuals who work and enroll in them (Chukwu and Amonye, 2022). These are institutions that educate and prepare the next generation of scientists, engineers, technicians, politicians, and economics who will be primarily responsible for steering and leading our planet into the future. Since the future is unpredictable, society and humanity as a whole need "managers" who are highly qualified, pragmatic, practical, and, most importantly, morally and ethically sound. They must make the appropriate choices to ensure that society and humanity's hopes, aims, and objectives are realized. The majority of the physical and tangible problems and resources that have been the focus of sustainable development (SD) literature and discussion include population expansion, exhaustion of resources, impact on the environment, climate change, illiteracy and poverty. The list is not all-inclusive, but several critics have overlooked the fact that the most important component and limited resource facing the sustainability concept is not found in the material assets of society, but rather in the moral and ethical principles of "managers"—those entrusted with organizing, supervising, and carrying out an effective program of social and economic development that will allow humanity to continue existing in harmony, peace, and prosperity with the cosmos (Chukwu and Amonye, 2022). Given that the processes and products that engineers develop with their knowledge and experience are the driving forces behind economic growth, engineers are important to the social and economic advancement of every country. Problem solving won't be accomplished at the expense of the environment until sustainability is prioritized and ethically ingrained in Nigerian engineering professionals' work.

Engineers and scientists need to identify innovative solutions to moral conundrums when the demands of their employers or clients collide with the needs of the larger community and environment. Sometimes it's possible to come up with original ideas that resolve criteria that don't seem to go together (Chukwu and Amonye, 2022). For example, requiring efficient in terms of energy building materials or lighting can lower carbon emissions and save money for the building owner. In other circumstances, the engineer might have to alert their customer or company about the moral ramifications of dangerous systems and technology. Engineering professionals have several options for voicing their concerns: they can do so with external groups like regulators or associations for professionals; they can also choose to work exclusively with clients or organizations that share their values, as demonstrated by Bell (2013).

In almost every economic sector of the global economy, including transportation, manufacturing, housing, commerce, agriculture, and communication, engineers allocate resources to power economic activity. The environment provides these resources, which include water, minerals, and fuels. Moreover, wastes resulting from engineering activities (production, transportation, storage, and use) are usually discharged into the environment. **Figure 1** shows the environment as both a sink for human waste and a supply of resources that engineering needs to raise living standards (Dunmade, 2016).

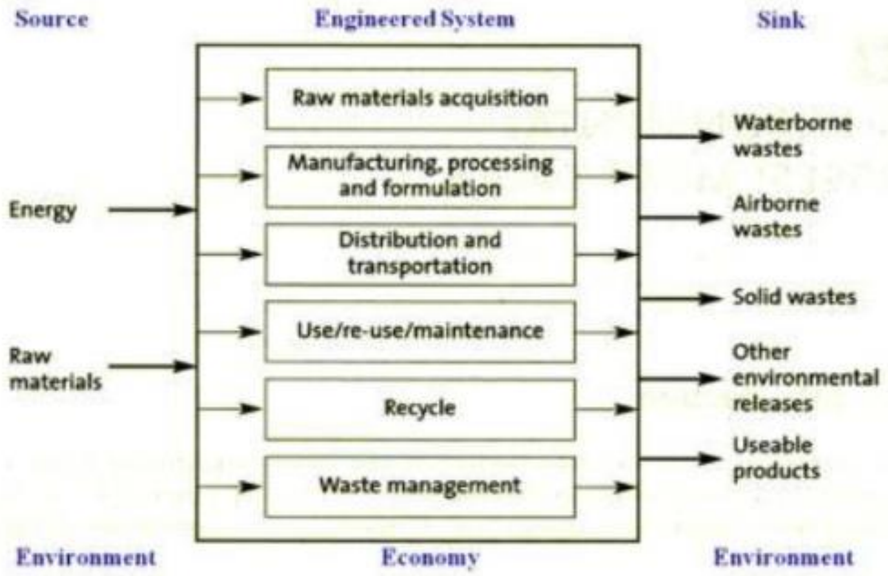

Figure 1. Engineering and the environment (as adapted from Dunmade, 2016).

Our environment is depleted of resources to provide us with home, clothing, transportation, food, and other essentials. However, the earth's potential for productivity has a limit. In order to meet the aforementioned needs, we take resources from the environment on a large number of occasions that are not renewable, and we harvest some resources too quickly for them to replenish. Analogously, the engineering endeavors we undertake to fulfil the previously stated demands for housing, electricity, transportation, and other aspects result in copious amounts of waste and pollution being released into the environment (Chukwu and Amonye, 2022).

The planet can no longer absorb the amount at the current pace of emission due to its enormous capacity. As a result of the massive waste releases and ravenous resource exploitation (Hussain et al., 2024; Nwankwo et al., 2023; Ukhurebor et al., 2023; Ukhurebor et al., 2024c), there is a need to take action to stop this adverse trend, which includes; "resource depletion, biodiversity loss, deforestation, desertification, global warming, ozone layer depletion, eutrophication, birth defects, as well as various diseases" (Kerry et al., 2022; Ukhurebor et al., 2022a, 2022b; Ukhurebor et al., 2021a, 2021b).

The globe is changing into a place where people live in greater density, consume more, pollute more, and are more connected to one another (Chukwu and Amonye, 2022; Ukhurebor et al., 2024b). The idea that humans are changing Earth's natural processes at all scales—from locally to global—at a never-before-seen pace is gaining traction. This has brought up the crucial topic of striking a balance between protecting our ecosystems' capacity for carrying biological and cultural diversity and meeting the demands of a population that is growing at an exponential pace (Hussain et al., 2024). What steps should be taken both now and in the near future to guarantee that everyone has access to clean water, hygienic conditions, food, safety, and fulfilling employment is a linked question. (Chukwu and Amonye, 2022). It is believed that engineers and scientists who develop vast and diverse technologies that have significant adverse effects on the environment and the lives of people around the world are best positioned to successfully mitigate environmental degradation acts by rearranging the ethics of the engineering profession. The connection between science and society is made possible by engineering (Chukwu and Amonye, 2022). Engineers and scientists working on a worldwide basis will assist in fostering the general recognition of the profession and understanding of the requirements and possibilities in today's evolving world so as to accomplish the eventual aim of sound, economically SD in the nation. As such, they have to actively advocate and collaborate in collaborations across disciplines with others in the profession, such as environmentalists, experts in economics, medical specialists, and sociological researchers, to efficiently tackle the issues and challenges of economically SD (Chukwu and Amonye, 2022).

Future generations bear a heavy price for most of Nigeria's current socioeconomic gains. For instance, waste and pollution from resource extraction and careless planning lead to environmental degradation and harm to ecosystems. Engineers and scientists have a major role in planning, resource exploitation, and other developmental strategies and tools utilized (Chukwu and Amonye, 2022). Management of waste, transportation, growth of urban areas, access to green spaces, availability of safe water, and fresh air supply are just a few of the challenges that confront most of the major cities in Nigeria as one of the top countries in Sub-Saharan Africa. These challenges highlight the fact that our developmental strategies and processes are not long-term viable (Chukwu and Amonye, 2022). Our communities' and municipalities' long-term viability is thus in jeopardy. Driving is one instance. Due to energy use, congestion in the roadways, and a decline in the quality of life for individuals involved, long-distance driving is considered unsustainable. As building materials and energy supplies are taken out of ecosystems, this kind of unsustainable growth strains the environment more and more. The difficulty lies in reversing this unsustainable trend and establishing a more equitable and balanced connection with the environment. For the reason that of Nigeria's exclusive reliance on oil and the way its engineers have explored and produced it, environmental contamination has gotten dreadfully out of control in recent years, particularly in the Niger Delta (Ukhurebor et al., 2023). One of the main causes of the contamination in the environment in this area is the exploitation of the significant petroleum resources found there (Chukwu and Amonye, 2022). Pollution and damage to the environment are further increased by the use of the same in transportation and energy provision. If we are to stop putting the lives of our future generations in jeopardy, we need to develop sustainable approaches in the exploration and exploitation of our environment's resources. Hence, this study encompassed an insight review of the available literature that critically studied the previous unsustainable strategies that contributed to the contamination and degradation of the environment that exist today as a result of the procedures and goods developed during the global practice of the fields of engineering, science, and technology. The piece is based on actual events as reported in books and articles. It suggests that all engineering-related professions' professional codes of ethics (COE) include the "Triple Bottom Line (TBL)" model and that curricula include courses on sustainability engineering and science as well as technology.

2. Sustainability and sustainable development

Empowering the world's educational systems to strive towards a more sustainable future is the goal of SD. In a nutshell, sustainability is viewed as an end in its own identity, whereas sustainable development refers to the various means and channels by which it could potentially be attained (Jeronen, 2013). Hence, there is a strong relationship between sustainability and SD. The concept of SD aims to meet the needs of the environment, natural resources, and human development while maintaining the capacity of environmental systems to deliver essential services to humanity economically in particular (Nnadozie et al., 2023; Ukhurebor et al., 2024).

The environment is a product of human actions, goals, and desires; in fact, attempts at protecting the environment in a vacuum from these concerns have given the word "environment" an adverse implication in some political spheres. In the international arena, many people instinctively dismiss the word "development" as being the domain of specialists or those involved in matters of "development assistance" because it has also been narrowed by some to the point of "what poor nations should do to become richer" (Chukwu and Amonye, 2022). However, the "environment" is our home, and "development" is what each of us does to try to make our situation better there. Both are essential to one another (Kates et al., 2005). A process that exhibits sustainability is one that can go on continuously at certain points in time. From the perspective of the environment, the word alludes to the possible lifespan of essential ecological support systems for humans, including the planet's climate system, agricultural, industrial, forestry, and fisheries systems, as well as human communities as a whole and the different systems that they depend on. A decision-making process known as sustainability takes into account the interdependencies and effects of social, economic, and environmental variables on the standard of living of both the present and future generations (Chukwu and Amonye, 2022). A process aims to be inclusive, transparent, equitable, informed, and responsible. It is a dynamic and developing idea (Qureshi and Nawab, 2013).

Environmental, economic, and social sustainability are the three main aspects of general sustainability that are frequently recognized. Attaining environmental, economic, and social sustainability concurrently is necessary for overall SD. It is a difficult task to achieve this balance (Rosen, 2012). When resources such as; "natural resources, industrial products, energy, food, transportation, shelter, as well as efficient waste management" are completely utilized to create jobs and generate revenue for the government in order to further economic development and transform society, then the difficulty of sustainable economic development is addressing human needs while protecting and preserving the environment for future human and capital and economic development (Chukwu and Amonye, 2022; Okoye, 2010).

According to Qureshi and Nawab (2013), the "TBL concept of sustainability" refers to these three fundamental values of "social, environmental, and economic accountability." **Figure 2** shows the basic aspects of the TBL model's representation of the SD domains.

Figure 2. The TBL model (as adapted from Chamberlain, 2023).

One of the primary frameworks utilized by organizations to evaluate the economic benefits resulting from their corporate sustainability initiatives is the TBL (Brusseau, 2019; Chamberlain, 2023). The TBL approach challenges people to look beyond the conventional bottom line of organization and consider the financial, social, and environmental gains the organization achieves. One of the greatest ways to gauge how successful and sustainable the organization is to measure it using the TBL (Chamberlain, 2023).

Social Sustainability: The sustainability of organization's earnings in human capital, including your standing in the community, are measured by the social bottom line. Fair and advantageous employment practices, corporate community involvement, and the effect of the organization's operations on the local economy all contribute to a higher social bottom line.

Environmental Sustainability: The Triple Bottom Line approach to sustainability is based on the idea that an organization will last longer and be more economically viable if it uses fewer natural resources and has less of an adverse effect on the environment. Managing, tracking, and reporting your consumption, waste, and emissions are essential to controlling your sustainability bottom line.

Economic Sustainability: According to the Triple Bottom Line approach, the sustainability of the economy goes beyond conventional corporate capital. According to the Triple Bottom Line approach as reported by Chamberlain (2023), the degree to which your company affects its surrounding economy should be used to calculate your economic capital. Since it enhances the general economic well-being of its support systems and community, the business that strengthens the economy of which it is a part will prosper going forward. Naturally, a company must also be conscious of its conventional profits, and the Triple Bottom Line takes this into consideration.

The procedure of bringing human activity into a pattern that may be continued forever is known as SD (Chukwu and Amonye, 2022). It is a step in the right direction towards growth and environmental challenges that aim to balance human needs with the planet's ability to handle the effects of human activity (Chukwu and Amonye, 2022). According to Dutta and Sengupta (2014), SD encompasses the three primary areas of "social, ecological, and financial responsibility," which together make up the TBL framework (Chukwu and Amonye, 2022).

Therefore, SD entails pursuing social justice, preservation of the environment, and economic prosperity all at the same time. Companies striving for sustainability need to evaluate their success against the TBL rather than just one financial bottom line (Chukwu and Amonye, 2022). The TBL model concept is a business approach that promotes environmental quality, sustainable and economic prosperity, and social development, as an integrated technique for commercial purposes. It goes beyond prior constructs of SD and corporate social responsibility (CSR) (Chukwu and Amonye, 2022). According to Amos and Uniamikogbo (2016), this model suggests that organizations should place more of an emphasis on long-term social, environmental, and economic consequences rather than short-term economic aims.

3. Engineering/scientific education and professional ethics

Science increases our understanding of how the natural environment functions. Engineering then uses this understanding to create practical technologies, which may lead to important discoveries and novel technologies that enable scientists to expand their understanding of the natural environment. The innovative application of scientific concepts to the planning, development, directing, guiding, management, or maintenance of systems that support and enhance our everyday lives is known as engineering. Hence, there is a strong nexus between science and engineering education. A large portion, if not the majority, of global economic activity is driven by engineering, science, and technology in almost every economic area. Additionally, materials utilized in engineering, science, and technology—such as water, minerals, or fuels—come from the environment, and wastes generated throughout the production, transportation, storage, and usage phases of engineering, science, and technology are usually dumped back into the environment (Chukwu and Amonye, 2022). Last but not least, engineering, science, and technology services enable high living conditions and frequently promote social stability in addition to cultural and social advancement (Rosen, 2012). It is clear that an essential component of attaining sustainable economic development is the active involvement of engineers, given the close linkages that exist between engineering as well as science and technology and the essential elements of SD (Chukwu and Amonye, 2022).

People who find solutions to problems are engineers, scientists and technologists. They (engineers, scientists and technologists) are required and are anticipated to make decisions that impact the operation of their business, their own well-being, and the well-being of their community in general, whether it be financially or otherwise. In their work and decision-making, they need to act morally, professionally, and with social responsibility. There are clear costs and advantages to society associated with engineering projects, including building airports, mining, petrochemical and chemical plants, waste management facilities, and petroleum and natural gas extraction. The planned engineering projects may have an impact on the communities that are close to them, either positively or badly. There are advantages and disadvantages to every project, product manufacturing process, or business endeavor, for that matter. The costs involved may be financial or not. Before approving the project, the environmental aspects must be thoroughly evaluated (Al-Rawahy, 2012).

The idea that engineering is about the "triumph of man over nature" is one that is widely believed. It is linked to building enormous dams for the delivery of water and electricity, cutting trade routes through the country, building bridges across wild waterways, building nuclear power plants with power transmission lines marching through the terrain, and launching humans into space. To a certain extent, this was accurate in the past, but one might also be pardoned for believing that engineering and science as well as technology had little to offer with sustainability or even that its goal is the opposite. But during the past twenty years or so, engineering has experienced a revolution in thought, and sustainability is quickly emerging as a pillar of every engineering and scientific practice (Mills et al., 2011). An equilibrium system or one that varies gradually and at a manageable pace is considered sustainable by engineers. Natural ecosystems serve as the best example of this idea of sustainability because they are composed of slowly changing, almost closed loops. For instance, in the food chain of both organisms, plants grow when they are exposed to sunlight, moisture, and nutrients. Afterwards, insects and herbivores eat the plants, and eventually larger animals eat the plants. Natural waste products that are produced as a result restore the nutrients needed for plant growth and the restart of the cycle. Humans must develop patterns that mirror these natural processes if we are to accomplish SD. A closed-loop human ecology that imitates natural systems can be used to demonstrate the responsibilities that engineers play in SD. According to the "Committee on Technology and CH2M HILL of the World Federation of Engineering Organizations (WFEO)" in 1990, this closed-loop ecosystem model was initially put forth (WFEO, 2002).

Numerous studies of engineering, scientific and technological education have continuously recommended for curriculum modifications since engineering education is often out of sync with the demands of contemporary society. Research indicates that the conventional approach to engineering education does not create courses that educate engineers to foresee and concentrate on the swift changes that will shape the 21st century, at least in part. The research suggests that to tackle the intricate problems of the future, contemporary engineers must possess 'a firm grasp of globalization; an appreciation of diverse cultures, particularly their social components; proficiency in collaborating with cross-border teams; awareness and comprehension of sustainability concerns' (Mills et al., 2011).

Engineers and scientists of today should continue to be responsible for supporting the ideas of sustainable development. Sustainable development (SD) aims to maintain and improve the quality of the surrounding environment while providing for current individual needs from naturally accessible reserves. The engineering community is an important one. This forces them to combine their determined efforts to find out all the pertinent information on the conception, creation, functioning, and potential results of all the options that could have an impact on society and the general public, both favorably and unfavorably. According to Dutta and Sengupta (2014), citizens are totally dependent on the planned products and things they purchase, which should be durable, safe, dependable, economically viable, and environmentally sustainable.

The engineering profession has to reevaluate its goals and adopt a new one: to help create a more sustainable, stable, and egalitarian world in light of the issues currently plaguing our planet and those predicted to surface in the first half of the twenty-first century. SD will be unachievable without the full involvement of engineering as well as the scientific and technological profession." In order for that to happen, engineers need to reevaluate how engineering disciplines interact with nontechnical domains and take a whole new stance towards natural and cultural systems. The twenty-first century demands that we start a global shift in engineering practices to one that is more comprehensive. This calls for three key changes in thought process: (a) a radical shift from controlling nature to cooperating with it; (b) an understanding of ecological systems, ecological services, and the restoration and preservation of natural capital; and (c) an entirely fresh perspective on how to improve both nature and humans while embracing the principles of SD. As rightly reported by Qureshi and Nawab (2013), engineers and scientists will play a crucial role in meeting those needs at different dimensions, from isolated small towns to expansive urban regions (megacities), typically in developing nations. If engineers and scientists lack the knowledge to meet these standards, then who else can?

According to WFEO (2016), considering their extremely dissimilar methodologies and traditions, many SD study issues also call for the integration of the engineering sciences and the humanities. As reported by Kelly and Fairfax (2016), the engineering report from UNESCO (2010) places a strong emphasis on sustainability and SD. Under Canon 4 protection of the natural and built environment, sustainability is specifically mentioned in the "WFEO Model COE" for engineering practice (Kelly and Fairfax, 2016). A thorough approach to sustainability in engineering practice is provided by the "WFEO Model Code of Practice" for SD and environmental stewardship (WFEO, 2016).

4. Modern engineering pedagogy

Research and academics have recently been impacted by the COVID-19 pandemic (Abiodun et al., 2024; Nneji et al., 2022; Sinan et al., 2024a; Ukhurebor et al., 2024b; Ukhurebor et al., 2021), and actual classrooms and laboratory studies have been significantly impacted by the recent closure of laboratories which is a core aspect of engineering as well as scientific and technological studies. This has led several innovative studies to deal with this problem, and several researchers and studies such as Ahmed and Opoku (2022); Alkabaa (2022); Amadasun et al. (2024); Mai-inji et al. (2024); Ndunagu et al. (2023); Rosario et al. (2022); Sinan et al. (2024), have attempted to offer innovative solutions. The significance of the results from these studies lies in their potential to assist educational decision-makers in improving the sustainability and quality of e-learning materials as well as virtual laboratories for STEM. In order to test the novel pedagogy, "Communicate, Active, Collaborate, Problem-based Solving, Learning, and Assessment (CACPLA)," on the learning outcomes of fourth-year civil engineering students at the "Ahmadu Bello University (ABU), Zaria, Nigeria", Eberemu et al. (2022) implemented it into a standard geotechnical design foundation course. It was determined that implementing the CACPLA pedagogy can increase students' interest in learning about geotechnical engineering. The backward design methodology can be used to teach engineering, scientific, and technological courses more successfully, as demonstrated by Obada et al. (2021). The backward design method was applied to contextualize five case studies of undergraduate engineering, scientific, and technological courses. It was determined that experiential learning goals may be assessed in real time in the classroom by emphasizing unique learning outcomes, coordinating assessment techniques, and utilizing all facets of the curriculum and instructional resources.

In an attempt to further address the difficulties involved in teaching engineering as well as scientific and technological courses that are highly attractive to students in Nigerian universities, a team of researchers (Obada et al., 2023) in the "Africa Centre of Excellence on New Pedagogies in Engineering Education (ACENPEE), ABU, Zaria, Nigeria," which is a "World Bank-supported Centre of Excellence for development impact," developed an improved innovative teaching and learning approach; the CACPLA. This CACPLA employs blended learning as part of its transitional pedagogy (see **Figure 3** as adapted from Obada et al. (2023)).

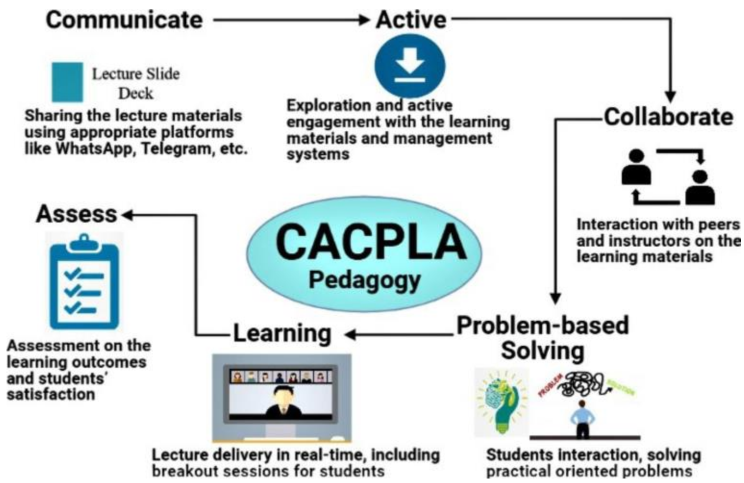

Figure 3. The main mechanisms of the CACPLA pedagogy (as adapted from Obada et al., 2023).

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".

Obada et al. (2023) show in their study how this novel strategy can initiate a phased transition for several engineering specialties from in-person classroom settings to totally online teaching. This approach has been explored as a module activity in a "Biomedical Engineering" degree program that can be combined with local enterprises and research facilities in sub-Saharan Africa. 253 students from third- and final-year classes made up the experimental group, and the classroom setting and resources were carefully thought out. Furthermore, the effect of critical thinking on students' overall performance was assessed before and after lectures. Two questionnaires were made with the intention of collecting data: one for technical questions and the other for receptiveness. Students felt that the teaching technique helped them understand the general idea of bioengineering in the context of materials chemistry and mechanical measurements. This was indicated by the results of a poll that was taken among the students. According to the findings, 80% of the students thought the blended learning (CACPLA) strategy was sufficient to achieve the learning goals of the study. The CACPLA approach can be utilized in place of more conventional teaching pedagogies and workshops because Zoom and Google Meet are so accessible and convenient. It can be swiftly and reasonably put into practice. Albeit, details on this newly innovative CACPLA pedagogy are contained in Obada et al. (2023).

5. Conclusion and future perspective of engineering and scientific education for sustainable development

SD initiatives have benefitted greatly from the development and advancement of engineering vis-à-vis scientific and technological R&D; nevertheless, this developmental and advancement mechanism poses challenges to our survival and development in the future. The capacity of future generations to meet their requirements is threatened by the current development that is unsustainable. Human demand is outpacing the ability of the environment to support it, as evidenced by the destruction of the ozone layer, acidification of land and water, desertification and soil loss, deforestation and forest decline, declining productivity of land and waters, and extinction of species and populations. A society in which resource consumption and living standards satisfy human demands without jeopardizing the stability and integrity of the natural system is the ideal situation. There is broad agreement in the literature that the production of electricity, flooding, erosion, and the extinction of aquatic life weaken and deplete the ozone layer, which changes the atmosphere's temperature. The earth will further crumble and flood as a result of the ice melting in these extreme locations, which has grave repercussions. Furthermore, petroleum and natural gas extraction contaminate the land, rivers, and oceans to the detriment of farming, resulting in unsustainable development. Engineers are responsible for carrying out all of these building and development projects, and it is possible to use engineering practice in a sustainable way to promote SD.

Ensuring the high standard of engineering and technological education globally is largely dependent on engineering accreditation and also on accreditation in related fields. The "National Board for Technical Education (NBTE)", the "Nigerian Society of Engineers (NSE)", the "Council for the Regulation of Engineering in Nigeria (COREN)", and other entities in the engineering and scientific profession are urged both individually and collectively to see to it that sustainable engineering and science is taught in all engineering and scientific fields and related disciplines. Any Nigerian university that offers an engineering degree is required to produce graduates who are critically aware of the sustainability of engineering and science and the effects that engineering and scientific work has on the industrial, social, and physical environments. Furthermore, exhibit knowledge of the uncertainties in predicting the relationships between engineering vis-à-vis science and technology and the legal, cultural, economic, social, health, and safety facets of society. Now is the moment to put this conditionality into effect.

The "TBL" approach should be enforced by the necessary practice-controlling and regulatory authorities in their COE for professional engineers, scientists, technologists and other comparable disciplines already in effect. Professional engineers, scientists, and technologists can gain a deeper understanding of its place in the current economy and its prospects for survival by implementing the TBL approach. The capacity for any profession to continue operating eternally is measured by its corporate sustainability, which takes into account its effects on the environment, community, and economy. In actuality, none of the three criteria can support a firm on its own; rather, they are all crucial in evaluating whether it can turn a profit and remain open for business. The TBL, in contrast to the conventional approach, enables the evaluation of any profession using social and environmental criteria and to view it as an entity. A COE is a set of guidelines intended to support professionals in acting honorably and morally in business. The purpose and values of the company or organization, the standards that professionals are held to, the ethical guidelines based on the organization's core beliefs, and the methods that professionals are expected to address difficulties are all included in a code of ethics document. A COE is crucial because it establishes expectations for behavior and serves as a foundation for proactive warnings.

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