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Environmental Sustainability Competency Framework for Polytechnics Engineering Programmes

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ABSTRACT Sustainability challenges such as degradation of ecosystem, loss in biodiversity, depletion and destruction of natural resources, numerous instances of pollution, and the extreme poverty of millions of human beings all originated from how people think. In an effort to improve the situation, the UN declared the years 2005-2014 as Decade of Education for Sustainable Development (DESD), calling for a thorough integration of competencies in sustainability issues at all levels of education. In line with this, addressing numerous sustainability-related problems requires an urgent need to reorient the school curricula, so that appropriate sustainability competencies are injected. Since the contents of HEIs curricula revolve around knowledge-based goals, skill-based goals and affective goals, this study investigated competencies (Knowledge, Skills and Attitudes) in the environmental sustainability suitable for incorporation into Higher National Diploma (HND) electrical/electronic engineering curriculum in Nigeria. The study employed qualitative approach through document analysis and semi-structured interview with the participants. The documents analyzed were twelve Journal Articles and five Skill Standards. The researchers also conducted interviews with electrical/electronic personnel in the academia and industry. The empirical findings of the semi-structured interviews corroborated the theoretical findings in the documents analyses. The study discovered several competencies in the document analysis as well as interviews, which were ultimately analyzed thematically. The themes include: Climate change, Ecology, Environmental Resource Management, System Thinking, Sustainable urbanization, Recycling/Re-use, and Empathy and Ethics. The researchers analyzed only 17 documents and conduct 10 interviews, thus, conclusions derived from these sources rely on the genuineness of the information provided by the participants. The findings provide the researchers, accreditation body as well as curriculum developers with competencies in environmental sustainability in the events of curriculum upgrade or renewal to integrate sustainability. The findings are the results of triangulated data elicited theoretically and empirically.

INDEX TERMS Concept of sustainability, environmental sustainability, engineering programmes.

I. INTRODUCTION

Engineering is a major constituent to any industrialized country. Nevertheless, as Desha [1] rightly observed, the profession has as well performed a significant role which facilitates the actions that created human generated climate or environmental change. Over the years, there has been wide outcry from across the globe about the growing consequences of unsustainable engineering activities of especially industrialized nations. These include for instance, the emission of GHGs, the release of waste water from industries in to the rivers and streams ruining agricultural lands, fishing activities and causing diseases. Research evidences showed that, the consequences of these activities led to: withdrawal of fresh water which has roughly increase twofold since 1960, and virtually half the globe's main rivers are

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going parched or terribly spoiled; 11 of the globe's 15 key fishing zones and 69% of the globe's main fish species have degenerated; and Climate change (global warming) is real, a foremost reason is fossil fuels, and effects are very serious [2]. These issues in environmental decline necessitated many discussions about the solution of such menaces. Susarla and Nazareth [3] reported that the start of this debate about the Development and Environment is usually attributed to Rachel Carson and her book 'Silent Spring' published in 1962. Decades later people realized that environment and development are interwoven, because development requires extensive use of natural resources and all the basic resources required for living come from the earth. From that time up till now the UN has spearheaded series of discourses concerning environment and development starting from UNCHE in Stockholm (1972) down to UNCSD in Rio de Janeiro [4]. A key feature of the conferences is the prominence on education as a significant instrument for advancing sustainable development and enhancing the ability of populace to tackle sustainability problems [5], [6]. This subsequently guided the UN to pronounce 2005-2014 as the 'UN decade for education for sustainable development' (DESD). The aim for this decade was to incorporate the principles, values and practices of sustainable development into all features of education and learning [7]. These incidents have also created the wider calls for Engineering Education for Sustainable Development (EESD) more broadly in declarations and reports such as the Arusha declaration, 1991; Engineering Education Workshop (Asia/Pacific), 1994; the 1997 Joint Conference on Engineering Education and Training for Sustainable Development (JCEETSD, 1997) in Paris and 2004 Declaration of Barcelona (EESD, 2004). The engineering profession has a vital part to play in achieving a sustainable, fair, and peaceful globe. One of the immense tribulations for technology and engineering professions is to play a part to the respite of the various problems worrying growing societies globally via making available knowledge, resources, and suitable and sustainable solutions [8]. This implies that engineering is an integral part of human developmental activities. However, how should engineering adjust to tackle the sustainable and human development concerns for the enormous globe's populace? If technology and engineering are critical to human development, in what ways can we educate engineers to address global sustainability issues? Esteemed researchers in engineering education advocated for timely and swift curriculum renewal about engineering education for sustainable development [9].

A. SUSTAINABILITY IN THE CONTEXT OF ENGINEERING

Sustainability according to [10] is ''a condition which natural systems and social systems survive and thrive together indefinitely''. Accordingly, sustainable engineering is the process of designing or operating systems such that they use energy and resources sustainably. Wong [11] refers to sustainable engineering to the doctrines of making preferences in engineering with regards to precincts in energy and materials and waste minimization. The importance of sustainability in engineering, and particularly in electrical engineering is paramount, and this is due to concern on the capability of natural resources and environmental systems to sustain the needs and wants of world's inhabitants. Boyle [12] stressed that though there has been a compromise amongst professional engineering societies that sustainability is crucial to engineers, and they have to significantly consider it in their practices [13], there has been no unanimity over how this is to happen. Even though sustainability in engineering developed out of the environmental engineering field, it covers the entire engineering speciality larger than environmental engineering does. Sustainability engineering entails modification in design to ameliorate efficiency or to even move from a product-based system to a service-based system. Vanderberg [14] indicated that the crucial judgment index normally centres on efficiency, productivity, profitability and cost-effectiveness. Therefore, incorporating sustainability into engineering education demands cautious evaluation of the fundamental principles and concepts of sustainability.

B. BASICS OF SUSTAINABILITY ENGINEERING

The fundamentals of electrical/electronic engineering in Nigerian polytechnics comprise basics of mathematics, design, materials, mechanics, electronics and programming. Boyle [12] inferred that these competences are predominantly centred on the design, development and management of technology. Ethics has furthermore, turn out to be imperative coupled with communication skills and certain underlying accounting dexterity. Duffell [15] reported that the integration of an extensive, cross-disciplinary course in environment, sustainability and ethics is widespread in higher education institutions. After adequate comprehension of the underlying skills, the students are required to learn the competences needed for electrical/electronic engineering specialization. Moreover, the students are required to effectively learn management skills, which involves comprehension of process, project management, time and people management skills, cost-benefit analysis and teamwork. This will ensure development of basic skills the students need for electrical/electronic engineering discipline, in addition to understanding of logical thinking. Students' thinking will progress from thinking about basic design concerns for working out simple challenges to project management where they are demanded to effectively organize their techniques to managing complex problems. The complex problems frequently entail more than merely engineering, but require some conception of management, ecology, sociology, etc [12]. As a result, for successful management of complex problems, critical, lateral and sustainability thinking are required as well as innovation and actual grasp of the fundamentals of entire problems. Moreover, essential to resolving complex problems is the capacity to ascertain what triggers the problem. Hence, to attain sustainability, a need exists for adequate description of the notion and the manner we are not sustainable established.

II. THEORETICAL FRAMEWORK

A. BASIC CONCEPT OF SUSTAINABILITY

Sustainability is a vast and complex concept which has no single definition. Its general definition as stated in Bruntland report inclined towards a policy perspective [16], albeit most of the definitions emanated from the report. The Bruntland report defined sustainability as: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). Sustainability refers to the capacity of people to adapt and cope with their environments as individuals and as a part of social organizations. The term 'sustainable development' is sometimes used, and mostly entails a more dynamic notion, emphasizing the need for individuals and organizations to actively learn and develop [17]. Sustainability is not only confined to local concerns such as conserving water, fuel consumption and the use of degradable material in our day-to-day living, but it is part of a set of universal priorities for us on this planet. Most researchers in matters related to sustainability such as [18] view it as a necessary component to the future well-being of the humanity and the planet. It is difficult to realize the goals of sustainability via changes in one sector alone. As such, higher education [4] is a focal point to aid speed up sophisticated and action-oriented discussion regarding global sustainability as well as provide sustainable solutions for the future. Achieving sustainability through higher education, even though an emerging field, but has deep rooted foundations in, and draws on various disciplines such as environmental education, policy analysis, economics, management theory, sociology, ecology, philosophy and psychology [18]. To emphasize the importance of achieving sustainability, Agenda 21 states that ''training is one of the most important tools to develop human resources and facilitate the transition to a more sustainable world''. Sustainable practices such as pathways to a low-carbon economy, renewable and clean technology are frequently understood as technical issues, entailing engineering knowledge and skills [19]. As industries re-engineer their resources and energy inputs, supply chain management, logistics, design and construction of the built environment, production processes, service and water and waste management; present procedures and practices in higher education institutions have to unfold so that it appreciably catch-up with the novel innovations.

B. ENVIRONMENTAL SUSTAINABILITY

The term sustainability itself originates in the French verb soutenir, ''to hold up or support'' and its modern conception has its origins in forestry [20]. Environmental sustainability is a dimension of sustainability that investigates the problems and possibilities of managing natural capital at a sustainable level [21]. Environmental sustainability seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human waste are not exceeded, to prevent harm to humans. The basic role of environmental sustainability is to protect human population and environment from impacts of human activities and to ensure environmental quality. To achieve environmental sustainability goals, advanced technologies are designed, such as processes of removing pollutants from air, water and soil so that risk in ecosystems are minimized, as well as guaranteeing positive conditions for life of humans and organisms [22]. Environmental sustainability focuses on pragmatic experience of a broad extent of research fields within the general discipline of environment which covers the following areas: waste water management, air and soil pollution control, waste disposal and recycling strategies, radiation protection, industrial hygiene, environmental technologies, processes linking environments, urban planning and development, environmental economics, policy and legislation [22].

C. THE CONCEPT OF ENVIRONMENTAL SUSTAINABILITY THINKING

Environmental sustainability thinking is thinking of the environment as supporting a defined level of environmental quality and natural resource extraction rates indefinitely. Environmental sustainability is the earliest pillar of sustainable development. It necessitates a transformation from ''business as usual approach'' to sustainable development approach of utilizing innate resources prudently, reducing waste and curb injury to surroundings as well as safeguard destructive climate change. This entails the sensible utilization of natural resources, energy, water and consciousness of the effects of production processes and environmental assessment system [23]. Morelli [24] a professional environmentalist, described environmental sustainability as a state of stability, resilience, and interconnectedness that permits the populace to gratify its desires, whilst neither exceeding the capability of its supporting ecosystems to persist to rejuvenate the services needed to summon those desires nor by our activities waning biological diversity. The object of ecological sustainability as viewed by professional environmental managers such as [25] is 'ecological balance', though may be separate, but related, from that of industries'. Requisite competencies in environmental sustainability are important to engineering graduates, considering the growing environmental burdens that have occurred from population expansion as well as from its related economic activities and consumption behaviors in a planet ever more industrialized and interconnected [26]. The ecological crisis is widespread as it comprises rising pollution, damage of habitat, damage of biodiversity and declining resources [24]. intensified human development and its industrialization has caused a mounting levels of greenhouse gas emissions, a key promoter to climate change, which has a variety of severe penalty for life on earth [26], [27]. To minimize these impacts, higher education institutions play a distinctive role in addressing environmental pressures and in creating a sustainable society as their education, research and community involvement can produce long-lasting environmental effects and societal change. Morelli [24] enriches the related body of knowledge by stressing that

"It is apparent that, without a sustainably productive environment to provide a resource foundation, it would be difficult or impossible to imagine having a sustainable society. Similarly, a sustainable economy depends upon a sustainable flow of material, energy, and environmental resources. Without it, economic systems will fail. However, a sustainable environment need not be dependent on the existence of either society or economy and, as evidenced in the wild, can stand alone as a sustainable system. As the only piece of the puzzle that can actually stand by itself, it should be the model to emulate, and indeed there have been attempts to do so (p.4)"

Contrary to Morelli's [24] view on the supremacy of environmental sustainability over other dimensions, namely economic and social, other scholars deemed this view superficial in the extreme, for it ignores the market forces and social inequalities that are driving environmental degradation [4]. In a sustainability framework, an overlap has been identified amongst economic, social, and environmental sustainability [19], chiefly the tough connection linking economic and ecological sustainability. It is appropriate that exclusive consideration has been set on environmental sustainability in current time, given the verity that development theory has centered on issues of economic underdevelopment and poverty mitigation in the upcoming nations, and was tardy in reacting to unprecedented hazards to the universal environment. However, it would be wrong to merge the principle of sustainability into one of attaining ecological sustainability alone. The safety of physical systems characterizes not an overall solution for achieving economic exuberance and social equity, but an essential part of a whole system for accomplishing economic, social and environmental sustainability, in which economic and social transformations are as imperative.

Meanwhile, the consequences of over-stretched environment that are outlined above, such as local, regional, and global air and water pollution, accumulation and distribution of toxic wastes, destruction and depletion of forests, soil, and water, depletion of the ozone layer and emission of "green house" gases threaten the survival of humans and thousands of other living species, the integrity of the earth and its biodiversity, the security of nations, and the heritage of future generations. As a result, the presidents, rectors, and vice chancellors of universities from all regions of the world deeply concerned about the unprecedented scale and speed of environmental pollution and degradation, and the depletion of natural resources, converged in 2001 at Talloires, France. They believed that urgent actions are needed to address these fundamental problems and reverse the trends. Ten points were agreed upon and prominent among them are directly related to environmental sustainability:

1) Increase Awareness of Environmentally Sustainable Development: Use every opportunity to raise public, government, industry, foundation, and university awareness by openly addressing the urgent need to move toward an environmentally sustainable future;
2) Educate for Environmentally Responsible Citizenship: Establish programs to produce expertise in environmental management, sustainable economic development, population, and related fields to ensure that all university graduates are environmentally literate and have the awareness and understanding to be ecologically responsible citizens.
3) Foster Environmental Literacy for All: Create programs to develop the capability of university faculty to teach environmental literacy to all undergraduate, graduate, and professional students, (Talloires Declaration, 2001).

This agreement had and is still helping a lot of higher education institutions across the globe to initiate programmes in environmental education to acquaint students with the educational process that deals with the human interrelationships with the environment. It is concerned with education progress of knowledge, understanding, attitudes, skills and commitment for environmental problems and considerations [20].

D. INTEGRATING ENVIRONMENTAL SUSTAINABILITY IN ENGINEERING PROGRAMME

The United Nations identified Education and particularly Higher Education Institutions (HEIs) as the most convenient and appropriate vehicle for advancing training and awareness for sustainability, and thus achieve the much desired goals of sustainable development. This was the main reason the United Nations' declared 2005-2014 as the decade for education for sustainable development (DESD) in Johannesburg [31]. Even before the proclamation, some institutions have in one point of time or the other, attempted to incorporate sustainability in their various educational aspects including the curriculum [32]. Most Higher Education Institutions are encouraged by the declaration to quicken the pace towards dealing with the pragmatic issues related to integrating sustainability in their diverse activities [33]. Evans *et al.* [34] summarized the work of embedding sustainable development into the curriculum that includes embedding sustainability education widely across curriculum areas, courses, and institution either through a dedicated core/compulsory subject, or through a component of a core/compulsory subject, or through a dedicated elective subject. Various models of integrating sustainability were used and/or proposed by different sustainability educators and researchers in higher education across the globe. Thomas *et al.* [17], for instance identified a number of models and approaches with their concomitant methods and requirements such as Modular approach, Intra-disciplinary framework, Inter-disciplinary framework, Exploring course culture, Professional practices, Experiential learning, and Flexible learning resources. Other researchers in sustainability education identified other approaches such as Broad and General Approach [35]; General Matrix approach [36]; Bolton, Built-in and Re-built approaches [37]; and Value Integration session approach [33]. Similarly, Lidgren *et al.* [38], and Scott and Gough [18] described an approach that requires the

need to think strategically about integrating sustainability in Higher Education (HE). Dubois *et al.* [33] discussed on other approaches that include problem solving, projects, demonstration, role-playing, role-modeling, study tours, industrial placement, ICT tutorials and conventional approaches (lectures, seminars and workshops). Thürer *et al.* [39] in their study on systematic review of literature on integrating sustainability in engineering curricula, presented three broad approaches of integrating sustainability in to the curriculum, which include embedding the concept of sustainable development into regular disciplinary courses; designing a new elementary course; and, providing the option to graduate in a sustainable development specialization. Following Kamp's presentation of the approaches of integrating sustainability, [37] analyzed models of sustainability integration and came up with three expansive approaches. They include: 'Re-built' or 'Re-design' approach, signifying wholly integration; 'Build-in' approach, which shows significant curricula changes; and 'Bolt-on' approach, implying cosmetic reform or just an awareness about sustainability. Cheah *et al.* [6], throw more light on the approaches suggested by [37], and refer the approaches using different terminologies as Transformation i.e., Education as sustainability or 're-build' strategy; Reformation i.e., Education for sustainability or 'built-in' strategy; and Bolting-on i.e., Education about sustainability or 'add-on' strategy. They lamented that the peak form of integration is the Transformation or 'Re-build' approach, which is inculcating the sustainability literacy in our graduates through understanding the immediate and long-term future of the ecology and socio-economy of societies and how they are impacted by human unsustainable actions; and through cultivating essential knowledge and skills that will make us adjust to a more sustainable way of doing things [40]. This study therefore, suggests the integration of environmental sustainability competencies through 'Bolt-on' approach. This is because the findings of [41] study revealed that 66.33% of the studies reviewed indicated a Bolt-on approach in integrating sustainability into curriculum. This is also consistent with the results of the study carried out by [42] who stressed that the early sustainability courses were often addition of series of lectures on to the existing programmes. This is also confirmed by [37], in their analysis of universities that integrate sustainability in the US and Canada. They reported that 'a majority of the examined universities bolted-on sustainability in to their existing programmes' (p. 225). Bascoul *et al.* [43], in their study 'using an experiential business game to stimulate sustainable thinking in marketing education' found out that vertical integration through role playing games helps students to begin to reconstruct Life Cycle Analysis (LCA) of a product according to their own perceptions and, subsequently, to confront these perceptions with reality. The use of online reflective journal is another approach to vertical integration used by [44]. She stressed the success of the approach in education and nursing, and helps to foster critical thinking and engage learners in dialogue with theoretical concepts and to accept the applicability of concepts to real-world situations. The strength of using vertical integration as suggested by [45] include that sustainability is explicitly stated in the competence matrix, as such encouraging integration in the curriculum. Another merit of vertical integration has to do with disseminating of a fresh course with sustainability contents as necessary for educating students about fundamental concepts and principles related to sustainability [46].

E. ENVIRONMENTAL SUSTAINABILITY COMPETENCE FRAMEWORK

As described earlier, environmental sustainability is a major pillar of sustainability that explores the tribulations and potentialities of managing natural capital at a sustainable level. The term competency refers to the knowledge, skills and attitudes that allow individual to successfully conduct the activities of a certain vocation or perform based on the anticipated norm in employment. Environmental sustainability competence according to [68] refers to a comprehensive and intertwined cluster of knowledge, techniques, practical skills, values and behaviors that are supposed to develop and improve job functioning as well as problem solving when tackling actual planet's ecological challenges.

This framework of environmental sustainability competence revolves around two theoretical standpoints that have influence people's acquisition of knowledge, skills and attitudes/abilities. These are social meliorist curriculum development theory and the model of domains of learning. Social meliorist theory, also known as social reconstruction or educational reconstruction theory propounded by George S. Count and Theodore Brughard Hunt Brameld looks up to school as a major force for social change and social justice, and are the vehicles to create new social vision. Social meliorist theory believed that students should immerse themselves in real-world problems, including working in their communities to find and present solutions that would improve their lives and the lives of their fellow citizens. The proponents founded the theory in the belief in democracy, and basic to this belief is an emphasis on education as a transformative force within society, not merely as a transmissional agent. The theory incorporates education, immersed in praxis, and is the only truly democratic, holistic, integrative approach to curriculum creation and improvement.

The social meliorist theory used in this study to guide the development of the framework of environmental sustainability competence is also supplemented by a model proposed by Dr. Benjamin Bloom's led committee of assessment experts in 1956. The model, termed Bloom's taxonomy of leaning domains was developed to promote higher forms of thinking in education, such as analyzing and evaluating concepts, processes, procedures, and principles rather than just remembering facts. It is often used when designing educational, training and learning processes to shape the content and delivery of the learning activities. Bloom [63] identified three domains of educational activities. These are: Cognitive – mental skills (Knowledge), Affective – growth in feelings or emotional

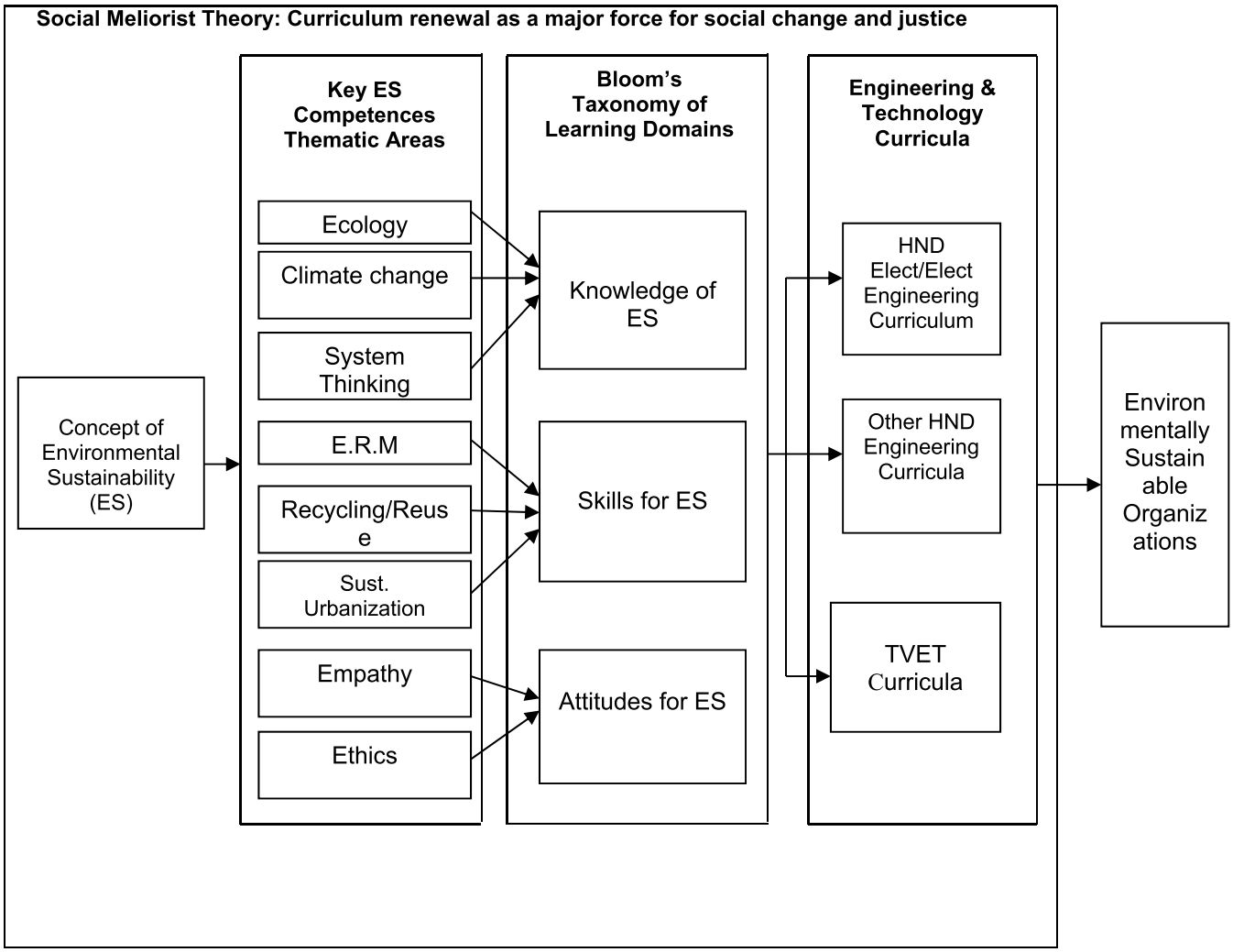

FIGURE 1. A framework for incorporating environmental sustainability thinking in electrical/electronic engineering curriculum in nigerian polytechnics.

areas (Attitude/Self), and Psychomotor – manual or physical skills (Skills). A fundamental comprehension of Bloom's model, and how to apply it for higher education, makes it easy for faculty to classify learning objectives, adapt technology and develop classroom activities for any course. The use of Bloom's taxonomy to teach sustainability has been pragmatically effective [41] especially in engineering where the model is best known.

In this context, the framework of environmental sustainability competence as shown in figure 1, refers to the knowledge, skills and attitudes that engineering students in polytechnics are required to acquire to contribute positively in helping the industries, society, and the country at large in mitigating the problems of environmental degradation, pollution, global warming and climate change. The knowledge is the essential basic concepts that students need to know to support environmental sustainability. Broad knowledge of environmental sustainability enables the critical analysis of current situations and identifies a more appropriate solution for a sustainable future [69]. Skills are the ability of a graduate to perform several activities needed in the process to find solutions in the workplace. Environmental sustainability skills provide both direct and indirect contribution to sustainability. Attitudes and values are emotional and behavioral dimension of learning. Most advocates of sustainability recognize the need for changes in human values, attitudes, and behaviors to achieve sustainability transition that will meet human needs while maintaining the life support system of the planet. The framework of environmental sustainability competence as shown in figure 1 is thus a guide towards understanding the key environmental sustainability competence thematic areas for incorporation into HND electrical/electronic engineering curriculum in Nigerian polytechnics.

Greening the engineering curricula in Nigerian polytechnics entails the integration of novel environmental sustainability knowledge, skills and attitudes; and is a gradual process used to create progress or advances in the courses offered by the institutions. This is because the world changes every

day and the curricula need to roped in the new discoveries. Engineering programmes are diversified, changing and vary in response to societal wishes, altering political and social environments, and quick progress in technology and knowledge. Engineering programmes possibly, more than any other field of higher education, are continuously developing to tackle rising problems and train graduates for novel distinct careers [49]. Consequently, the institutions need to identify and acknowledge these shifts, and then be able to implement them in their curricula.

III. OBJECTIVE OF THE STUDY

The main objective of this study is to qualitatively investigate the competencies (knowledge, skills and attitudes) in the environmental sustainability suitable for incorporation in to Higher National Diploma (HND) electrical/electronic engineering curriculum in Nigeria.

IV. RESEARCH METHODOLOGY

The study adopted a qualitative approach of data collection through two phases. The first phase involves document analysis, and the second phase involves interview with the research participants. The researchers accomplished this study at the polytechnics and manufacturing industries of Nigeria with total population of 274 experts. The researchers used cluster sampling to select four states out of seven in the study area, and quota sampling procedure in selecting 10 participants, which includes 6 electrical/electronic lecturers from the six polytechnics, (i.e., one from each institution); and 4 electrical/electronic engineering personnel from manufacturing industries (i.e., one from each sampled state). Six electrical/electronic experts validated the interview guide/protocol used in the study. These experts are practitioners in the areas of sustainable development, education for sustainable development, and engineering education for sustainable development.

A. METHOD OF DATA ANALYSIS

The researchers used document analysis and semi-structured interviews for data collection to investigate the research question. In document analysis, journal articles that discussed competencies in environmental sustainability were sought in Scopus database using the following keywords: environmental sustainability competences, ecological sustainability competences, and green competences. Google scholar was also searched to locate appropriate skill standards that describe environmental sustainability competencies. The authors discovered several documents that discuss the concept of environmental sustainability. However, we selected only articles and skill standards that described competencies (Knowledge, Skills and Attitudes) with respect to incorporation into curricula. Ultimately, the authors selected twelve journal articles and five skill standards for inclusion into the study. The researchers analyzed the documents using thematic analysis with aid of a form constructed to guide the document analysis process. We reviewed the documents to identify the environmental sustainability competencies (KSA) suitable for incorporation into the engineering curriculum, (see Table 1).

Furthermore, the analysis of the semi-structured interview firstly began with the visit to the institutions and the industries slated for this study, to introduce the purpose of the study and make appointments for the interview with the selected participants. Later the researchers conducted the interviews with the participants on the scheduled dates, venues and times. The interview protocol specifically asked the participants to state in their perceptions, the cognitive, psychomotor, and affective competencies in environmental sustainability suitable for incorporation into HND electrical/electronic engineering curriculum in Nigeria. For instance, the first question reads ''In your perception, what theoretical knowledge in environmental sustainability is suitable for incorporation into HND electrical/electronic engineering curriculum?'' The authors also used thematic data analysis in analyzing the data generated from the semi-structured interviews. The researchers started the analysis of data by transcribing the audio-recorded version of the data immediately after the first interview. The researchers continued in the same manner of conducting and transcribing the interview, before conducting the next interview until the researcher felt the data reached a saturation point. The analysis continued with thorough reading and re-reading the transcribed data which was later presented to the interview participants for their corrections and confirmations to enhance the validity of the data. This was then exported in to Nvivo version 11software to help organize the data. The software assists in accomplishing thematic data analysis to condense the data to manageable and meaningful codes based on the research question. In analyzing the interview data, the researcher opted for data benchmarking technique based on the analyzed documents and journal articles in the study. References [47], [48], discussed and proposed data benchmarking technique. This technique suggests the researcher to starts the analysis with a predetermined themes and coding based on the previously reviewed literature regarding the scope of the study. The researchers modified the outcomes of the analysis in to a framework for incorporating environmental sustainability thinking in electrical/electronic engineering curriculum in Nigerian polytechnics. To preserve secrecy of the research participants, the names of the institutions and industries, as well as the interviewees are not identified in this paper.

V. RESULTS

The researchers theoretically established the data collected to answer the research question by document analysis and empirically through interview with the research participants as described below:

A. DOCUMENTS ANALYSIS

The documents analyzed to identify the competencies in environmental sustainability were: Twelve (12) Journal Articles and five (5) Skill Standards. The researchers analyzed

TABLE 1. Findings matrix from documents analysis (journal articles and skill standards) on competencies in environmental sustainability.

Journal Articles	Natural Resources	Climate Change	Disaster Prevention & Mitigation	Preservation of Bio-diversity	Human Ecology	Environmental Management	Sustain-able Urbaniz-tion	Recycling/ Reuse
Morelli [25]	√			√		√		√
Vincent & Focht [50]	√		√			√		
Boutin & Chinien [51]	√			√	√	√		√
Bronfman, et al., [52]	√	√		√	√			
Siva, Gremyr & Halldórsn, [53]						√	√	
Álvarez-Nieto, et al., [54]		√			√	√	√	
Pappas [55]	√							√
Wiek, et al., [56]	√						√	
Siew [57]			√			√		
Besong & Holland [58]	√	√	√	√	√	√	√	√
Jena, et al., [59]	√	√		√		√		√
Iyer-Raniga & Andamon [60]	√	√		√		√	√	
Skills Standards	**Natural Resources**	**Climate Change**	**Disaster Prevention & Mitigation**	**Preservation of Bio-diversity**	**Human Ecology**	**Environmental Management**	**Sustain-able Urbaniz-tion**	**Recycling/ Reuse**
Skills Standard 1		√		√		√		√
Skills Standard 2	√				√		√	
Skills Standard 3	√	√	√	√	√	√		√
Skills Standard 4	√	√		√	√			
Skills Standard 5	√	√	√	√	√	√		

KEY: Skills Standards
Skills Standards 1: Wisconsin Standard for Technology & Engineering.
Skills Standards 2: Michigan State University (MSU) Global Sustainability Competencies
Skills Standards 3: Green/Sustainability knowledge and skill statements
Skills Standards 4: Wisconsin Standards for Environmental Literacy and Sustainability
Skills Standards 5: Eco Canada: Competencies for Environmental Professionals in Canada

Journal articles that focused on the development of competencies in environmental sustainability. These include: [24], [49]–[59]. Likewise, the researchers analyzed five (5) Skill Standards developed from across institutions globally. They include: Wisconsin Standard for Technology and Engineering, Michigan State University (MSU) Global Sustainability Competencies, Green/Sustainability knowledge and skill statements, Wisconsin Standards for Environmental Literacy and Sustainability, and Eco Canada: Competencies for Environmental Professionals in Canada. It is worthy to emphasize here that both documents proposed numerous competencies for attaining environmental sustainability, which makes it impossible to produce a mere 'laundry list' of competencies. Barth *et al.* [60] stressed that any attempt to that effect will

TABLE 2. Findings of the interview on competencies in environmental sustainability.

Competencies Proposed by the Participants	Respondents	Subthemes
Cognitive Competencies An understanding of the meaning of climate change; An understanding of ecological degradation; An understanding of environmental health threats; Understanding of how resources are conserved that are unusable for the present generation; Understanding the meaning of ecological sustainability; Knowledge of renewable resources and energy; Knowledge of environmental pollution; Knowledge of ecological dysfunction; Ability to understand and apply the concept of system thinking approach in addressing issues in environmental sustainability; Ability to understand and apply the concept of systemic approach in dealing with sustainability challenges;	EEL 1, EEL 2, EEL 3, EEL 4, EEL 5, EEL 6, CEO, OM, SE, TEC	Ecology Climate change Renewable resources System thinking
Psychomotor Competencies Carry out series of activities leading to waste prevention; Ability to recycle/reuse materials; Reducing hazards; Practical aspect of environmental sustainability; Ability to conserve the diversity of natural resources; To maintain the quality of the planet; To conserve ecological endowments such as a natural landscape due to their importance in human welfare; Ability to conserve the diversity of cultural resources; Describe how markets, government policies, enterprise and innovation affect the environment in terms of the use of resources, and ecological sustainability; Preventing littering,	EEL 1, EEL 3, EEL 4, EEL 5, EEL 6, CEO, OM, SE, TEC	Environmental Conservation Environmental Resource Management
Affective Values and Attitudes Care of water; Care of natural resources; Empathy for the depletion of ozone layer and ecosystem; Cultural diversity; Cultural heritage; Identify one to the laws that govern the physical and environmental systems;	EEL 1, EEL 2, EEL 3, EEL 4, EEL 5, CEO, OM, SE,	Empathy Ethics

fail arbitrarily (p.2). As a result, the researchers employed thematic analysis, and the competencies coded under various categories as shown in table 1 below.

B. INTERVIEW FINDINGS

The analysis of the data collected from the interview participants on their perceptions of competencies in environmental sustainability for incorporation in to HND electrical/electronic engineering curriculum, revealed three different dimensions of environmental sustainability competencies grouped under three (3) sub-categories namely: Cognitive, Psychomotor, and Affective values/attitudes. Furthermore, four (4), subthemes emerged from cognitive subcategory which include ecology, climate change, renewable resources and system thinking. Similarly, two (2) sub-themes emerged from psychomotor subcategory and are environmental conservation and environmental and resource management. Ultimately, two (2) sub-themes also emerged from the subcategory of affective values and attitudes. This comprised empathy and ethics. Thus, table 2 summarizes and shows the analysis of the data on the competencies in environmental sustainability proposed by the interviewees.

Based on the findings, the interview participants firstly established that environmental sustainability is one cardinal pillar of sustainable development required for incorporation in to HND electrical/electronic engineering curriculum. This is so via demonstrating and presenting adequate knowledge on the competencies in the said environmental sustainability. Secondly, the interview participants proposed competencies that cover all the domains of learning which include

TABLE 3. Summary of interview feedback for competencies in environmental sustainability.

Categories and Subthemes	Electrical/Electronic Engineering Lecturers in the Polytechnics						Electrical Engineering Personnel in the Industries			
	EEL 1	EEL 2	EEL 3	EEL 4	EEL 5	EEL 6	CEO	OM	SE	TEC
Cognitive Competencies										
Ecology	√			√	√	√	√	√	√	
Climate Change	√	√	√		√		√	√	√	√
Renewable Resources	√	√	√	√		√	√	√	√	
System Thinking	√	√			√		√	√		
Psychomotor Competencies										
Environmental Conservation			√	√	√	√		√	√	
Environmental Resource Management	√		√	√		√	√		√	√
Affective Values and Attitudes										
Empathy		√		√	√		√		√	
Ethics	√	√	√		√		√	√	√	

theoretical knowledge, practical skills and values. Table 3 gives summary of the research findings from the perspective of the participants.

VI. DISCUSSION AND CONCLUSION

A. DISCUSSION

The findings of the document analysis of our study clearly shows that the literature is very rich in aspects of environmental sustainability, and specifically the competencies required for higher education students to acquire while in school. Moreover, the results from the interview also revealed that the participants have an adequate understanding of the environmental sustainability competencies and their relevance in the engineering curriculum. While the appreciation of environmental sustainability competencies in engineering is quite novel, educationalists for several times have recognized the necessity for such competencies for inclusion in the curriculum. The notion of sustainability competence as a method has developed considerably in the preceding decade and is currently properly recognize that competence entails the application of knowledge and skills with aptitude to practice [61]. Hence, with the quick rate of transformation of technology, society, and demographics, engineering instructors are currently challenged with the problems of assessing the package of knowledge, skills and aptitudes which prospective cohorts of engineers will require to endure and thrive in the hurried globalization of life in the 21st century. The competencies as proposed by the interview participants were generally categorized in to three: Knowledge, Skills and Attitudes. Knowledge relates to facts, information, concepts and principles obtained via know-how, education or investigation [62]. Bloom [63] identified six levels within the knowledge-based domain (also classically known as cognitive domain), from the simple recall or recognition of facts as the lowest level, through increasingly more complex and abstract mental levels, to the highest order of evaluation. Great deal of knowledge associated to sustainability exists, and albeit having a multi-disciplinary method is essential, a learner cannot discern all linked to sustainability. There are crucial notions that a learner requires to discern to support sustainability. In an attempt to assist undergraduate engineering students to acquire knowledge toward an expert-like thinking of sustainability, [64] described two methods of discerning prerequisite to think in an expert-like way. They are knowledge of content (what is all about the discipline) and structure of content knowledge (the thought and application of content knowledge). They also described the diverse fundamentals of these methods of knowing (declarative, theoretical, procedural and conditional knowledge and critical thinking). For engineering education students to have adequate knowledge and understanding in sustainability concepts, they must have

factual and theoretical knowledge of sustainability, apply that knowledge appropriately to contextualized decision-making, and be adept at judging the ethics and sustainability of one's decisions and decision outcomes [64]. Skill is capacity to execute kinesthetic endeavour in an simple, accurate, pleasant manner with the steady varying situation. Practical environmental sustainability skills, according to [65] as cited in [66] are the capacity of students to carry out numerous actions required in the process to find solutions in the work place. These skills are classified by [63] to belong to psychomotor domain of learning objectives and are inclined to a demonstration and three practical instructional levels: Imitation, Practice, and Habit. Psychomotor skills are categorized in an indefinite number of classes ranging from plain skills that don't necessitate lots of physique (organs/senses) to be used, the skills that lots of strengths are employed, and circulation skills that require body-to-body activity. Gu *et al.* [16] described skills for environmental sustainability as the doable skills which engineering programmes ought to deliver to learners in order to conquer the environmental sustainability problems in their particular profession (p.22). Evidences revealed that psychomotor skills afford equally a direct and indirect input to sustainable development. At first, various researches have not just integrated the theoretical knowledge, but also capacity to cooperate, and communicate with stakeholders in diverse disciplines [67], [68]. The psychomotor skills are vital to accomplish sustainability that call for teamwork from a variety of groups of people [4]. Secondly, enhancing psychomotor skills possibly improves practitioners' knowledge in some speciality. Purposeful skill practice with concentration and preparation let novices to build up further complex knowledge. The UNEP (2006) white paper states that learning-by-doing aids students to build up aptitude to organize and analyze. Stubbs [65] defined attitude/value as favourable students' viewpoints of sustainability issues. Soebagio [66] viewed the term 'sustainability value' as equivalent to positive stance towards sustainability issues or towards the sustainability learning process. According to [69], sustainability value is an emotional and behavioural dimensions of learning, and most advocates of sustainable development recognize the need for changes in human values, attitudes, and behaviours to achieve a sustainability transition that will meet human needs and reduce hunger and poverty while maintaining the life support systems of the planet [30], [70]. The movement towards sustainability depends more on the development of our moral sensitivities than on the growth of our scientific understanding [71]. Education for sustainable development is not only about specialities that enhance our awareness of nature, in spite of their undisputed value. Achievement in the effort for sustainable development demands a method to education that reinforces our commitments corroborating other values – particularly justice and fairness and the understanding that we share a uniform future with others. Gu *et al.* [16] posited that having the necessary theoretical knowledge and practical skills for sustainability is not enough, development of attitudes towards sustainability is crucial as well. Attitudes are founded on values and the worldview which an individual carries on through his/her life. It is evident in earlier studies that learning institutes are one of the foremost donors to change and advance learner's attitudes [69]. As a result, higher education institutions and establishments ought to develop those attitudes which will facilitate their students to feel empowered to effectively sustain sustainability in their careers [71].

B. CONCLUSION

Negative consequences of sustainability issues are widespread that affects millions of people around the world. Due to the alarming rate of the spread of sustainability problems, such as global warming caused by GHG emission, deforestation, acidification of lakes, particularly in developing countries, the United Nations identified Education and particularly Higher Education Institutions (HEIs) as the most convenient and appropriate vehicle for advancing training and awareness for sustainability, and thus achieve the much desired goals of sustainable development. However, while numerous institutions in the developed nations have reached an advanced stage in matters related to sustainability integration, their counterparts in developing countries lagged behind in aspects of curriculum renewal to integrate sustainability. This study recognized the crucial need to that effect, and therefore, analyzed documents on environmental sustainability competencies to identify key thematic areas needed for inclusion in to electrical/electronic engineering programme in Nigerian polytechnics. Subsequently, the authors conducted a semi-structured interview with experts from both academia and industry, to corroborate the findings theoretically revealed in the document analysis. Findings showed that required key competencies for inclusion are ecology, climate change, renewable resources, environmental conservation, empathy, and ethics, among others. The authors also advocated for ''Bolt-on'' approach of integrating sustainability in to curriculum. This approach proposed by [37] is applicable in many institutions in US and Canada, and simply implies cosmetic reform or awareness about sustainability.

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