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. BACKGROUND
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 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
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 pronounced 2005-2014 as the ‘UN decade for education for sustainable development’ (DESD). The aim for this decade is 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].

1.1 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 in to engineering education demands cautious evaluation of the fundamental principles and concepts of sustainability.

1.2 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. Duffel [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
2.1 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 [19] 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 etc, are frequently understood as technical issues, entailing engineering knowledge and skills [20]. 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.

2.2 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 [21]. Environmental sustainability is a dimension of sustainability that investigates the problems and possibilities of managing natural capital at a sustainable level [22]. 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 [23]. 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 [23].

2.3 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 [24]. Morelli [25] 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 [26] 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 [27]. The ecological crisis is widespread as it comprises rising pollution, damage of habitat, damage of biodiversity and declining resources [25]. 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 [27, 28]. 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 [25] 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 [25] 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 [19]. In a sustainability framework, an overlap has been identified amongst economic, social, and environmental sustainability [20], 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 an 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 and believed that urgent actions are needed to address these fundamental problems and reverse the trends. Ten points are agreed upon and prominent among them are directly related to environmental sustainability. These are:

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 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 [21].

### 2.4 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’ declare 2005-2014 as the decade for education for sustainable development (DESD) in Johannesburg [32]. Although, 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 [33], 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 [34]. Stevenson, Lasen, Ferreira and Davis [35] summarized the work of embedding sustainable development into the curriculum that includes: embedding sustainability education widely across curriculum areas, courses, and institution; through a dedicated core/compulsory subject; through a component of a core/compulsory subject; and 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, Kyle, and Alvarez [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 [36]; General Matrix approach [37]; Bolt-on, Built-in and Re-built approaches [38]; and Value Integration session approach [34]. Similarly, Lidgren, Rodhe and Huisng, [39], and Scott and Gough (2006) described an approach that requires the need to think strategically about integrating sustainability in Higher Education (HE). Also Dubois et al. [34] 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). Thurer, et al. [40] 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; the design of 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, [38] analyzed models of sustainability integration and came up with three expansive approaches. These are: ‘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, Yang and Sale [6], threw more light on the approaches suggested by [38], 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 [41]. This study therefore, suggests the integration of environmental sustainability competencies through ‘Bolt-on’ approach. This is because the findings of [42] study revealed that 66.33% of the studies reviewed indicated a Bolt-on approach in integrating sustainability in to curriculum. This is also consistent with the results of the study carried out by [43] who stressed that the early sustainability courses were often addition of series of lectures on to the existing programmes. This is also confirmed by [38], 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, [44], 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 [45]. 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 [46] 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 [47].

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.

4.1 Method of Data Analysis

The researchers used semi-structured interview for data collection and subsequent analysis and answering the research question. The researchers in the first place, visited the institutions and manufacturing 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 interview with the participants on the scheduled dates, venues and times. Moreover, 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. This was then exported in to Nvivo version 11 software 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. [48, 49] 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.

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:

5.1 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 Journal articles that focused on the development of competencies in environmental sustainability. These include: [25, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60]. 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., [61] stressed that any attempt to that effect will 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.

<table>
<thead>
<tr>
<th>Journal Articles</th>
<th>Natural Resource</th>
<th>Climate Change</th>
<th>Disaster Prevention &amp; Mitigation</th>
<th>Preservation of Biodiversity</th>
<th>Human Ecology</th>
<th>Environmental Management</th>
<th>Sustainable Urbanization</th>
<th>Recycling/ Reuse</th>
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<tbody>
<tr>
<td>Morelli [25]</td>
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<td>Vincent &amp; Focht [50]</td>
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<td>Boutin &amp; Chinien [51]</td>
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<td>Bronfman, et al., [52]</td>
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<td>Alvarez-</td>
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Table 2. Findings of the Interview on Competencies in Environmental Sustainability

<table>
<thead>
<tr>
<th>Competencies Proposed by the Participants</th>
<th>Respondents</th>
<th>Subthemes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Competencies</td>
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<tr>
<td>An understanding of the meaning of climate change;</td>
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<td>Ecology</td>
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<tr>
<td>An understanding of ecological degradation;</td>
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<td></td>
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<tr>
<td>An understanding of environmental health threats;</td>
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<td></td>
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<tr>
<td>Understanding of how resources are conserved that are unusable</td>
<td></td>
<td>Climate</td>
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</tbody>
</table>

**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

5.2 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) subcategories 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. In the same vein 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 sub-category 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.
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;

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,

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;

Based on the findings, the interview participants firstly established that environmental sustainability is one cardinal pillar of sustainable development required for incorporation into 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 theoretical knowledge, practical skills and values. Table 3 gives summary of the research findings from the perspective of the participants.

<p>| 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 Manufacturing Industries |
|                                          | EEL 1 | EEL 2 | EEL 3 | EEL 4 | EEL 5 | EEL 6 | CEO | OM | SE | TEC |
| Cognitive Competencies                    |       |       |       |       |       |       |     |    |    |     |
| Ecology                                   | √     |       |       |       |       |       |     |    |    |     |
| Climate Change                            | √     | √     | √     |       |       |       | √   |    |    | √   |
|                                            |       |       |       |       |       |       |     |    |    |     |</p>
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<th>Renewable Resources</th>
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<td>System Thinking</td>
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<td>Psychomotor Competencies</td>
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<td>Environmental Conservation</td>
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<td>Affective Values and Attitudes</td>
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<tr>
<td>Empathy</td>
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**VI. DISCUSSION AND CONCLUSION**

6.1 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 time 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 [62]. 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 [63]. Bloom, et al [64] 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, [65] 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 [65]. Skill is capacity to execute kinesthetic endeavour in an simple, accurate, pleasant manner with the steady varying situation. Practical environmental sustainability skills, according to [66] as cited in [67] 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 [64] 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, Gomez and Brizuela [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 [68, 69]. 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 [66] defined attitude/value as favourable students’ viewpoints of sustainability issues. Soebagio [67] viewed the term ‘sustainability value’ as equivalent to positive stance towards sustainability issues or towards the sustainability learning process. According to [70], 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 [31, 71]. The movement towards sustainability depends more on the development of our moral sensitivities than on the growth of our scientific understanding [72]. 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, Gomez and Brizuela [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 [70]. 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 [72].

6.1 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 [38] is applicable in many institutions in US and Canada, and simply implies cosmetic reform or awareness about sustainability.

REFERENCES


