ENGINEERING EDUCATION FOR ACHIEVING SUSTAINABLE DEVELOPMENT GOALS BY 2030: REVEALING THE PATHS FOR CHALLENGING CLIMATE CHANGE AND COVID 19

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ABSTRACT: *This is a review article on problems and solutions relating to Education for Sustainable Development (ESD) in Engineering education. The review policy for this study was to use documents published by the United Nations (UN), research and working papers published in refereed journals and reports on ESD for Sustainable Development Goals (SDGs). About 75% papers of this review were published between 2010-2017; 20% between 2017-2020 and rest 5% at the end of the last century. This review focused on ESD for engineering education climate change, environment, pollution and COLID 19 issues in relation to SDG-3 (Good health and well-being), SDG-4 (Quality education), SDG-6 (Clean water and sanitation) SDG-7 (Affordable and clean energy), SDG-9 (Industry, innovation, and infrastructure), SDG-11 (Sustainable cities and communities), SDG-12 (Ensure sustainable consumption and production pattern), SDG-13 (Climate action) and SDG-17(Partnerships for the goals).The research revealed that major engineering schools of all discipline are using ESD as an add-in strategy in curriculum due to various constraints. The main barriers to implementing ESD for engineering are: the lack of policy of the countries, shortage of experienced academic staff, trade-offs policy between current curriculum and ESD; lack of partnership among university, society and industry. The findings would have some implications for global institutions involved in policy issues related to SDGs and ESD. The findings would be also useful for the countries and universities that meet annually to review progress on developing curriculum for engineering education towards Agenda 2030.However, this is a fundament work which bring the insight of trade-offs between current curriculum for ESD in engineering education in that aspect, the work is novel.*

Keywords: Engineering education, Sustainable development, Quality education, Clean water, Renewable energy, Climate change, COVID-19, Engineering

1.0 INSIGHT OF ENGINEERING EDUCATION AND CHALLENGES TO ACHIEVE SUSTAINABLE DEVELOPMENT GOALS

The Agenda 2030 encompasses sustainable development goals (SDGs) which seeks to strengthen the social, economic and environmental dimensions of development. The Implementation of the Agenda 2030 requires science and logic based on holistic, coherent and integrated approach at the global, regional, national, social and individual levels; as well as inter-linkages within and between the relevant stakeholders [1]. As per the expert review commissioned by the UNESCO (2005a), the key objective of the ESD is to give a deep understanding to the students on complex environmental, economic, and social systems for achieving SDGs by 2030[2].

Currently, the world is suffering from unsustainable development due to higher levels of pollution in the air (due to carbon emission), water (due to toxic effluent) and soil (due to industrial and agriculture solid wastes) [3]. Likewise, the major climate fossil fuel at power plants, industrial wastewater treatment plants, decomposing industrial and agriculture waste biomass. In this regard, Shahidul et al. (2020) stated that the main sources of increasing global warming, climate change and biodiversity loss are the industrial pollutions, carbon emission, and industrial toxic effluent[4]. In all these activities indeed, engineers are significantly involved with other professionals. However, a common social idea has prevailed that the professionals involved in the industrial production process may not be fully competent to reduce the pollution level to the acceptable limit; and may be due to that reason, the environmental quality is declining towards a devastated level [3].

However, during the Earth Summit 1992 and UNESCO meeting held in 2005, four areas were highlighted as the fundamental tools for achieving global sustainable development goals. The areas are the Quality of basic education; Education programs toward sustainable development; Public awareness and Understanding of sustainable development; and training promotion on sustainable development [5] [2][6].

Indeed, it is evident that industrial pollution is significantly responsible for the current poor-quality environment, climate change, and biodiversity loss. It was also found that engineering activities are involved in all these industrial processes. These phenomena have inspired us to consider the ESD for engineering education [4] [7].The relationship of SDGs and engineering activities for sustainable development could be elucidated in Figure 1

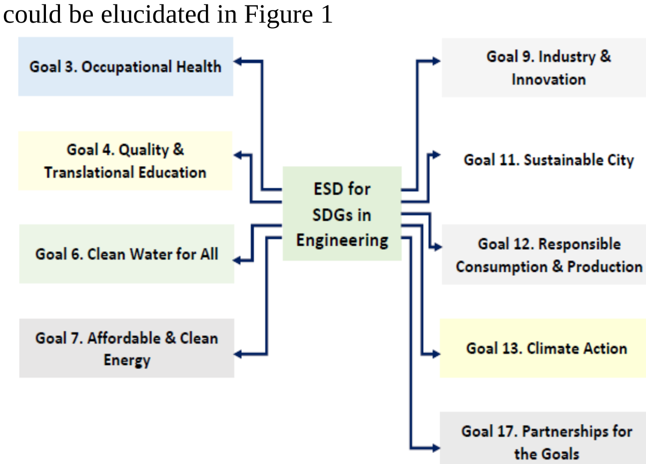

Figure 1: ESD in SDGs for Engineering Education [7, 2]

However, on this background, the nine goals mentioned could be added in the ESD for engineering education in order to speed activities towards Agenda 2030[2, 5].

1.1 Effects of Climate Change and COVID 19 on Sustainable Development

A basic question floating in the air globally, is there any relationship existing between Climate Change and Covid-19?; the answer from the experts is that, there is no direct relation found between these two. However, for the first time, two global phenomena in the form of Climate Change and Covid-19 came simultaneously with devastating destruction on this planet, transverse throughout all borders. But it led to cut huge amount of GHG emissions globally, the estimated figure is about 17% below what it was in the same first week of April, last year. Global industrial GHG emissions are now expected to be about 8% lower in 2020, the largest annual drop since World War [8].This phenomenon is telling us that due to the declining trend of industrial operations affected by COVID-19, GHG emissions are reducing where industrial operations are significantly responsible for poor quality environment. In this aspect, the hypothesis is that world needs the engineered production process in all sectors for sustainable economic growth. The engineered production process would also contribute to keep the world on track to meet the Paris Climate Accord's ambitious goal of only 1.5 degree Celsius warmer than it was before the Industrial Revolution. In support of this hypothesis, several reports have been published recently on COLID-19 and responsibility[8–10].

Hector Pollitt (2020), OECD (2020), UNIDO (2020) and Noy et al. (2020) had addressed the question, how to model the economic impacts of COVID-19? The indirect costs of COVID-19 associated with economic recession due to the value chain disruptions and widespread quarantines are huge. Mainly many countries are suffering from reduction of the international demand for goods due to [10–13].

The virus gravely affects the lives of most scientists, engineers, and entrepreneurs working today. The computer scientists rushed to model the coronavirus's next move, biotech entrepreneurs pivoted to develop diagnostic tests, the civil engineers openly shared building designs for making buildings inexpensive for medical equipment [14, 15]. The scientists and engineers involved in the ICT profession have started to work very hard to develop fundamental ways for working from HOME. The mechanical engineers are working on developing a new model of air ventilators for easy operations to supply oxygen for COVID-19 patients. But still, the speed of the virus is not reducing since December 2020 till middle of 2020. Rather it has been predicted that it will continue further to middle of 2021 [14, 1 6].

The background discussed on SDGs, engineering activities and global economic recession has postulated that the poor-quality environment and climate change effects are top listed barriers to achieving Agenda 2030. The causes of pollution, climate change, and carbon emissions are the major outcomes of industrial operations; indeed, engineers are mostly involved with these industrial operations. Engineers have a role to play in reducing the pollutions by improvising the industrial operations through increasing further competence level on the topics depicted in Figure 1. On that 1ackground, it can be stated that ESD for engineering curriculum would be modelled with nine (9) goals for reducing potential barriers to SGD. Hence engineering curriculum would be reinforced with SDG-3 (Good health and well-being), SDG-4 (Quality education), SDG-6 (Clean water and sanitation), SDG-7 (Affordable and clean energy), SDG-9 (Industry, innovation, and infrastructure), SDG-11 (Sustainable cities and communities), SDG-12 (Ensure sustainable consumption and production pattern), SDG-13 (Climate action) and SDG-17 (Partnerships for the goals) [2, 7]

1.2 Objectives of The Research

Based on the problem discussed on SDGs, the broad objective of this work is to present the potentials and barriers to remodel the engineering curriculum in line with the ESD. However, the broad objective is divided into three specific components:

1.2.1 To present the theoretical framework of the ESD for engineering education.

1.2.2 To demonstrate the components of SDGs needed to add in ESD curriculum for engineering education.

1.2.3 To figure out the models required to adapt in the Engineering curriculum to support Sustainability Agenda 2030.

2.0 THEORETICAL FRAMEWORK OF STUDY FOR SUSTAINABILITY

This section develops to address problem and solution related objective one stated in section 1.2.1. ESD for engineering education is often regarded as just an issue of add-in some topics in some courses to train up the next generation of technological leaders. Indeed, engineering academic disciplines shall embrace sustainability as their core legitimation to fulfil the current requirement of social, economic and environmental dimensions of development [2]. However, as per the expert opinions the key features of the theoretical framework of ESD are four:

2.1 The Brundtland Commission defined sustainable development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Basically, this concept is regarded as the foundation of mankind's responsibility to make the environment sustainable without compromising the ability of future generation's requirement [17]. Indeed, based on this concept, the idea of ESD was developed. However, sustainability science can be defined as ''the comprehensive study on the multiple and complex interactions of the human, societal, environmental, balancing biodiversity and global ecosystem with the aim to achieve sustainable human well-being and societal development ''[18] .

2.2 The traditional growth models developed based on higher productivity with higher yield by the aid of one time use of natural resources and without paying much attention to environmental sustainability, biodiversity loss and carbon emission. Nowadays, many of these economic growth models have appeared to be quite unfit for the current vulnerable environment. However, the ESD for engineering education has potentials to contribute to the reformulation of the traditional growth model to make growth sustainable in the aspect of society, economy and environment by 2030[6], [19].

2.3 Sustainability should be the core business in all academic disciplines of engineering, because the products should not just have to be manufactured in a cleaner way; but it also should be more resource-efficient in use while keeping an option of needs for the future generations. Education has to play an important role in society with aim to bring material and energy consumption within the limits of our planet [20], [21].In this aspect, the ESD should be reinforced with the principles, and values of sustainable development goals, focusing on learning with critical thinking and problem-solving approach. The world's leading educational and scientific organizations had signed an agreement to be known as the Ubuntu Declaration for making the sustainable development agenda to be achievable. The key points of this declaration were[22]:

- Strengthening of collaboration between educators and S&T researchers
- Better integration of S&T into educational programs for sustainable development at all levels
- Problem-based approach for education and scientific research
- Innovation in knowledge transfer to bridge the gaps and inequalities in knowledge.

2.4 The core theoretical foundation of ESD was given by Sociologist Erin Czech (2014). The concept of Erin Czech could be incorporated into engineering education as the program outcome (PO), the core values of this concept are Professional and ethical responsibilities; Understanding the consequences of technology; Understanding how people use machines and Social consciousness. It was also suggested that the course outcome (CO) development, lecture delivery and assessment shall be based on PO1- PO12 [23, 24] Thus, this section delicately develops and presents the basic theoretical framework of ESD for Engineering education towards Agenda 2030.

3.0 ELEMENTS OF ESD IN ENGINEERING EDUCATION FOR SDGS

This section develops to focus on problems and solutions related to objective two stated in section 1.2.2. It has been reported that elements of nine (9) goals of SDGs are directly related to engineering activities which are shown in Figure :1 [7, 2]. The nine goals of SDGs relating to engineering education are described in the following subsections.

3.1 Engineering Education on Occupational Health

Quality health relates to SDG-3; indeed, quality health is the central part of all successful activities that can contribute to achieving sustainable developed goals by 2030. The well-being is a feeling of satisfaction in life, which relates to quality health, happiness, and prosperity. The quality health concerns-the care of the human body towards protection from sickness, intoxication and prevention of chronic diseases. Indeed, with poor health, engineers are not able to work and contribute to produce goods and services. In this aspect, students and professionals involved in the engineering domain need to acquire basic knowledge on occupational health. The SDG-3 is an essential part of T&L for engineering [14, 16, 25].

The SDGS-3 could be a part of life-long learning on managing mental and emotional health, physical stress, and to prevent in working a poor a quality environment.

Through academic process of learning, the students and professionals involved in engineering shall acquire the necessary skills to critically analyse factors affecting health at work[26]. A comprehensive handbook could be developed based on the ESD models in consultation with the occupational health specialists [27]. Quality health, hygienic environment, eating healthy food, prevention method for the spread of infectious diseases could be integrated in the curriculum under SDG-3 [28]. Lectures delivery and assessment of the teaching outcomes shall be based on COs and POs for preparing students for future engineering services to achieve Agenda 2030 [9, 11].

3.2 Quality Education for Engineering Towards Sustainable Development

Quality Education for Engineering relates to SDG-4. Traditionally, quality education for engineering entails relevant knowledge and skills of students and academic staff together with educational materials, laboratory equipment, scholarships, social engagement, research and publications. The nine (9) SDG goals shown in Figure:1 are also essential as part of engineering education for achieving sustainable development [3, 27]. In this aspect, SDG-4 could have been integrated in engineering curriculum together with nine goals of SDGs for achieving Agenda 2030 [1, 2].

To meet the challenge of SDGs, it is suggested to reform the current T&L process; because only teaching from books and laboratory practice is not fully suitable to achieve sustainable Agenda 2030[2]. Learning by forming partnership with industries and societies is an important pedagogical methodology that can contribute to learning about current real-time world problems and its solutions [28]. In this aspect, Al-Rawahy (2013) stated that the engineering schools must be competent in exposing students to industrial, social and environmental problems by developing active partnerships in the light of SDG-17 [29]. For example, to challenge the sustainable development barriers, Japan, the USA and Australia have launched some engineering and science programs for achieving SDGs. This programs could be the guideline for other nations to follow for launching ESD for Engineering education [29, 30, 31].

The academic staff of engineering has a vital role to play for providing integrated vision to students in the light of ESD for Agenda 2030. To perform this job, the lecturers shall participate in acquisition of knowledge and practical skills related to the natural sciences, biodiversity, climate change, carbon emission, causes of global warming, pollution effect on health and economy together with the methodology for developing required course plan, POs and Cos [18, 32, 33].

3.3 Engineering Education for Clean Water Towards Sustainable Development Goal-6

The SDG-6 focused on 'Ensure availability and sustainable water and sanitation for all by 2030 [34]. In this aspect, a basic question is why we need to add SDG-6 in ESD for engineering education? The reply has been given by experts, the answer is engineers are heavily involved in to producing clean water and distribution; effluent treatment, recycling wastewater, and to perform these activities require a huge amount of theoretical knowledge and skills. Additionally, water treatment technology involved mechanical, civil, electrical and instrumentation engineering' [35] [36]. In this aspect, Goal-4 (quality education in engineering) and SDG-6 are required in ESD for engineering curriculum. In this aspect, SDG-6 is also a right choice for engineering education.

More importantly, in 2015, the World Economic Forum addressed the water insecurity as the greatest long-term risk for society and economy [37]; and water has remained one of the top global risks. In 2016, the UN World water development report suggested that, if society continues to pursue the current operating model for water "business as usual" then by 2050, water demand and supply gap would exceed over 40%, which would be a risk for global GDP, health, and agriculture [38]. In this aspect, SDG-6 is also a right choice for engineering education.

To address the water crisis issue, students, professionals and academic staff involved in engineering shall be exposed to real problems in water domain. Thus students should get the opportunity to acquire required practical experience in water treatment processes, plant machinery manufacturing, process control systems, and relevant technology on water `treatment [39]. It was also suggested to reinforce curriculum with components of SDG-6 including 6.1-drinking water, 6.2-hygiene and sanitation, 6.3- water quality and waste water, 6.4-water use and scarcity,6.5-water resource management,6.6-water related Eco-system, 6a,-co-operation and capacity building, 6b-staeholder participation [34, 37] In this regards, Shields (2002) suggested to add the required information on curricula including indices, indicators, current data, data analyse procedures in the engineering curriculum [40]. Thus, the academic staff and professionals would be able to contribute to achieve SDG-6 towards Agenda 2030 [32, 33].

3.4 Engineering Education for Sustainable Development Goal-7

The SDG-7 focuses on "access to green and clean energy". Basically, sustainable green energy supply is a key issue for the balanced development and environmental sustainability. Many countries are struggling to ensure affordable renewable energy resources to achieve sustainability in energy supply and environment [42-42]. More importantly, as the renewable energy is considered as one of the potential solutions to climate change and energy security, hence the future generation shall have the required competency in renewable energy harvesting and supply [4, 43]. As green energy is a crucial issue for sustainable Agenda 2030; SDG-7 could be incorporated into the core courses of the relevant engineering programs for producing competent professionals for the future. This concept has been also supported by Ranjula (2007) and Shahidul et al. (2020) in order to achieve SDG-13 (climate change) as well [44].

Current energy and environmental scenarios demand, the SDG-7 shall be a part of the courses in the relevant engineering programs together with SDG-4 and SDG-17[44]. It is also expected by the experts to have quality T&L on SDG-7 for contributing to achieve Agenda 2030 [32, 33, 45].

3.5 Engineering Education and Sustainable Development Goal-9

The SDG-9 discuses on Industry**,** innovation, and infrastructure in the light of Agenda 2030, and has appeared as a key in achieving factors of sustainable development [18, 38]. In order to achieve SDG-9 and get things done efficiently and effectively, society requires capable professional engineers with the requisite theoretical knowledge and skills. In this aspect, a curriculum in engineering education is required with specific focus on components of SDG-9 including transportation for efficient supply chain, growth barrier and its solution, waste reduction and waste recycling, emission and pollution control [46]. Meanwhile, a few countries have made a bit of progress in SDG-9 by the aid of ESD. A report published by DataPoint (2020) for 2014-2018 demonstrates that the achievement of some universities on research for industry, innovation and infrastructure was 11.6%, on university spin-offs enterprise was 34.6%, research income from industry was 38.4% of the total research volume [47]. This information demonstrates that SDG-9 could be a worthy option for engineering curriculum

On this background, Pradhan (2019) and Cloud (2014) have suggested to add SDG-9 in ESD for engineering education, and trade-offs policy could be adopted between ESD and existing curriculum for implementing this goal[32, 33, 45]. However, it is also evident that engineering schools require collaborative activities with society and industry as per the guideline stated in SDG-4 and SDG-17 for implementing SDG-9 in ESD [48].

3.6 Engineering Education for Sustainable Development Goal-11

The SDG-11 relates to make cities and human settlements safe, resilient and sustainable, which implies that people shall have a living environment with good conditions for quality health, green environment without hazardous wastes, get affordable traffic for smooth transportation and utilities supply at a reasonable price [48]. As the priorities of Agenda 2030 are social, economic and environmental in nature, society needs competent engineers and architects with relevant theoretical knowledge and skills in achieving this goal. In order to produce professionals with the required competence in all these areas mentioned, SDG-11 is a favourable option for engineering curriculum [32,, 33]. The experts' opinion on the implementation of SDG-11 in engineering curriculum for schools are [45, 42]:

-SDG-11 shall integrate with SDG-4(quality education) and SDG-17,
- provision of required laboratories,
- exposure to societies and industries for exchanging knowledge and skills,
- competence of academic staff with hands-on skills for developing required POs and COs matrices.

3.7 Engineering Education for Sustainable Development Goals-12, 13 and 17

The achievement of Agenda 2030 crucially depends on how efficient the world will utilize the synergy effect of SDG goals; specially, SDG-12 (Responsible consumption and production) -13 (Climate actions) -17 (Partnership) [6].

The SDG-11 (Sustainable City), SDG-12 (Responsible consumption and production) and SDG-13 (Climate actions) are contributing to increased carbon emissions (CO_{2eq}) and various pollutions, which have contributed to effects on climate change. In order to reduce carbon emissions and pollutions, society needs competent professionals with relevant theoretical and industrial skills. In this regard, the engineering topics associated with SDG-12 and SDG-13 could be added in the engineering curriculum. A trade-offs policy could be adopted between ESD and traditional engineering curriculum for implementing these goals [7, 41].

More importantly, as per the Paris Climate Accord, it is long overdue to begin the learning process focusing on the indepth research to expand the lessons, and SDG-12 and SDG-13 will serve this purpose [2].

It has also been expected that if T&L, research and innovation activities move (SDG-4) with relevant industrial partners (SDG-17), the scenarios of academic and industrial performance would improve and will contribute to reduce the dangers of global warming and climate change [49–51].

4.0 THE PATH OF ESD FOR ENGINEERING EDUCATION TOWARDS AGENDA 2030

The ESD for engineering has appeared to be a key to achieve SDGs by 2030. The launch of ESD in engineering requires us to start with curriculum development. The second step of work is preparing academic staff with relevant theories, cognitive skills and academic competency. At the third level, schools need to prepare program outcomes (PO1-PO12 as suggested by various accreditation authorities) and to develop COs matrix for all relevant courses. The final stage is to prepare the required laboratories and academic facilities, as well as to build partnerships with relevant societies and industries [52], [53]. In this regard, Burmeister et al. (2012) have also suggested a few models to be integrated in ESD for engineering education [54] A few experts including Lilag and Debra (2015), Cloud (2014), Perrenent et al. (2000), Haan et al. (2010,) have also suggested some models to reinforce the ESD for engineering education; and all models are listed here as the paths towards Agenda 2030 [19, 34, 45, 46, 47].

4.1 Model 1: Adopting principles from sustainable practices in science, engineering and technology for hands-on education through laboratory, industry and work in the light of SDG-4, SDG-12, SDG-13 and SDG-17. This implies that students would be able to learn the sustainable principles in green technology, green engineering, green manufacturing and relevant topics in collaboration with industrial partners. The students will also be able to learn to perform work with minimum resources to optimize the production process; and at a minimum wastes to protect the environment [18].

4.2 Model 2: Adding sustainable science as content of the engineering curriculum in the light of SDG-4, SDG-11 and SDG-17. In this approach, the green technology for developing cities, green technology for infrastructure development with engineering principles shall be included as topics in the curriculum. For examples; the student will learn efficient industrial manufacturing systems, utilities production and supply in collaboration with the industrial, social and professional partners [18, 55].

4.3 Model 3: The ESD for engineering education with the socio-scientific issues in the light of SDG-1, SDG-2 and SDG-4. The strength of this approach in the curriculum will be based on OBE principle for developing appropriate skills for shaping the sustainable society, economy and environment. SDG-4 (quality education) will be the foundation for developing course plans, POs, COs, lecturer's delivery and assessment of the teaching outcomes. As stated by Burmeister and Eilks (2012), this model would contribute to produce responsible members in the society with knowledge, skills and values to innovate sustainable solutions to societal problems including solid wastes, toxic effluents, and hazardous pollutions [54].

4.4 Model 4: The ESD-driven school development for science and engineering education in the dimension of SDG-4, SDG-7, SDG-12, and SDG-17. The association of university leaders for a sustainable future (2003) has developed guidelines on how engineering schools shall build, operate and educate for future generation. The schools and relevant industries (as the education partners) and societies could work as laboratories for students to learn sustainability through the use of available resources. Thus, students will get an opportunity to learn the optimum use of water, energy, printing materials, food, chemicals, and waste recycling. In this model of education, all stakeholders will be engaged from learning to practice [56].

4.5 Model 5: Blending theories, research and industrial practices in ESD. The curriculum for engineering education could be developed in the light of SDG-3, SDG-4, SDG-12, SDG-13 and SDG-17. In this regard, Stuckey et al. (2013) has stated that the ESD shall represent a well-justified concept on education for all disciples. The author's opinion is, the ESD shall have the strength to contribute to essential dimensions: including individual, societal, natural and global relevance. Under this option, students will get quality education for occupational health, environmentally friendly production process, matrix of environment related climate actions in collaborations with social, professional and industrial premiership [33].

4.6 Model 6: Required theories, research and industrial practices shall be in the curriculum for engineering relevant to social, economic and environment in the light of SDG-3 SDG-4, SDG-13, and SDG-16. The ESD shall be executed with POs and COs for the requirement of Agenda 2030 [4].

4.7 Model 7: The ESD for Engineering education would be developed with an industrial advisory panel. This model will contribute to enriched ESD with SDG-17(partnership). Under this option, students will be educated under the guideline of SDG-4 and SDG-17 to contribute to achieve Agenda 2030 [5, 56].

4.8 Model: The ESD for engineering education would be developed with industrial training and CPD for lecturers under the guideline of SDG-4 and SDG-17. The European higher education, Washington accreditation authority and professional bodies have suggested to add the training and CPD programs as the essential activities for lecturers involved in engineering education [51], [57]. This model will contribute to increase T&L quality of engineering education towards achieving Agenda 2030.

5.0 CONCLUSION AND RECOMMENDATIONS FOR IMPLEMENTING ESD IN ENGINEERING EDUCATION

The aim of this study is to reveal the current status of ESD in engineering education with respect to Agenda 2030, proposed by the UN. Total 60 articles and reports reviewed were published by the UN, academic experts, and institutions involved in the Agenda 2030. The findings disclose the insight of the ESD for engineering education, which demonstrates that the current T&L level in engineering is quite far away compared to the requirement for achieving SDGs by 2030.The theoretical aspect of ESD in engineering education has seven (7) core areas relating to SDGs; and engineers are directly involved with all the areas, namely SDG-3 in the form of occupational health, SDG-6 service for clean water and sanitation, SDG-7 for electricity generation supply, SDG-9 for industry, innovation, and infrastructure, SDG-11 sustainable cities and communities, SDG-12 for ensuring sustainable consumption and production pattern and SDG-13 for climate action [1].

The expert opinion on T&L for engineering education is that both academic staff and students shall be involved in all seven core areas of SDGs together with the SDG-4 (Quality education) and SDG-17 (Partnership with society and Industry) [23]. Various academic experts and researchers have also proposed eight (8) models for educating engineering professionals for achieving Agenda 2030.The summary of the models have four core steps to implement. Step one is to launch ESD for engineering education. The starting point is developing the curriculum based on the nine (9) core areas of SDGs. At the second stage, we need to prepare academic staff with relevant theories, cognitive skills and academic competency. At the third stage, it needs to prepare program outcomes (PO1-PO12 as suggested by various accreditation authorities) and COs matrix for all relevant courses (SDG-4). The fourth stage is to prepare required laboratories, academic facilities and to build partnership with relevant societies and industries (SDG-17) [45,46, 47]. However, the curriculum for T&L and research shall focus on social values, professional ethics, economic and environmental sustainability [22, 23]

5.1 Barriers to Implement ESD in Engineering Education

This study reveals the evidence of a widespread and alarming inability in implementing the ESD for engineering education. The major barriers are [58, 7, 53]:

a. ESD has been adopted in engineering curriculum as an optimal topic in the light of add-in strategy and not as a core course.

b. Lack of guidelines in T&L planning for implementing ESD in engineering education.

c. Lack of trade-offs policy between ESD for engineering and traditional engineering curriculum.

d. The fourth identified barrier is engineering schools and the academic staff are not fully ready to adopt ESD for engineering education in the light of nine core (9) areas and eight models discussed.

e. Lack of teaching facilities and laboratories in the major engineering schools to adopt ESD in T&L process.

f. And finally, the current academic and research loads for academic staff and students are high and it has appeared as cumbersome task to accommodate further load for the ESD

5.2 Implications of research findings

The findings published in this article would have some important implications in engineering education. Specifically, the information disclosed here would be useful for the global institutions dealing with ESD and SDGs for remodelling education policy towards Agenda 2030. Even the information published here would be useful for country-level leaders who review ESD, trade-offs policy for Agenda 2030. More important use of the findings would be at management level of engineering schools for reformatting T&L policy, curriculum review, reconstruction of POs, COs, delivery, assessment policy and as well as restructuring work of CPD for lecturers
[30, 59, 60].

5.3 CONCLUDING WORDS

The implementation of ESD for engineering education towards Agenda 2030, requires strong supports from academic staff, society, industry and policymakers [30]. Even to develop curriculum for reinforcing ESD for SDGs, may require a strong co-operations from relevant engineering disciplines in order to reduce institutional capacity barriers [59]. Interactions and relationships within Nine (9) goals of SDGs relating to engineering activities can be used for implementing ESD in order to reduce academic and financial loads. The trade-offs policy between ESD and traditional engineering curriculum is one of the recommended options in engineering education towards 2030[7]. The ESD for engineering education shall focus to achieve (i) a low-carbon society, (ii) a sound waste material-cycle society as zero waste economy, and (iii) a society in harmony with balanced biodiversity, quality health and environment [29]. At the beginning, engineering schools may start with (a) development of model programs at undergraduate and graduate schools, (b) development of a consortium through the partnership of industry, government, and the public, and (c) development and strengthening of networks among the Universities [30].

All in all, findings offer a starting point for how researchers and policymakers can resolve the challenge of interactions between the SDGs and ESD for engineering education, particularly regarding the persistent issue of trade-offs. This paper has focused on some best practices of ESD where it would be possible to use trade-offs between ESD and traditional engineering curriculum for achieving synergies in education. Further research would be carried on this area to explore and uncloak all potentials to speed up implementation of ESD for engineering education. Further research is also urgently needed into how the current trend can be reversed otherwise the barriers to implementing the ESD would seriously threaten the achievement of the UN Agenda 2030.

6.0 ACKNOWLEDGEMENT

Author appreciating the supports received from stakeholders involved in this study including M.Sc student Mr Eugene and Mr Mamunur Rashid. The author also offers his special thanks to Malcolm Mussen Lamoh for his sincere contribution for reviewing the paper. And also sincere thanks to TFE Global for providing technical assistance for collecting some required information. The author thankfully acknowledges the financial and logistic supports received through RIEC UNIMAS for the grant UHSB/B-AM2018/096.

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