MEASURING SUSTAINABLE DEVELOPMENT EDUCATION FOR INFORMATION TECHNOLOGY EDUCATION PROGRAM REVIEW USING STAUNCH© CRITERIA INSTRUMENT

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ABSTRACT

This article explains the results of a study that focuses on measuring Sustainable Development (SD) education for Information Technology Education (ITE) program review in UPSI. A Sustainable Development Education Model (SDEM) was constructed in this study using two integration approaches, namely a horizontal integration and a vertical integration. Both integration approaches were used to measure courses offered in the existing program with selected courses on the implementation of the SD education. The SD education in the selected programming and networking courses was measured using a self-assessment of sustainability criteria based on the Sustainability Tool for Assessing Universities Curricula Holistically (or STAUNCH©). STAUNCH© is an analytical software used to analyze courses and academic programs across all disciplines specifically on assessing the contribution of their curricula to SD. The software analyzed two parts of SD education evaluation which are curriculum evaluation and concept evaluation, using descriptive statistics with percentage cross-tabulation method. The results from the first part show that there is a normal distribution in ESD contribution by each course and a low indication on the grade strength for SD contribution in curriculum evaluation. The results from the second part show that there is a high importance to agree on the components used in the design of SD integration concept and an average rate of SD integration into the curriculum. For the teaching and learning method used, it was found that a cross-disciplinary approach, a mix-method approach, and a project-based learning (PBL) is extremely important for the successful SD integration into the curriculum. The study concludes that upon measuring the selected programming and networking courses in the ITE program, the SD integration within these courses are above average and necessary steps are needed to be taken accordingly. The study implies that SD education not only benefits the curriculum provider, but also the students because they are the future inheritors of technology as it benefits a sustainable future.

KEYWORDS

Sustainability development (SD), STAUNCH©, information technology education program review

1. INTRODUCTION

With the world population currently at 7.7 billion people, and growing exponentially every day [1], coupled with the finite number of natural resources found on earth, humans need to learn to live more sustainably. As human beings, there is a need to understand that today actions today can have major future implications on the lives of the people and the planet. To assure a sustainable future, humans should have a full understanding, and appreciation, of the strong

interplay and overlaps among the three pillars, which are the basis of sustainable development [2][3].

Sustainable development is the overarching paradigm of the United Nations. We can imagine Sustainable Development (SD) as an individual and social search, learning and design process in which all members of society participate. The concept of sustainable development was described by the 1987 Bruntland Commission Report [4] as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

There are three pillars of SD, namely, the economic, social, and environmental pillars and their strong interplay and overlaps. There is no single point of origin of this three-pillar conception, but more accurately that it emerged steadily from various early analysis of the academic literature on the economic status quo from both social and ecological perspectives [5]. It was stated that the pillars concept also originated, on the other hand, from the quest to reconcile economic growth as a solution to social and ecological problems on the part of the United Nations (UN).

UN urges the philosophy of Education for Sustainable Development (ESD) [6]. ESD empowers learners of all ages with the knowledge, skills, values, and attitudes to address the interconnected global challenges we are facing, including climate change, environmental degradation, loss of biodiversity, poverty, and inequality. ESD is the umbrella term that refers to the various forms of learning and teaching associated with SD in societies. Such a participatory process requires that all actors have the appropriate knowledge and skills to participate in it [7]. Thus, ESD is a key enabler for SD and vital component of the educational mandate [8]. While United Nations Educational, Scientific and Cultural Organization (UNESCO) stated that ESD can empower people to change their perspectives and work together towards a sustainable future [9]. UNESCO also stated that there is growing international recognition of ESD as an integral element of quality education and a key enabler for SD. Their commitment towards ESD was solidified by the institutions decision to include it in its Sustainable Development Goals (SDGs).

According to the United Nations Development Programme (UNDP) the SDGs are first introduced at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. The SDGs are developed as a follow-up to the Millennium Development Goals (MDGs) and adopted by the United Nations (UN) General Assembly in September 2015 [9]. The MDGs have played an important role in shaping both development and development discourse. However, the MDGs have been widely critiqued. The MDGs were led by a set of goals, targets, and indicators, this indicator-led development agenda has been critiqued for allowing these indicators to drive development agendas, rather than being used to measure progress towards broader development aims. Informed by their origin in the Rio+20 process and the critiques of the MDGs, the objective was to produce a set of universal goals that meet the urgent environmental, political, and economic challenges facing our world. In short, the SDGs are a universal call to action to shift the world onto a more sustainable path.

There are seventeen interconnected SDGs as seen in Figure 1 with one hundred and sixty-nine targets, but for the purpose of this study goal number four which is quality education is the focus.

Figure 1. The UN Sustainable Development Goals (SDGs)

As shown in Figure 2, which shows goal number four of UNESCO SDGs, goal number four is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. According to UNESCO achieving inclusive and quality education for all reaffirms the belief that education is one of the most powerful and proven vehicles for sustainable development [9].

Figure 2. Goal 4 of the UN Sustainable Development Goals (SDGs)

According to UNESCO Sustainable Development Goals (SDGs) target 4.7 states that:

By 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of cultures contribution to sustainable development [9].

More importantly target 4.7 of the SDGs stated, in part, that by 2030 we should ensure that all learners acquire the knowledge and skills needed to promote sustainable development. To achieve SD, the world needs reflective, innovative, forward looking, and responsible women and men [9]. The indicators for target 4.7 under the SDGs are amongst others the extent to which ESD is mainstreamed at all levels in national education policies, curricula, teacher education and student assessment.

It is an important requirement for Higher Education Institutions (HEIs) to integrate SD as an effective way to share and promote ideas with future generations. During the last two decades, many higher education institutions have become involved in embedding SD into their academic systems [10]. HEIs play a vital role in shaping the earth's future generations whom after their studies will assume key roles in society and can actively and decisively help to shape SD. Higher Education Institutes (HEIs) have the potential to prepare and increase student information and knowledge with the use teaching and learning [11], research, community engagement [12] and general campus operations as tools in a move towards a sustainable future, for the reason that they are the future leaders and inheritors of technology. Moreover, students generally regarded

sustainability competences as important to the future labor market [13]. Furthermore, greening by Information and Communication Technologies (ICT) is a new opportunity in terms of employment for smarting buildings and the grid [14].

The ICT sector is viewed as important in ensuring SD [15]. It is important to note that ICT presently interpenetrates and is vital to the economic, social, and environmental dimensions of many nations around the globe [16]. Furthermore, the pervasive diffusion of ICT also aides in addressing societal and sustainability challenges in energy [17]. ICT contributes immensely on the design of smart grids, moreover it has a vital role in energy efficiency and low carbon energy strategies in areas such as behavioral medications towards energy conservation [18].

There was a lack of qualified specialists with high expertise in ICT who can design, develop, deploy, and maintain both pervasive computing systems and communication architectures for sustainable development [19]. This has led to the necessity of incorporating SD principles into Higher Education (HE). There is evidence that pointed to the need for more emphasis on energy efficiency and renewable energy concepts and technologies within HE [20]. Goal seven of the SDGs deals with 'affordable and clean energy' and target 7A states in part that.

By 2030 enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency…[9]

All advancements of energy efficiency are consequential because any small step towards higher energy efficiency steers the world towards a more sustainable future. Furthermore, it is important to remember that sustainability is a journey of continuous improvement, not a target place [21].
For this study, it was limited to a single HEI and a pre-determined number of courses. This study covers part of the undergraduate IT curriculum at Sultan Idris Education University in Perak, Malaysia. The coverage of this study is limited to courses that deal with computer programming and computer networking. This research aims to integrate sustainability into the curriculum using the courses (programming and networking). There is lack of literature on the topic of energy efficiency education for IT students as most of the literature available pertains mostly to other fields of study i.e., engineering. Moreover, model design and development examples that dealt with the topic of energy efficiency education for IT students are few and far apart because it is still an emerging field.

It is evident from the background that energy efficiency education is integral for future Information Technology (IT) students to aid them to garner the competencies required to strive for a more sustainable future, therefore the aim of this study is to design, develop and evaluate a model for the energy efficiency education of undergraduate IT students. Here are the four main reasons on why this study was conducted:

The lack of investigation on SD and ESD implementation and integration strategies: Although there is a plethora of literature on ESD, a closer look at the literature revealed that there are still major areas of concern, such as better integration of ESD into curricula, research, and most importantly holistically into HEI's system. HEIs are making advancements in SD implementation but creating a process in the local and global context to incorporate ESD in their institutions is a challenge that is being faced by many. Future research should consider the core activities of HEIs. Furthermore, research activities are important at all stages of transition to reflect on ESD innovations [22]. SD practices in HEIs and their impact on HEIs and society should be the focus of future research, whilst the drivers of and barriers to sustainability change should be empirically explored and assessed [23]. To better understand the organizational context for implementation of ESD from an HE perspective more research needs to be conducted.

The lack of exploration and the need to report on the SD and ESD TMFAs: More exploration of the sustainability tools, methods, frameworks, and approaches (TMFAs) used in HEIs is required [24], since this exploration captures the TMFAs that might not have been recorded in the academic literature.

Scarcity of energy efficiency education models for undergraduate IT students: There is a need for more ESD centered models that foster sustainability and the development of alternative values since they are still scarce around the globe [25]. There is a huge gap in the literature on the topic of energy efficiency education, furthermore there are very few examples of models for energy efficiency education of undergraduate IT students. There are suggestions to teach energy efficiency [26]. An expressive demand for energy exists in HEIs, and for this reason it is important to educate students on energy efficiency. Moreover, education requires the merging of updated technology with energy education [27]. The importance of a project designed to link different parts of the institution together in such a way that the campus becomes a living laboratory in which innovation and ESD principles may be implemented and tested together. Energy efficiency education is of great importance since there is a need for long-term planning for energy efficiency education within the HE, government, and industry [28], as this is an evolving topic where there will continue to be new knowledge and skills to be integrated.

The importance of evaluating the model: Evaluation is always an integral part of any program, and it is important to monitor the effectiveness and efficiency of sustainability programs [29][30][31] that are integrated and/or implemented into HEI systems.

For further reading, this paper is organized as follows. In Section 2, the literature was done towards the main discussion, which is the findings on systematic literature method used to identify relevant research. Section 3 provide the details of four-phase of model research. Followed up by Section 4, this section discussed the findings regarding the curriculum evaluation and SD integration into curriculum. Finally, the paper concludes with a discussion on the contribution and recommendation of future study.

2. LITERATURE REVIEW

To further discuss on the existing research on the same and similar field, a systematic literature method was introduced in this study. The flow and procedures are as following.

2.1. Systematic Literature Method

A systematic literature review method utilizes systematic and clear-cut methods to identify, select, and critically assess relevant research, and to collect and analyze data from the studies that are included in the review [25].

The systematic literature method was divided into a few steps:

Scoping: The researcher formulated research questions and clarified whether such research already exists. The researcher managed to clarify that although there is a plethora of literature on ESD, there are still major areas of concern and further research is required to investigate the holistic integration and/or implementation of SD and/or ESD into HEI systems and explore the effectiveness of sustainability tools, methods, frameworks, and approaches (TMFAs) used in HEIs.

Planning: Formulating the search terms is the second step for the researcher and it took a few attempts to find the search terms that have a balance between sensitivity and specificity. At this step of the process the researcher also formulated the inclusion and exclusion criteria to be used.

Identification (Screening): The researcher searched three high quality databases namely, Web of Science, ScienceDirect® and IEEE Xplore™. Additional hand searches for articles mentioned in and/or found in the references of the articles found while searching.

Screening: The researcher read the title and/or abstract of all the articles identified by the searches and set those fitting the inclusion and exclusion criteria aside.

Eligibility: The researcher then read the full text of the articles that had made it through the first screening and set the one fitting the inclusion and exclusion criteria aside for sorting. The researcher then rigorously extracted the relevant information that would be used.

Inclusion Criteria: These are inclusion criteria used for the screening and sorting purposes:

1. Only articles from ScienceDirect®, Web of Science and IEEE Xplore™ are used as they are reliable sources of academic literature.
2. Only articles published after 1st January 2014 to 31st May 2019 are used as per UPSI postgraduate literature regulations.
3. Only English articles are used.
4. Only review and research articles are used as they offer source reliability.
5. Only articles that focused on and discussed ESD, SD, sustainability education and environmental education in the HEIs context are used.

Exclusion Criteria: These are exclusion criteria used for the screening and sorting purposes:

1. Articles that focused on and discussed ESD, SD, sustainable education, and environmental education in the Early Childhood Development (ECD), Primary and Secondary school contexts were excluded.
2. Articles that focused on and discussed Sustainable Development (SD) but not in the educational context were excluded.
3. Articles that focused on and discussed Environmental Education (EE) but not in the context of sustainability were excluded.

Search Query and Keywords

Search Query:
("Education for Sustainable Development" OR "Sustainable Education" OR "Sustainability Education" OR "ESD" OR "HESD") AND ("Higher Education Institution" OR Higher Education Institutions" OR "HEI" OR ‘HEIs" OR "University OR Universities")
Keywords:
Education for Sustainable Development, Sustainable Education, Higher Education Institution/s

Figure 3 shows the systematic and clear-cut methods to identify, select, and critically assess the relevant research papers that are used in the systematic literature review. After a search of the three academic databases ScienceDirect®, Web of Science and IEEE Xplore™ a total of 1209 articles were selected for title and abstract screening. Only 170 articles from the screening process were deemed suitable for the purpose of this research, with an additional 16 more articles collected from a hand search. Hand searching is manual method of scanning select journals for relevant articles in case they were missed during indexing. The full text screening concluded that only 148 met the criteria for the research.

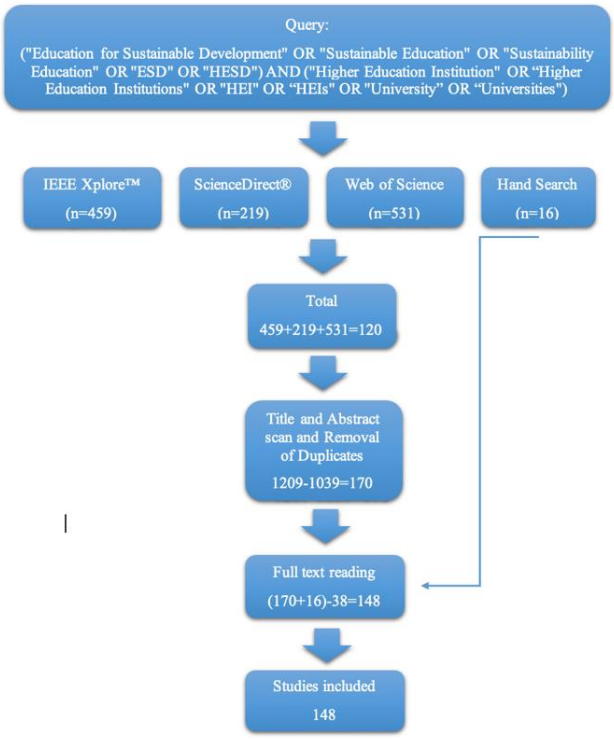

Figure 3. Literature Selection Flow Diagram [25]

2.2. Statistical Overview

Figure 4 shows a graph of the number of articles and the database (Web of Science, ScienceDirect® and IEEE Xplore™) the 148 articles are sourced from. Including those sourced through hand searching [25].

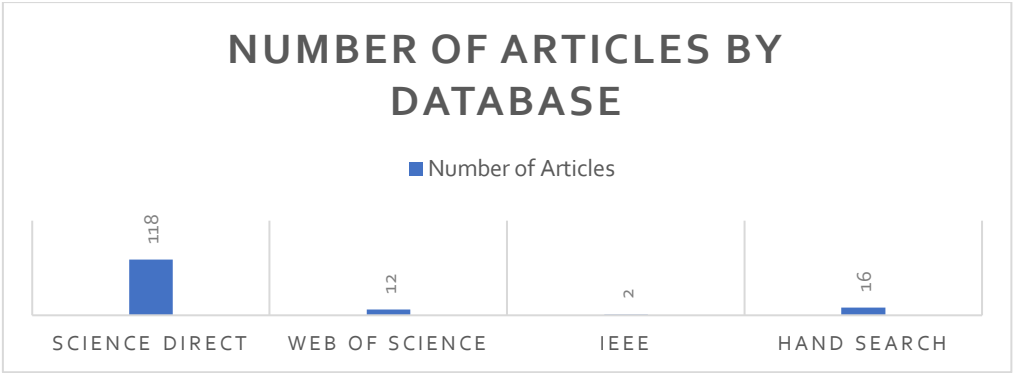

Figure 4. Number of Articles by Database [25]

Figure 5 shows a graph of the number of articles that are found on the six main categories (implementation of SD, perception and engagement, assessment and reporting, organizational change, curriculum orientation and campus operations), the databases (Web of Science, ScienceDirect® and IEEE Xplore™) including the year in which the articles were published (2014-2019)[25].

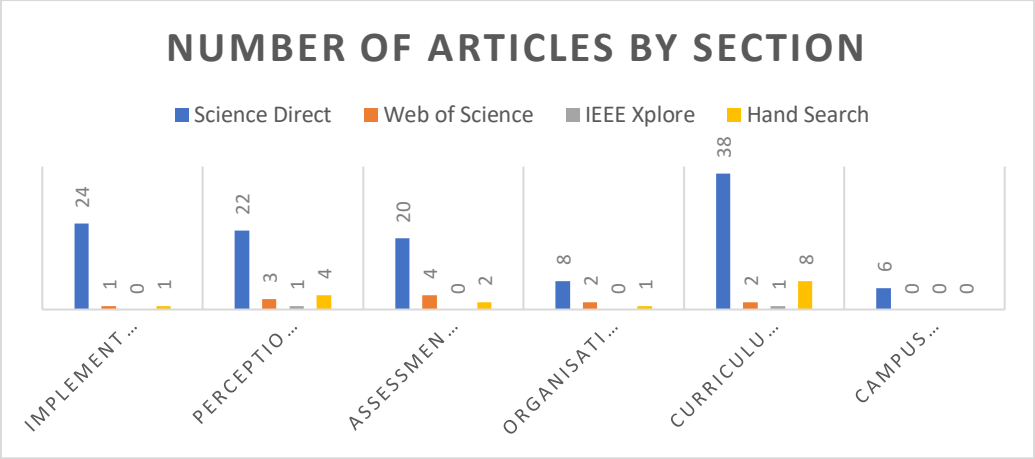

Figure 5. Graphical Representation of the Articles Count Using the Six Main Sections [25]

Figure 6 shows the taxonomy of the articles used in the systematic literature review which has three layers. The first being the main layer of ESD. Followed by the second layer which consists of six sections, namely, implementation of SD, perception and engagement, assessment and reporting, organizational change, curriculum orientation and campus operations [25]. The third layer further divides the six sections into smaller subsections as seen in Figure 6.

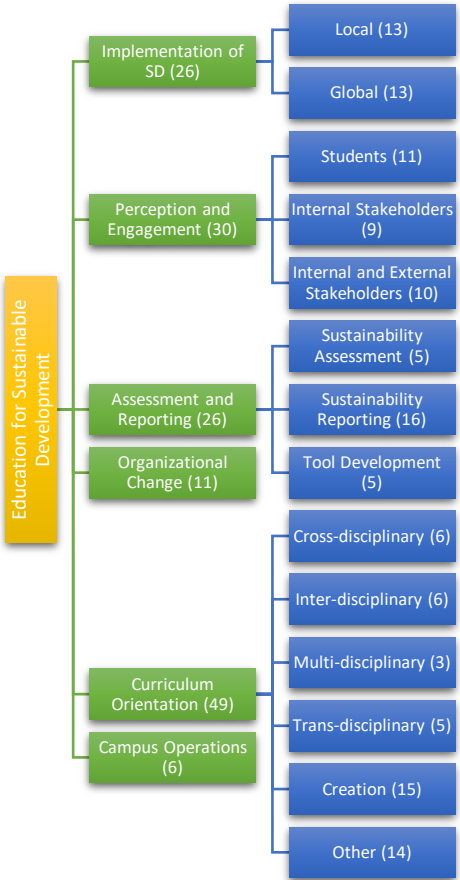

Figure 6. Taxonomy of the Articles Based on the Motivation or Focus of the Study [25]

2.3. Education for Sustainable Development (ESD)

After a rigorous analysis of the articles are sorted into six main sections (implementation of SD, perception and engagement, assessment and reporting, organizational change, curriculum orientation, campus operations) [25].

Implementation of SD: A total of twenty-six articles focused on the implementation of SD into the HEIs' system. The articles reviewed the progress of sustainability in HEIs and forecast the future of ESD in HEIs, the role of HEIs in implementing SD into HEIs' systems, addressing the existing lack of profundity when it comes to sustainability and HEIs, and further identifying and categorising the critical attributes and finding solutions to them. These articles further analyzed the importance of policy agreements and conferences for SD amongst HEIs.

Perception and Engagement: A total of thirty articles address stakeholders, their perceptions, and their engagement in the incorporation of ESD. These articles focused on stakeholder (internal and/or external) perception of ESD and/or SD approaches in HEIs, concentrated on the role of stakeholders in ESD and/or SD in HEIs, further analyzed the factors influencing stakeholder engagement in ESD, and focused on the stakeholder and/or HEIs collaboration. These are further categorized according to three subsections to further investigate the study's area of stakeholder perception. Whether it is student perception (eleven articles), internal stakeholder perception (nine articles) or internal and external stakeholder perception (ten articles).

Assessment and Reporting: A total of twenty-six articles discussed how sustainability is being assessed and reported in HEIs. The articles focused on the structuring factors and visibility of sustainabilty content in HEIs degree titles and curriculum, on planning and monitoring ESD and/or SD activities in HEIs and outside of the HEIs setting, concentrated on the validity and reliability of the tools that are developed, analyzed pedagogy and pedagogical tools that can be used for ESD in HEIs, and comparing the practices of HEIs.

Organizational Change: A total of eleven articles focused on the dynamics of organizational change management for sustainability. The articles also focused on identifying and overcoming the factors to integrating ESD and/or SD into HEIs, concentrated on the policy and/or implementation, focused on the pedagogy of organizational change management, and comparing organizational change processes in different HEIs.

Curriculum Orientation: A total of forty-nine articles presented examples on sustainability educational approaches, and course design, development, and delivery. The articles focused on pedagogical approaches and tools for ESD in HEIs, concentrated on sustainability consciousness, examined value creation in support of transition to sustainability for stakeholders (internal and/or external), embedding ESD and/or SD in HEIs to understand and address future employment challenges, on ESD course and methodology creation for HEIs, further examined the factors that influence ESD and/or SD integration in HEIs, shows the emergence of green ICT, and focused on comparing the ESD and/or SD practices of HEIs, and examines the role of paradigms in engineering practice and ESD. These are further categorized into six additional subsections to check how and where sustainability is in the curriculum or whether only analysis is reported. These are cross-disciplinary (six articles), inter-disciplinary (six articles), multi-disciplinary (three articles), trans-disciplinary (five articles), creation of a new sustainability-centered course or program (fifteen articles) and analysis (fourteen articles).

Campus Operations: A total of six articles presented the results and findings of research on campus operations. The articles explored behavioral and institutional change, focused on

comparing HEIs SD performance, concentrated on organizational carbon foot printing, and aim to assess sustainability in HEIs.

2.4. Tools, Methods, Frameworks, and Approaches (TMFAs)

Twenty-four articles are found to have reported on TMFAs [25]. An exploratory study on the simulation game technique using "napuro" as a tool. "napuro" is a business simulation game that conveys essential features of corporate sustainability and Corporate Social Responsibility (CSR). A study discussed the overall conceptual framework of the Constructionism in Learning: Sustainable Life Cycle Engineering (CooL:SLiCE) platform. CooL:SLiCE is a collaborative research project to: 1) support the sustainable product design learning in a constructionist mode, 2) provide a distributed cyber learning environment, 3) provide tools for design and visualization of products, sustainable supplier architecture and selection, and sustainable manufacturing processes, and 4) offer an integrated platform for analysis of manufacturing processes and supply chains through the development of models that can assess the sustainability performance early in the product design phase [25].

A study introduced and analyzed the design of an open learning environment based on the idea of living laboratories [25]. A glocal model for transnational collaboration for sustainability which combines the use of digital technologies for global collaboration with experiences and engagement for local learning and impact. The glocal curriculum rethinks the engagement of students' knowledge, skills and mind-sets through the demands posed by learning about sustainability problems and solutions on global and local scales and across geographical and cultural contexts. An analysis of the social learning process that took place in the interdisciplinary and intercultural Competencies for A Sustainable Socio-Economic development (CASE) team during the participatory development process of the new master's program. CASE aims at developing modules for a joint master's program that can be adopted by various European HEIs. Another study employed citizen science as a data collection and educational tool in two engineering courses. Citizen science is an emerging practice which refers to the public participation in scientific research through the collection and the reporting of data. One study reported on the toolsets use and stated that the Accelerator is a toolset comprising four process and analysis tools and one underlying method for integrated strategic planning from a sustainability perspective. A group of researchers studied a lab-based learning environment known as the Challenge Lab. The Challenge Lab allows master students to engage in and create value in support of the transition to a sustainable society. A study presented and analyzed the "Climate.now" online course material as an example of interconnecting climate change education. "Climate.now" is an online course for interconnecting climate change education. A study described four capstone projects developed by students from the Erasmus Mundus, Master Course in Pervasive Computing and Communications for Sustainable Development (PERCCOM). It described the development of the PERCCOM international master's degree program. PERCCOM aimed at providing students with the basic knowledge and skills in Information and Communications Technology (ICT) and advanced competencies in green ICT.
Another study developed a new Renewable Energy program using a well-equipped laboratory, containing state of the art equipment in various fields [25]. While a study highlighted the importance of Living Labs as innovation infrastructures in HEIs. A study proposed a model for generating "trend-based scenarios", in which this tool identifies possible, probable, or preferred spaces of the future from the intersection of different trends. The Michigan Sustainability Cases are problem-driven, solutions-oriented tools to enable experiential learning inside and outside the classroom [25]. The initiative builds on the familiar case-based approach by adapting it in three ways to support active, engaged learning: 1) integration of audio-visual elements into the conventional text-based case narratives, 2) strong partnerships among students, faculty, and practitioners to flip the curriculum, and 3) a digital platform for enhanced flexibility to configure

case-based curriculum design. Another study utilized collaborative community action research vignettes to addresses gaps in developing SE to promote new generations of academics and practitioners [25]. A report presented analysis of the selected programs, the methodology, self-evaluation and external auditing process, evaluation criteria and results of the Quality system of European Scientific and Technical Education for Sustainable Industry (QUESTE-SI) evaluation. QUESTE-SI is an evaluation and accreditation tool that gives attention to the presence and realization of sustainability strategies at institutional and unit department.

Another study presented a regionalized educational initiative for integration of SD in HEIs [25]. PACTE 2D (Acronym in French for Partnership, Learning, Collaboration and Transfer in Sustainable Development Education) is an ongoing collaboration project amongst seven HEIs in Quebec. Another study assessed the effectiveness of ESD through eLearning in HEIs [25]. While a study described an international sustainability-oriented teaching and learning program at the HEIs level [25], where theoretical concepts developed over recent decades were applied in teaching practice, tested and reflected upon. The Interdisciplinary Study Programme on Sustainability (ISPoS) is aimed at developing and evaluating a blended-learning study program for undergraduates. A study presented the methodology and the general framework followed in the "USE Efficiency" program [25]. "USE Efficiency" is an inter-institutional and interdisciplinary educational program targeting energy efficiency in buildings.

A group of researchers presented a variety of assessment tools [25]. The Auditing Instrument for Sustainable Higher Education (AISHE), which is based on five fields (vision and policy, expertise, educational goals and methodology, education contents, and results assessment). The Graphical Assessment for Sustainability in Universities (GASU) tool, which is based on the Global Reporting Initiative sustainability guidelines and complements them with an educational category. The Sustainability Tracking, Assessment & Rating System (STARS), which assesses sustainability according to three major categories: education and research, operations, and planning, administration, and engagement. The Sustainability Tool for Assessing Universities' Curricula Holistically (STAUNCH©), focuses specifically on assessing the contribution of curricula to sustainability using course descriptors. Other researchers explained how the dual education-system works. The dual-education system relies on the simultaneous training of apprentices in theory and praxis for a specific profession [25].

2.5. Discussion

The results of the literature review indicate that there are a few main aspects, namely, stakeholders, TMFAs, pedagogy and organizational change, which are integral for the success of models for sustainability purposes [25]. First, on the aspect of stakeholders, a unified role in sustainable development is key. Furthermore, the participation of all interested parties, including industry representatives, instructors, foreign experts, and representatives of government is required in reassessing and creating new educational standards and/or ideas about sustainability. Stakeholder dialogue is crucial to feed investment into sustainability projects. Secondly, on the aspect of TMFAs, they are integral in the successful implementation and/or integration of sustainability, although the choice of the TMFAs was relative to the application context. Third, on the aspect of pedagogy, sustainable pedagogy cannot be unidimensional. Furthermore, educators are required to accurately gauge their students' perspectives before tailoring suitable pedagogy and learning activities. Moreover, to strengthen the effectiveness of educational responses, educational practices need to be designed in line with learning goals. Finally, on the aspect of organizational change, there is also a need to modify the operating dynamics of HEIs when implementing and/or integrating sustainability into their systems.

The results of the literature review also further indicate that even though HEIs are engaged in implementing and integrating ESD into their curricula, there are still many barriers impeding the progress of these programs. Moreover, since there is a lack of studies being done on energy efficiency education and examples of models are extremely scarce. Subsequently, the results of the literature review also indicate that there is a need for research on energy efficiency education and ways to implement and/or integrate it. Thus, further research needs to be conducted on models that can be used for the purpose of energy efficiency education and the proper implementation and/or integration approaches and methods of these models into HEIs. Finally, the results further indicate that it is integral to note the importance of monitoring the effectiveness and efficiency of sustainability programs [25].

These results should be considered when considering how to design a model for the energy efficiency education of undergraduate IT students.

3. FOUR-PHASE OF MODEL RESEARCH

This research utilized a Model Research (MR) method, which is a subcategory of the Design and Development Research (DDR) method. The MR method is suitable for this study as it pertains to research that deals with the development, validation and use of design and development models. Furthermore, the MR method is suitable for this study because it focuses on the model and processes themselves, rather than their demonstration [25]. By using the MR method, this research aims to outline the design and development of a model and the conditions which facilitate its use.

Subsequently, it is vital to note that model research studies tend to be more generalizable than the other types of design and development research methods. However, findings cannot be generalized based on statistical techniques, such as, focusing on generalizations from sample to population [25]. Alternatively, one must invest in analytical forms of generalization. In the case of this research, a four-phases methodology detailing the analysis, design, development, and evaluation phases of the model is proposed as shown in the overview provided in Figure 7.

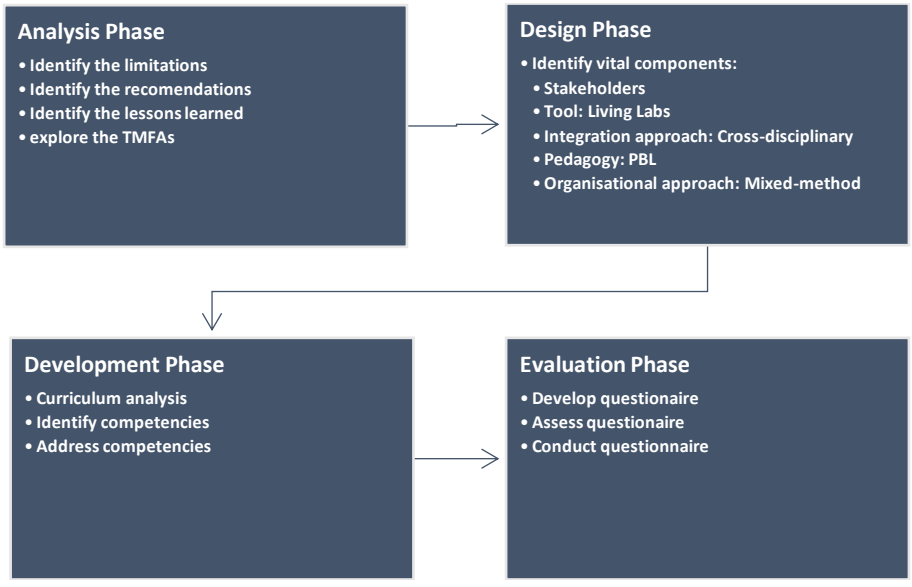

Figure 7. Overview of the Four-Phase of Model Research [25]

3.1. Analysis Phase

This phase aims to tackle the first and second objectives of the research. In that, it investigates holistically how HEIs are implementing and/or integrating ESD and/or SD into their systems and explores the ESD and/or SD tools, methods, frameworks, and approaches (TMFAs) used in HEIs [25].

3.2. Design Phase

ESD should not be limited to teaching and learning methods or curricular content and cannot be developed in a vacuum, rather it depends upon parallel efforts in other dimensions including stakeholders' involvement and curriculum development [25]. Five identified integral components required for the successful integration of ESD namely, stakeholders, tools, integration approach, pedagogy, and organizational approach.

3.3. Development Phase

This is the third phase of the proposed methodology. During this phase, parameters for the curriculum analysis are provided and the fundamental ideas from the concept design which are used to develop competencies for energy efficiency education of undergraduate IT students. The development focused on which competencies are required and how to address these requirements. The processes involved in the development phase, namely, curriculum analysis, identifying competencies, and addressing competencies [25].

Curriculum Analysis: The desire to perform a curricular assessment can result from a variety of broader activities, but regardless of why a HEI selects to perform it, curricular assessment can offer stakeholders a starting point for change [32][33]. Furthermore, although there are few assessment tools available to researchers, The Sustainability Tool for Assessing Universities' Curricula Holistically (STAUNCH©) is best suited for this research. The reason being that its assessment focuses specifically on curricula and is aimed at helping universities in a holistic and systematic way to assess the contribution of their curricula to SD. Whereas, assessment tools such as AISHE, GASU, STARS are mainly focused on providing an overview of HEI activities and on improving the sustainability of campus operations [34].

In this study, STAUNCH© was used for assessing ITE program offered in UPSI. STAUNCH© is based on cross-cutting theme issues which integrate economic, environmental, and social dimensions. STAUNCH© is also based on the SD contribution, taking into consideration their strengths, using the following levels:

- 0: When a particular issue is not mentioned;
- 1: The issue is mentioned but there is no further explanation given on how it is addressed;
- 2: The issue is mentioned and there is a brief description of how it is addressed; and
- 3: There is a comprehensive and extensive explanation on how the issue is addressed.

Identify Competencies: The future labor force will be reliant on sustainability competencies [35]. The development of key competencies is based both on cognitive and non-cognitive dispositions [36]. Furthermore, through combining formal (i.e., classrooms) and informal (i.e., living laboratories) learning settings within HE, a variety of contexts can be given, and competence development can be enhanced. Subsequently, for HESD common competencies have been identified to include skills, motivations, and affective dispositions for solving real-

world sustainability [25]. Key competencies are also described as multifunctional and context independent. Although, it is important to note that there is no common agreement on the proper approach to select, define and rank key competencies required for sustainable development. Knowledge, skills, and attitudes are agreed to be the three most crucial components [35]. It is also important to note that the United Nations Economic Commission for Europe (UNECE) described competences in ESD. It is also important to remember the six general characteristics of PBL to identify the proper competencies for this research. The competencies used for this research are adopted from [21]. The identified competencies are divided into three main categories, namely, knowledge, skills, and attitude. The skills category is further divided into four subsections, namely, professional expertise, human resources, functional flexibility, and innovation.

Addressing the Competencies: The competencies are divided into three main categories, namely, knowledge, skills, and attitude. The skills category is further divided into four subsections, namely, professional expertise, human resources, functional flexibility, and innovation.

3.4. Evaluation Phase

Evaluation is a process used to critically examine something. It involves collecting and analysing information on activities, characteristics, and outcomes. Its purpose is to make judgments and to improve effectiveness, and/or to inform decisions. It is important to note that, for this research only formative evaluation is conducted [25]. Subsequently, no summative evaluation is conducted. The reason being that summative evaluation is conducted after the completion and implementation of a model. This research, however, is limited by the lack of physical facilities required for summative data collection procedures and methods. Formative evaluation, however, is fundamental because it is conducted to identify the deficiencies in the proposed model during its development. It involves collecting data on adequacy and using the data to for any further amendments. It may be done internally and externally or by combining the two. The processes involved in the evaluation phase, namely, questionnaire development, questionnaire assessment, and conducting the questionnaire.

Questionnaire Development: This research utilizes a case study method which focuses on the IT department of the Faculty of Arts, Computing and Creative Industry (FSKIK) at Sultan Idris Education University (UPSI). Case studies can be explanatory, exploratory, or describing of an event. To this research, an exploratory case study method was used. This type of case study is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes [25]. For data gathering, a two-phase survey using a questionnaire which can shortly be described as a series of written questions a participant's answer is utilized.

1. The first survey is developed to collect data on the respondents' agreement towards the components utilized in the design of the concept for energy efficiency education of IT undergraduate students. It is also developed to collect data on the importance and quality of the components utilized in the design of the concept for energy efficiency education of IT undergraduate students. Furthermore, it is developed to establish whether vital ESD components that are necessary for a successful model have been omitted from the design of the concept for energy efficiency education of IT undergraduate students. The questionnaire consists of a section for respondent information and a further two sections. The section on respondent information aims to collect data on the respondents' gender, age, academic rank, main disciplinary background and ESD experience. The first section deals with the utilized components and requires the respondents to rate the questions on a Likert scale of 1 to 5. In this section the respondents are required to answer questions on the stakeholders, tool, pedagogy, integration approach and organizational change

components. The second section deals with structure of the concept and requires the respondents to answer open-ended questions. This is because, open-ended questions are useful in exploratory research. In this section the respondents are once again required to answer questions on the stakeholders, tool, integration approach, pedagogy, and organizational change components.

2. The second survey is developed to collect data on respondents' agreement towards ESD in IT and energy efficiency education in IT. It is also developed to collect data on the importance and quality of ESD in IT and energy efficiency education in IT. Moreover, it is developed to collect data on the importance of the competencies used in the creation of the proposed model for energy efficiency education of Information Technology undergraduate students. Finally, it is developed to collect data on the respondents' agreement towards how the ESD competencies used in the creation of the proposed model for energy efficiency education of Information Technology undergraduate students are being addressed. The questionnaire consists of a section for respondent information and a further four sections. The section on respondent information aims to collect data on the respondents' gender, age, academic rank, main disciplinary background, and modules taught. Moreover, the respondent information section also collects data on the quality of the respondents' knowledge of ESD, energy efficiency and ESD competencies by rating questions on a Likert scale of 1 to 5. As for the four further sections, the respondents are required to answer questions on ESD, energy efficiency, identified competencies and addressing the competencies. Each of the four sections requires the respondents to rate the questions on a Likert scale of 1 to 5.

Questionnaire Assessment: Questionnaires are assessed through a process where an expert evaluates and edits questions to make it free of inaccuracies. The importance of vetting and re-vetting of examination questions cannot be overstated. Subsequently, the questionnaires are checked to amend any possible inaccuracy or ambiguity in the questions. Any inaccuracy and ambiguity may lead to confusion or misunderstanding of the questions by the respondents. Furthermore, questionnaires are assessed to check the validity (face and content) and reliability. The questionnaire verification form validates the two questionnaires used for this research. Face validity assesses the appearance of the questionnaire in terms of feasibility, readability, consistency of style and formatting, and the clarity of the language used [37]. Content validity involves evaluation of a new survey instrument. This is to ensure that the surveys include all the essential items whilst excluding unwanted items in the context of the research.

Conducting Questionnaire: The sample consists of lecturers from the computing department in the FSKIK at UPSI. Specifically, the respondents consist of only lecturers from the computing department. Furthermore, the lecturers should have taught any of the selected modules at least twice in the past five years (2014-2019). This is done to ensure the reliability of the data collected. The data deals with perception so it is important for the sample group to have prior knowledge of teaching the selected IT modules. The lecturers are chosen to ensure the validity of the data collected. A total of twenty-five lecturers have taught the selected IT modules in the past five years. Only sixteen of the lecturers have taught any of the selected modules at least twice in the past five years (2014-2019). Subsequently, only twelve lecturers are used as respondents, because four are retired and/or no longer employed at the HEI. The survey is sent to lecturers to generate the quantitative data that is analyzed. After the use of the (quantitative) cross-tabulation method and a thorough (qualitative) content analysis, the data is used to amend the design of the model if amendments are required [25].

4. FINDINGS

This study describes the results of the STAUNCH© analysis carried out on the selected programming and networking modules from the undergraduate IT course at UPSI. Furthermore, this chapter provides a comprehensive explanation of how SD can be integrated into the selected networking and programming modules of the undergraduate IT curriculum of the FSKIK at the UPSI. Integrating IT with sustainability awareness enables better sustainability education. Furthermore, integrating IT with sustainability awareness also contributes SD competencies for future IT professionals who can build cleaner, greener, more resource and energy efficient cyber-physical systems.

4.1. Curriculum Evaluation

For the context of this research, the key point is the analysis of the level of SD contribution. The higher the contribution's value, the better the balance amongst economic, environmental, social, and crosscutting dimensions. The following graphs and tables show that criteria are identified in all the selected modules descriptors. However, the grade strength for SD contribution is very low for all the selected modules. The data provided by the Department of Student Affairs at UPSI, stated that the total population amounted to 438 respondents of which one were enrolled in semester eight. The curricular focus of the research are the selected IT programming and networking modules, as shown in Table 1.

Table 1. Proposed Modules Analysed Using STAUNCH© Assessment Criteria [25]

Code	Title	Integration Field	Semester	Credits
MTD3033	Database System	Networking & Programming (SQL)	2	3
MTD3043	System Analysis and Design	Programming	4	3
MTD3063	Database Driven Web Programming	Programming (HTTP/CSS/JavaScript)	5	3
MTN3023	Computer Networks	Networking & Programming (Python)	5	3
MTN3033	System Administration	Networking	7	3
MTS3023	Data Structures	Programming (C++)	2	3
MTS3033	Object-Oriented Programming	Programming (Java)	3	3
MTS3063	Principles of Programming	Programming (C++)	1	3

A summary of the main criteria for SD contributions identified in the tables is shown in Figure 8. The criteria are divided into four categories namely, economic, environmental, social, and cross-cutting. It is also evident that criteria from the cross-cutting category dominant within all modules. Figure 9 shows the strength of ESD contribution by the individual modules. Most modules only put an emphasis on the systems thinking and/or application criterion, except for one, that further focuses on ethics, namely, System Administration (MTN3033).

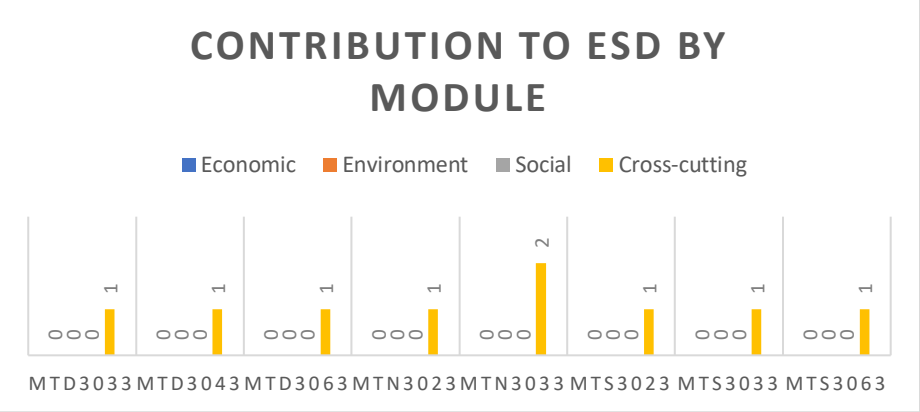

Figure 8. Contribution to ESD by Each Module Using the STAUNCH© Assessment Criteria [25]

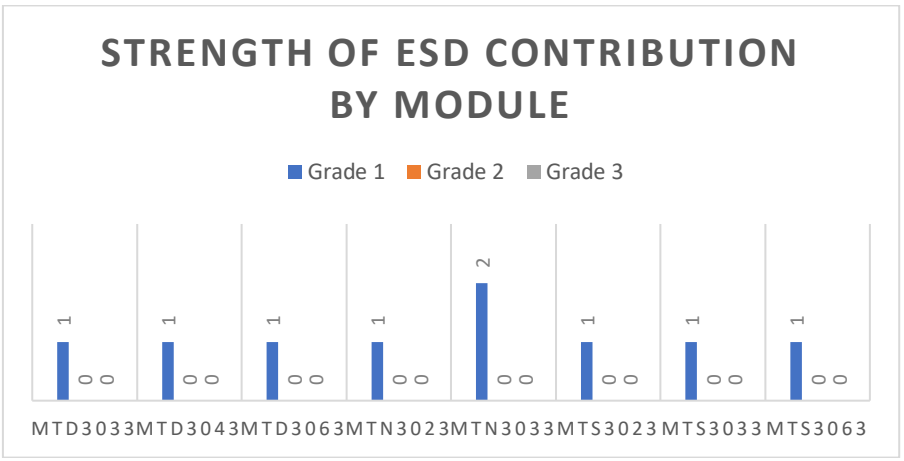

Figure 9. Strength of ESD Contribution by the Individual Modules [25]

4.2. SD Integration into Curriculum

The integration process is very important and there is a need to ensure that it is carried out to meet all the predetermined knowledge and competency requirements [25]. The integration was designed in such a way that it provided a comprehensive knowledge foundation for the programming and networking courses, whilst emphasizing on the economic, environmental, and social issues that require the students' attention for a more sustainable future. The focus of this research is on energy efficiency education. However, because the living laboratory plays an integral role in the design of this model, it offers students the chance to learn about the peripheral knowledge that is associated with it.

Subsequently, the integration of SD, in the context of this research, focuses on three key areas of knowledge. These are, namely, sustainability, IT, and living laboratories. Furthermore, the three are further divided into the key components for each area of knowledge, as seen in Figure 10. Furthermore, the main sustainability component energy efficiency offers the opportunity for students to learn about renewable energy resources. This is aided by the use of the living lab which further offers students' knowledge about smart grids, smart and/or green buildings and HEMS.

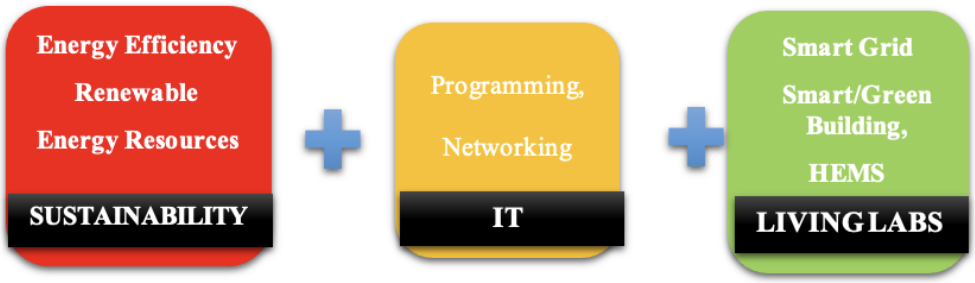

Figure 10. Overview of SD Integration

As seen in Figure 10, the red blocks pertain to sustainability which, in the context of this study, refers to energy efficiency and renewable energy resources. The yellow blocks pertain to IT which, in the context of this study, refers to the selected programming and networking modules. The green blocks pertain to living laboratories which, in the context of this study, refers to smart grids, smart and/or green buildings and HEMS. Table 2 shows the SD contributions integrated into the curriculum in relation to the environmental, energy, social and cross-cutting issues which they address. This table was compiled with the aid of the STAUNCH© Criteria for assessing the curricula contribution to SD [25].

Table 2. SD Contribution in Relation to Category [25]

Category	Contribution	STAUNCH© Criteria
Economic	• Efficient energy use	• Resource use (energy)
	• Natural energy management	• Resource use (energy)
	• Sustainable processes	• Production/consumption patterns
Environmental	• Efficient energy use	• Resource efficiency
	• Natural resource management	• Resource depletion/conservation (energy)
	• Alternative energy generation systems	• Eco-efficiency
	• Eco-efficiency	• Pollution
	• Sustainable processes	• Alternatives
	• Energy distribution systems	
Social	• Negotiating	• Social cohesion
	• Conflict Management	• Social cohesion
Cross-Cutting	• Social Responsibility	• Responsibility
	• Energy management and monitoring laboratory	• Systems thinking/application and Disciplinarity
	• Technology for the efficient use of renewable energy	• Systems thinking/application and Disciplinarity

Figure 11 shows hierarchically the various SD contributions related to environmental, energy and social issues that are integrated into the curriculum. These SD contributions were formulated with the aid of the competencies that are developed for this proposed model. With the use of the key provided, one can relate the hierarchical structure to three key knowledge areas shown in Figure 10.

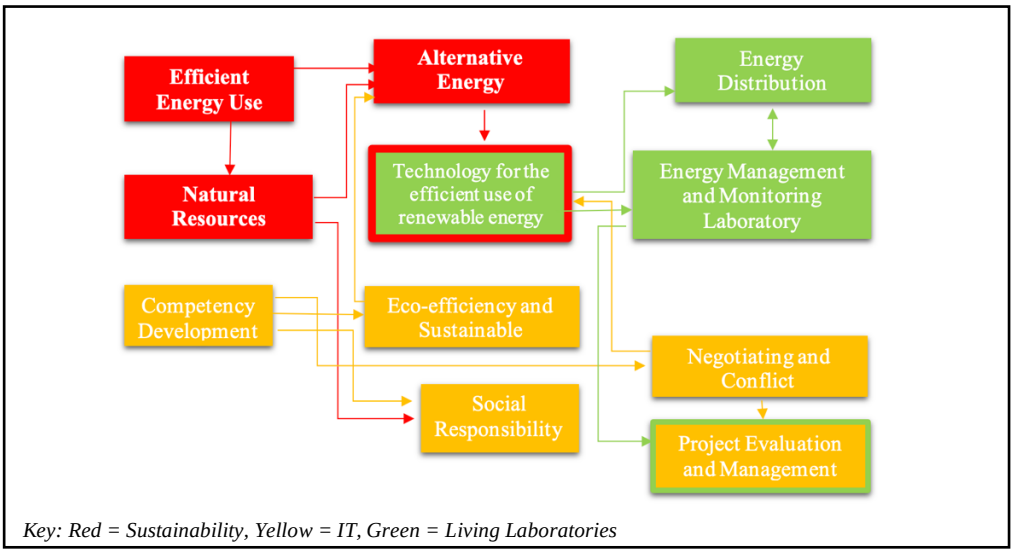

Figure 11. Hierarchical Structure of the Integration of SD Contributions into the Curriculum

Using the already stipulated course learning outcomes from the 2018-2019 pro forma (syllabus) documents, areas within the selected modules which can be used to integrate SD into the curriculum are established. However, it is important to note that not all the learning outcomes provided in the pro forma documents are utilized. Only those learning outcomes that are in-line with the stipulated five inclusion criteria are used. This allowed for a pragmatic restructuring of the existing course curricular without requiring the complete design and development of a new curriculum. The inclusion criteria are as follows [25]:

- Learning outcomes that which allow for easy adoption by providers.
- Learning outcomes that can aid in addressing the developed competencies.
- Learning outcomes that can be adopted into a living laboratory setup.
- Learning outcomes which allow for cross-disciplinary integration of SD.
- Learning outcomes that can be taught using the PBL pedagogy.

5. CONCLUSIONS

This article discusses the integration process into the curriculum using the networking and programming modules from the IT curriculum at UPSI. The integration process plainly exhibits the hierarchical structure of the integration, the SD contributions that are realized because of the integration and the inclusion criteria for the learning outcomes included in the integration process. The study clearly illustrates all the necessary steps that are required during the design, development, and evaluation of a model for energy efficiency education of undergraduate IT students, starting with the necessary components required to successfully integrate and/or implement such a model into the curriculum. Furthermore, this research also distinctly identifies the sustainability competencies and presents the ways in which to address said competencies with clarity. Moreover, this research comprehensibly displays the curriculum analysis process before proceeding to exhibit the how energy efficiency education can be integrated into an existing IT curriculum. Finally, this research plainly evaluates the proposed model for energy efficiency education of undergraduate IT students using a formative evaluation method.

5.1. Contribution

By analyzing the collected data on the need for ESD and energy efficiency education in the undergraduate IT curriculum, this research illustrates that although there are still a number of those that are undecided, the majority agree that there is indeed a need for the components and thus a need for more models that can be used in the integration and/or implementation of ESD and energy efficiency education into the undergraduate IT curriculum.

Based on the analysis of the literature, it can be concluded that ESD is still an emerging field of research as whole and more so in the ICT context. This is because most of the current research on the topic of ESD in centered around two prominent fields of study, these being namely, engineering and business management. However, ESD research in the field of tourism and hospitality has seen a rise in recent years. Furthermore, analysis of the literature also indicated that of the available TMFAs only a small number are geared toward the integration and/or integration of energy efficiency education into the undergraduate IT curriculum.

5.2. Recommendation

Subsequently, more research can be carried on the effects of energy efficiency education, in the ICT context, on HEIs students. Furthermore, future research in general is required in the field of ICT, since most ESD research is focused on two main areas namely, engineering and business management. Another reason for future research is that more collaborative research amongst HEIs is required in developing countries, as most ESD research is conducted in Europe and North America. Any HEIs must conduct their academic program review align with the SDGs as a response for building a resilient and future-proof academic program.

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