SUSTAINABILITY INTEGRATION INTO ENGINEERING CURRICULA WITHIN FIVE RESEARCH UNIVERSITIES IN MALAYSIA

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FACULTY OF SCIENCE
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ABSTRACT

Sustainability or sustainable development has become a recent focus in industries and education. Tertiary education, especially engineering education plays an irreplaceable role in sustainability education in view of the active roles played by engineers in steering technology development. There is however, limited information on the relationship between sustainability integration into formal, informal and non-formal engineering curricula with engineering undergraduates' knowledge and interest on sustainability in Malaysia. Therefore, this study aims at identifying the current integration strategy used by the Malaysian Institutions of Higher Education (IHEs) in integrating sustainability into the formal engineering curricula of four traditional engineering disciplines, which are Chemical, Civil, Mechanical and Electrical Engineering and identifying the response of the respective engineering students to such integration strategies through evaluating students' knowledge and interest in sustainability. Besides, this study also aims at proposing a possible sustainability integration strategy for the respective engineering discipline by combining formal, non-formal and informal curricular approach with an additional discussion on whether vertical (stand-alone or specific subjects on sustainability) or horizontal approach (intertwine of sustainability components into the existing subjects) is more suitable for an engineering discipline in Malaysia based on the proposed strategy. Curricular analyses were conducted in this study to identify the current integration strategy while a questionnaire was the main research instrument for measuring students' knowledge and interest in sustainability and collecting data for developing the possible integration strategy for sustainability integration in each engineering discipline. Statistical Packages for Social Science (SPSS) were used for analytical purposes. A total of 871 questionnaires were collected from the four engineering disciplines from five research-based IHEs in Malaysia which have the most established history in offering the respective engineering programmes compared to the other IHEs in Malaysia. The curricular analyses revealed that 87% and 92% of the sustainability related courses for Chemical and Civil Engineering, respectively were of the horizontal approach while 100% of the sustainability related courses for Mechanical and Electrical Engineering were of the horizontal approach. The analyses showed that generally, the engineering students had moderately high to high knowledge and interest level in sustainability with the Civil Engineering students having the highest score. For the possible sustainability integration strategy, further analyses showed that the integration strategy varied with engineering disciplines and it was found that the vertical approach was preferred for Chemical and Civil Engineering while the horizontal approach was preferred for Mechanical and Electrical Engineering. The secondary finding from the questionnaire revealed that peer influence was among the main motivating factors for students' participation in sustainability activities. In summary, the study showed that the current strategy used by the IHEs for sustainability integration into engineering education had yielded some satisfactory results by cultivating certain intellectual or interest level among the engineering students in Malaysia towards sustainability, but there are rooms for improvement, as detailed in the thesis. This study successfully developed a possible sustainability integration strategy for each of the targeted engineering disciplines in this study to further improve the effectiveness of sustainability education for the Malaysian engineering students.

ABSTRAK

Kelestarian atau pembangunan lestari telah menjadi perhatian di dalam golongan industri dan pendidikan sejak kebelakangan ini. Bidang pengajian tinggi, terutamanya jurusan kejuruteraan memainkan peranan yang tidak dapat diganti dalam pendidikan kelestarian disebabkan oleh peranan penting yang dimainkan oleh jurutera dalam pembangunan teknologi. Walau bagaimanapun, maklumat mengenai hubungan antara integrsi kelestarian ke dalam kurikulum *formal, informal* dan *non-formal* dengan tahap pengetahuan dan minat pelajar sarjana muda kejuruteraan terhadap kelestarian adalah terhad. Justeru itu, tujuan kajian ini adalah untuk mengenalpasti strategi pengintegrasian kelestarian yang digunakan oleh Institut Pengajian Tinggi di Malaysia untuk mengintegrasikan pendidikan kelestarian ke dalam kurikulum *formal* jurusan kejuruteraan tradisional iaitu kejuruteraan kimia, awam, mekanikal dan elektikal serta menilai respon pelajar-pelajar terhadap strategi pengintegrasian tersebut dari segi tahap pengetahuan dan minat ke atas kelestarian. Selain daripada itu, kajian ini juga bertujuan untuk mencadangkan satu strategi pengintegrasian kelestarian yang sesuai untuk setiap jurusan kejuruteraan yang dikaji dengan menggabungkan kurikulum *formal*, *non-formal* dan *informal* serta membincangkan samaada pendekatan *horizontal* (pengintegrasian unsur kelestarian ke dalam kursus-kursus yang sedia ada) atau *vertical* (kursus kelestarian yang spesifik) adalah lebih sesuai untuk sesuatu jurusan kejuruteraan di Malaysia. Analisa kurikulum telah dijalankan untuk mengenalpasti strategi pengintegrasian kelestarian semasa dan soal selidik digunakan untuk mengumpul maklmat berkenaan untuk menilai tahap pengetahuan dan minat pelajar-pelajar terhadap kelestarian dan untuk membangunkan strategi pengintegrasian kelestarian yang sesuai untuk setiap jurusan kejuruteraan yang dikaji. *Statistical Packages for Social Science (SPSS)* telah digunakan untuk tujuan analisis. Sebanyak 871 borang soal selidik telah dikumpul dari 4 jurusan kejuruteraan dari 5 Institut Pengajian Tinggi di Malaysia yang

paling berpengalaman dalam manawarkan program kejuruteraan. Analisis kurikulum menunjukkan bahawa 87% dan 92% daripada kursus berkaitan kelestarian yang terdapat dalam kurikulum Kejuruteraan Kimia dan Awam menggunakan pendekatan *horizontal*, manakala 100% daripada kursus berkaitan kelestarian yang terdapat dalam kurikulum Kejuruteraan Mekanikal dan Elektrikal menggunakan pendekatan *horizontal*. Keputusan analisis menunjukkan bahawa secara keseluruhannya, pelajar-pelajar kejuruteraan tersebut mempunyai tahap pengetahuan dan minat terhadap kelestarian yang sederhana tinggi ke tinggi dengan pelajar-pelajar kejuruteraan awam mendapat markah yang paling tinggi. Keputusan kajian juga menunjukkan bahawa strategi pengintegrasian kelestarian adalah berlainan untuk setiap jurusan kejuruteraan. Pendekatan *vertical* adalah dicadangkan untuk Kejuruteraan Kimia dan Awam manakala pendekatan *horizontal* dicadangkan untuk Kejuruteraan Mekanikal dan Elektrikal. Kedapatan sekunder kajian ini juga menunjukkan bahawa pengaruh rakan sebaya adalah antara faktor utama yang menggalakkan penyertaan pelajar-pelajar di dalam aktiviti kelestarian. Rumusannya, kajian ini menunjukkan bahawa strategi pengintegrasian kelestarian semasa yang digunakan oleh Institut Pengajian Tinggi di Malaysia berjaya memupukkan tahap pengetahuan dan minat pelajar-pelajar kejuruteraan terhadap kelestarian ke tahap tertentu, tetapi strategi tersebut boleh diperbaiki lagi, seperti yang dibincang dengan teliti dalam tesis ini. Kajian ini telah secara berjayanya, mencadangkan strategi pengintegrasian kelestarian yang sesuai untuk setiap jurusan kejuruteraan yang dikaji dalam kajian ini untuk meningkatkan lagi keberkesanan pendidikan kelestarian untuk pelajar-pelajar kejuruteraan di Malaysia.

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LIST OF ABBREVIATIONS

ACU	:	Association of Commonwealth Universities
ASCE	:	American Society of Civil Engineers
ASEE	:	American Society of Engineering Educators
BEM	:	Board of Engineers of Malaysia
CGSS	:	Centre for Global Sustainability Studies
COPERNICUS	:	Cooperation Programme in Europe for Research in Nature and Industry through Coordinated University Studies
DESD	:	Decade for Education for Sustainable Development
DUT	:	Delft University of Technology
EAC	:	Engineering Accreditation Council
ec. act.	:	Extra-curricular Activities
IAU	:	International Association of Universities
ICE	:	Institute of Civil Engineers
IHE	:	Institution of Higher Education
IHEs	:	Institutions of Higher Education
Env.	:	Environmental
EESD	:	Engineering Education for Sustainable Development
EPU	:	Economy Planning Unit
ESD	:	Education for Sustainable Development
HEFCE	:	Higher Education Funding Council for England
IChemE	:	Institution of Chemical Engineers
IR3S	:	Integrated Research System for Sustainability Science
otc. act.	:	Out-of-classroom Activities
pg.	:	Page
SD	:	Sustainable Development
SDEP	:	Sustainable Development Education Panel
SOLO	:	Structure of Observed Learning Outcome
Sus.	:	Sustainability
TSCP	:	Taiwan Sustainable Campus Programme
UK	:	United Kingdom
UKM	:	*Universiti Kebangsaan Malaysia*
UM	:	University of Malaya
UN	:	United Nations

UNCED	:	United Nations Conference on Environment and Development
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
US	:	United States
USM	:	*Universiti Sains Malaysia*
UTM	:	*Universiti Teknologi Malaysia*

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CHAPTER 1: INTRODUCTION

1.1 Background

Sustainable development (SD), as defined in Brundtland Commission Report (1987), is development that meets the needs of the present without compromising the ability of future generations to meet their needs (UNESCO, 2012; World Commission on Environment and Development, 1987). It has always been used together with 'sustainability' which is defined as design of human and industrial systems to ensure that human's use of natural resources does not lead to diminished quality of life due to losses in further economic opportunities or adverse impacts on society, human health and the environment (Mihelcic et al., 2003).

In the last decades, there is a rising emphasis on these two terms among the industrial players, governmental agencies, educational sectors and professional engineering organisations (Miller, 2014; Thomas & Nicita, 2002) in view of the mounting evidence on the destruction of environmental quality such as rising sea level, resource depletion, climatic change, disease outbreak and others. However, despite heavy use of the terms, it remains a puzzle on how well people understand sustainability.

Overwhelmed with the current environmental and societal issues, the society, at large, is generally concerned on how education can help in achieving a sustainable future. The role of education as a means for disseminating knowledge and skill is not debatable (Sterling, 1996). While primary and secondary education serve as the basic platforms for acquiring sustainability education which is an impetus to sustainable development (Wójcik, 2004), the society has much hope on tertiary education to lead and facilitate sustainability education (Carew & Mitchell, 2006; Abdul-Wahab et al., 2003; Cortese, 2003).

There are a number of world declarations that have highlighted the roles of higher education in shaping a sustainable future. These declarations include Talloires Declaration of University Leaders for Sustainable Future 1990, Rio Declaration, 1992, Copernicus University Charter for Sustainable Development of the Conference of European Reactors 1993, Kyoto Declaration of the International Association of Universities 1993 (Thomas, 2004), Barcelona Declaration 2004, which is the most relevant to engineering education and the most recently held United Nations Conference on Sustainable Development or Rio+20 (UNESCO, 2012).

Many governmental agencies and Institutions of Higher Education (IHEs) have also responded to the needs of sustainability education [1] by outlining various strategies and policies. For example, the United Kingdom has a governmental strategy in place to emphasize sustainability literacy for graduates (Kagawa, 2007). The Malaysian government, on the other hand, have steadily put more emphasis on sustainability in industries in the last few years (EPU, 2010). For example, tertiary education, quality research and sustainable development are all highlighted in the 9th and 10th Malaysian Plan (EPU, 2006, 2010), although there are yet any concrete plans specifically on sustainability education in Malaysian IHE. The Malaysian government's effort in this context remains unclear. This is quite worrying as according to Abdul-aziz et al. (2013), the environmental knowledge level, which is one of the components for sustainability education, remained moderately low among Malaysian students. Furthermore, according to a report by *Universiti Sains Malaysia* (USM) in 2012, the leading IHE which pioneers institutional sustainability promotion in Malaysia, most of the curricula

[1] 'Sustainability education' refers to education on sustainability and this term is used throughout the thesis. It is used instead of Education for Sustainable Development (ESD) because education should aim at achieving 'sustainability' as the ultimate goal, which is the outcome of sustainable development based on definitions in literatures. The relevant definitions derived from literature review are further elaborated in Chapter 2. This term was also used by Du et al. (2013).

was still thin in sustainability component then (Centre for Global Sustainability Studies, 2012). It can therefore be interpreted that sustainability integration into the tertiary education, including the engineering education in the Malaysian IHEs is low. This may indicate that the Malaysian engineering graduates may not be well prepared towards developing this country in a sustainable way.

Sustainability requires competencies and higher thinking skills, therefore, tertiary education serves as a crucial platform to integrate such knowledge into the mindset of people (Wals & Jickling, 2002). The knowledge and skills undergraduates learn in IHEs are what they will apply and utilize at the workplace (Segalàs et al., 2009; Jucker, 2002). Therefore, sustainability components should be incorporated into any discipline of tertiary education to enhance the graduates' abilities to relate sustainability to their profession.

This is inevitably true for engineering education which produces engineers who have a direct impact on sustainable development (Downey & Lucena, 2004; Huntzinger et al., 2007; Jucker, 2002; Quist et al., 2006). The competence of the curricula through which engineering knowledge is acquired is therefore, of high importance as the learned knowledge is what they will apply and utilize in the future at the workplace (El-Zein et al., 2008; Segalàs et al., 2009). Even if the graduates choose to venture into another field in the future, their influence on the society, especially those who have lower educational level should not be underestimated. They are considered the group who enjoys privileges and is respected by people from the lower social classes due to their educational level (Hughes and Kroehler, 2008). They have the capability to influence people in lower social classes, who usually exploit the environment for their basic living (Miller and Spoolman, 2008). The graduates should therefore be well equipped with knowledge on sustainability.

On top of that, it should be noted that some corporations have emphasized sustainability in their policies, putting employees who have competent knowledge in sustainability in a favoured position (Miller, 2014). This is another reason why sustainability components should be integrated into the engineering education to enhance the competency level of the engineers in the modern world (EESD, 2010).

Fortunately, out of the wide array of academic disciplines in tertiary education, engineering education is among the most active professions in seeking to integrating sustainability into its education (Huntzinger et al., 2007). It is in-line with what Chandu & Kancharia (2012) recommended: engineering education should enhance students' knowledge level , skills and attitudes to solve sustainability problems. Conventional engineering education normally teaches the students to provide end-of-pipe solutions rather than sustainable design or approach (Chandu, 2012) and therefore, a cultural change is needed for engineering education by training the students to understand all sustainability related issues, to think and work sustainably (Chandu, 2012; Perdan & Azapagic, 2000).

Some foreign IHE have tried implementing sustainability in their campus and integrating sustainability into their engineering curriculum. For example, Delft University of Technology (TUD) has integrated sustainability into its engineering education based on the rationale that the graduates should be able to use such knowledge in the future (Quist et. al., 2006). Besides, some courses related to sustainability have also been introduced into engineering curricula in some IHEs, for example, Michigan Technological University (Kumar et al., 2005).

Literature also shows that there are various approaches to integrating sustainability components into engineering education. Kumar et al. (2005) and Crofton (2000) proposed that sustainability can be integrated into engineering curricula through individual subjects on sustainability, incorporation of sustainability or environmental components into certain subjects and development of specialization subjects on sustainability. These options can be further categorized as horizontal or vertical approaches, as suggested by Cuelemans & De Prins (2010). In the vertical approach, sustainability or environmental related subjects are separated as stand-alone subjects while for the horizontal approach, sustainability or environmental components are integrated into the existing subjects. Some researchers have pointed out that the vertical approach may fail to stimulate interdisciplinary learning essential for sustainability education for engineers (Thomas & Nicita, 2002) while some argued that the second approach can be challenging as the curricula needs to be reorganized with the sacrifice of some traditional engineering knowledge (Hegarty et. al, 2011). Besides, some IHEs have pointed out that the former approach is more efficient (Crofton, 2000) like the one adopted by University of Cape Town (von Blottnitz, 2006) while the others argued that the latter approach can be more fruitful (Kumar et al., 2005). Both the vertical and horizontal approaches are among the means used to integrate sustainability components into engineering education, especially in the context of formal education.

Other than the vertical and horizontal approaches, some researchers have discussed the sustainability integration approach in the dimension of formal, informal and non-formal educational types (Singh, 2009). Formal education can generally be defined as education that occurs in an organised and structured environment; non-formal education is always linked to planned learning activities while informal education refers to learning through activities associated with family, work and leisure (Cedefop, 2009).

There is no consensus on which educational approach works the best for sustainability integration into engineering curricula, with different researchers supporting different combinations of educational types for sustainability integration into engineering disciplines (Kumar et al., 2005; Nomura & Abe, 2010).

It was found that most of the publications relevant to sustainability integration into engineering education are based on the IHEs in the western or industrialized countries such as those in the European countries, North America or Australia. There is relatively much less research or literature based on relevant case studies in the Asian countries including Japan, which is widely known for her environmental-friendly practices and education for sustainable development (Nomura & Abe, 2010). While the Malaysian government is trying to make Malaysia an educational hub in Southeast Asia, Malaysian IHEs should not only focus on conventional professional training, but sustainability education to catch up with the global needs for engineers who are well versed with sustainability knowledge.

Although efforts for integrating sustainability into engineering curricula are observed in some Malaysian IHEs, there have not been any published studies on how effective the current integration strategy is. Some studies have been conducted overseas to identify the knowledge and interest level of engineering graduates towards sustainability (Azapagic et al., 2005; Carew & Mitchell, 2002; Nicolaou & Conlon, 2012), but no similar studies have been conducted in Malaysia, at least to the author's knowledge. There is therefore a need to evaluate the current Malaysian engineering undergraduates' knowledge and interest in sustainability to assess how competent our future engineers are. Next, there is also a need to identify and develop a suitable strategy for sustainability integration into engineering education to further improve the effectiveness of sustainability integration within the local context.

1.2 Problem Statement

Some European, American and Australian IHEs have long realized the importance of sustainability integration into their engineering education and implemented it. A paradigm shift in the research focus in the last 20 years in these industrialized countries was observed in the literature. The earlier publications in the 1990s were on sustainability integration efforts by IHEs; it was then followed by evaluation of those efforts and proposals on continuous improvement plans over the last 10 years.

While there is valuable research based on this scenario from the foreign IHEs, the scenario in Malaysia is unclear. Based on the literature review, there is almost no research specifically on sustainability integration into engineering disciplines in Malaysia; the existing research related to the sustainability context is mainly on evaluation of the engineering outcomes and products, for example, sustainable building (Abd-Razak, Mustafa, Che-Ani, Abdullah, & Mohd-Nor, 2011), institutional efforts to promote sustainable development in the campus and among the community (Angel, 2010; Osman, Ibrahim, Koshy, & Marlinah, 2014; Sanusi & Khelgat-Doost, 2008) and effects of sustainable development on student's knowledge and behavioral changes (Abdul-aziz et al., 2013).

Though there is no literature indicating when exactly Malaysian IHEs started committing to the relevant efforts, it is assumed that the Malaysian IHEs have integrated sustainability into the engineering education based on the fact that it is a requirement by the Engineering Accreditation Council (EAC), the only recognized accrediting body for the engineering degree programmes in Malaysia (EAC, 2010). The sustainability component has also been given a higher emphasis in the new accreditation manual since 2012 compared to the previous manuals (BEM, 2012). Therefore, any accredited undergraduate engineering programmes in Malaysia must have inserted the sustainability components into the curricula, but it is not known how the components are integrated into the curricula.

Whichever the strategies that the Malaysian IHEs have taken, no research has been done to evaluate the current engineering student's knowledge and interest level in sustainability, which are the main indicators used to measure the effectiveness of an education (Huntzinger et al., 2007; Morris et al., 2007; Orr, 2002). It should be emphasized that engineering graduates should be literate with knowledge on sustainability and the engineering education system should be capable of delivering the relevant knowledge in order to be in-line with the global trends towards sustainable development.

It was found that the relevant publications on sustainability integration into engineering education could generally be categorised into three groups, or rather, stages: implementation, assessment and continual improvement. The relevant publications by the IHEs in the industrialised countries in the 1990s mainly focused on initiation and implementation of sustainability integration, which indicated that these IHEs started incorporating sustainability into their engineering curricula since then. This observation is in agreement with the observation by Velazquez et al. (2006) who reported that most of the sustainability initiatives in IHEs started between 1997 and 2001. In the 2000s, IHE in the industrialised countries started publishing studies on assessment of their integration approaches and until recently, there has been a rising trend on publications on continual improvement of the integration approach. For the Malaysian IHEs, the publications on implementation strategies and assessment of integration strategies were found in the 2000s and late 2000s, respectively. To-date, there have not been publications on continual improvement of sustainability integration plan for the Malaysian IHEs. A comparison on the status of sustainability integration efforts into engineering curricula between the IHEs in the industrialized countries and Malaysia, based on the three stages mentioned above, is illustrated in Figure 1.1.

As observed, the foreign IHEs have been moving progressively toward integrating sustainability into engineering education and they are at the stage of 'continual assessment' while Malaysia is lagging behind in such effort with the Malaysian IHEs being at the stage of 'assessment of existing effort'. Therefore, in order to close this gap in the progress of sustainability education, there is a need to assess how effective the Malaysian IHEs are doing now, after years of effort, in integrating sustainability into their engineering curricula through assessing the knowledge and interest level of the engineering undergraduates in sustainability. This study also proposed a possible sustainability integration strategy to further improve the sustainability integration into engineering education.

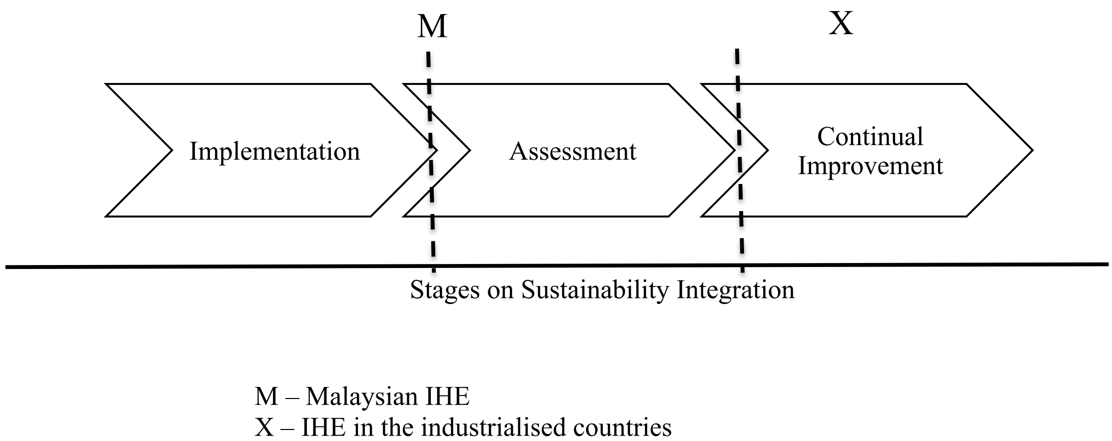


Figure 1.1: The current scenario of sustainability integration in the Malaysian IHEs versus IHEs in the industrialised countries

1.3 Research objectives and scopes

This project was designed to address the following objectives:

1. To evaluate the effectiveness of the current sustainability integration strategy into the formal curricula of engineering disciplines in Malaysia through evaluating student's knowledge and interest level in sustainability;
2. To develop a strategy for sustainability integration into engineering education of different engineering disciplines in Malaysia.

This study covered the following scopes in order to achieve the objectives.

1. Analyze the formal curricular content of Civil, Chemical, Mechanical and Electrical Undergraduate Engineering Programme from five research-based IHEs in Malaysia.
2. Evaluate the knowledge and interest level of the final-year engineering students from the respective engineering disciplines.
3. Identify the approach under the formal curricula that has the strongest correlation with students' knowledge and interest level in sustainability.
4. Identify the approach under the non-formal learning that has the strongest correlation with students' knowledge and interest level in sustainability.
5. Identify the approach under the informal learning that has the strongest correlation with students' knowledge and interest level in sustainability.

1.4 Research Focus

Engineering education was targeted in this study as engineers are among the main solution providers for environmental problems and also among the most active professions in seeking to integrate sustainability in its education (Fien, 2002).

This project targeted on four traditional engineering disciplines in five research-based IHEs in Malaysia, anonymously known as IHE A, B, C, D and E. The four traditional engineering disciplines selected were Chemical, Civil, Mechanical and Electrical Engineering. They were chosen because they were the most commonly offered engineering programmes in the other IHEs in Malaysia. The developed strategies could then be more useful for the other IHEs.

The five research-based IHEs were chosen as they were among the oldest IHEs in Malaysia, which offered the undergraduate engineering programmes of interest in this study and had the most established history in offering engineering programmes. They always serve as reference points for the other IHEs due to their research-based IHEs status. Besides, they had a higher focus on research, within which sustainability could be incorporated (Fien, 2002) to encourage overall sustainability integration, making them possibly having a more established strategy for sustainability integration compared to the others. The data obtained from these IHEs could be more meaningful and representative for developing the best strategy for each identified engineering discipline.

1.5 Research Methodology

The project was carried out in three major stages, namely background information collection from the respective engineering disciplines at the selected IHEs, including the curricular outline and the number of the final-year engineering graduates; data collection through the questionnaire distributed in the form of hardcopies by systematic random sampling in order to get a higher response rate, and; data analyses using the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel with correlation analysis being the main analytical method to determine the relationship of each integration approach with respondents' knowledge and interest level in sustainability.

1.6 Thesis Outline

Following this introductory chapter this thesis is divided into four remaining main chapters.

Chapter 2 is the literature review. It gives an insight into various approaches used for sustainability integration into engineering education and challenges, which should be addressed to improve the effectiveness of sustainability integration into engineering education.

Chapter 3 details the methodology applied in this research. It is divided into five major parts – analytical framework, background information collection, questionnaire, data analyses and research context.

Chapter 4 presents the findings of this research. Apart from the written discussion, the findings were tabulated or portrayed through graphical means where appropriate. The results were analysed and discussed in order to fulfill the objectives of this study. The proposed sustainability integration strategies for the selected engineering disciplines are presented in this chapter.

Chapter 5 concludes this research and outlines the recommendations for future studies.

CHAPTER 2: LITERATURE REVIEW

2.1 Sustainability and Sustainable Development

There is a growing world concern on sustainable development and sustainability among the industrial players, governmental agencies and educational sectors who voice their concerns over depleted resources (Miller, 2014; Thomas & Nicita, 2002). Sustainability and sustainable development (SD) are two terms that are usually used interchangeably (Mitchell, 2000) in the literature. While they look alike, there is a difference between them where SD can be viewed as a tool to achieve sustainability, as argued by IEAust (2014) and Mitchell (2000).

2.1.1 Definition of Sustainable Development

The most widely used definition of sustainable development is from Brundtland Commission Report, 1987 (WCED, 1987) which defined SD as a development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. This definition does not specify the underpinning elements of sustainable development and it somehow leaves room for imagination to the interpreters on what SD really covers. A more clarified definition outlining the underlying elements of SD can be sourced from the American Society for Civil Engineers (ASCE), which defined SD as 'the process of applying natural, human, and economic resources to enhance the safety, welfare and quality of life for all society while maintaining the availability of the remaining natural resources' (ASCE; Miller, 2014). This definition clearly pinpoints the 'natural', 'human' and 'economic' aspects of SD, which form the three pillars of SD (Jucker, 2002). Based on the definition, there should be a balance among the three pillars. However, literature shows that there is always a debate over the underlying dimensions or balance among the three pillars of sustainable development (Berglund et al., 2014). A search through the literature showed that the researchers in the field tend to be biased while discussing sustainable development with most of the earlier research focusing on the environmental aspects and the latter had an interest on the societal aspects. Yencken & Wilkinson (2000) also pointed out that previous studies usually focused on only one of the pillars.

2.1.2 Definition of Sustainability

'Sustainability' is defined as 'design of human and industrial systems to ensure that humankind's use of natural resources and cycles does not lead to diminished quality of life due either to losses in further economic opportunities or to adverse impacts on social conditions, human health and the environment' (Mihelcic et al., 2003). The American Society for Civil Engineers (ASCE) defined it as 'A set of environmental, economic and social conditions in which the society has the capacity or opportunity to maintain its quality of life indefinitely without degrading the quantity, quality or availability of natural, economic and social resources' (ASCE; Miller, 2014) while American Academy of Environmental Engineers (AAEE) defined sustainability as 'the supporting of the quality of life while living within the carrying capacity of all systems'. In short, they all delineate that a long-term balance among environmental stewardship, economic development and social well-being must be achieved' (Miller, 2014). All the definitions share the similar main points, which are: fulfilling current needs, improving the quality of life, taking care of environmental well-being and taking care of future needs. Based on the abovementioned information gathered from literature, the underlying elements for sustainability are summarized in Figure 2.1.

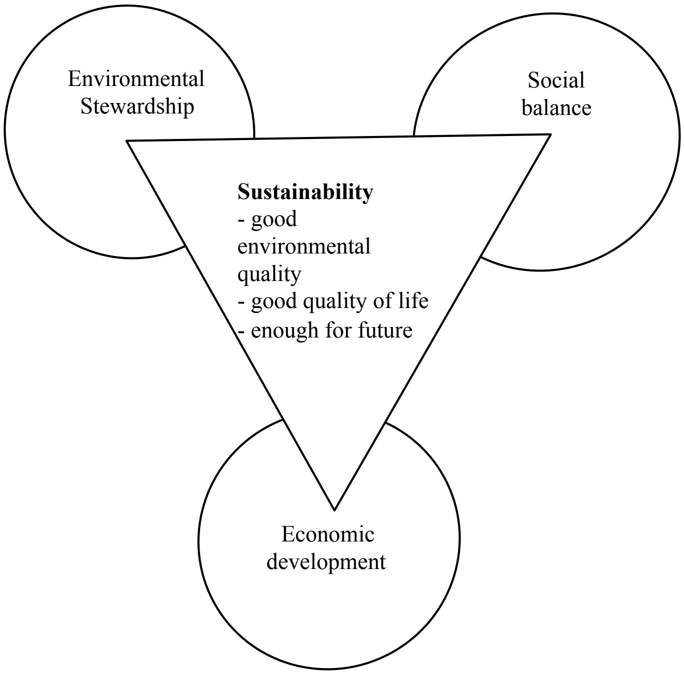


Figure 2.1: The underlying elements of sustainability

Based on these definitions, it is suggested SD can be understood as a 'method' to achieve sustainability which is a 'condition'. Similar to SD, sustainability always suffers a debate on 'how to get a balance among the three pillars'. Shrivastava & Berger (2010) suggested an explanation for this dilemma, stating that sustainability is always defined with abstraction so that it is applicable in a broad range of situations. It is not easy to give a defined and precise definition of 'sustainability' with regard to the balance among the three pillars as sustainability is understood as a knowledge or perception (Kollmuss & Agyeman, 2002). In fact, clear indicators on the balance among the three pillars of sustainability have never existed mostly due to the fact that it is a perception encompassing an ideal model (Steiner & Laws, 2006). It is interesting to note that this concept is not new, but first surfaced around 200 years ago when there was a vast deforestation for developmental purposes, which resulted in environmental pollution and eventually led to the awareness on the needs for planned development (Steiner & Laws, 2006). However, the term 'sustainability' did not appear apparent for the people in that era as they did not realize that the so-called planned development that they aimed at was in fact sustainable development (Steiner & Laws, 2006).

Generally, despite many definitions, there is no well-established agreement on the concept of sustainability (Jamison, 2013). We need the ecology or environment as one of the pillars because we need to cater for the ecological needs (Jucker, 2002). 'Economy' is needed as it is directly related to development and the overall growth of human kind. A sustainable economy makes sure that our needs are met, as well as our offspring's. For this to happen, the development must be within the carrying capacity of the biosphere (Miller & Spoolman, 2008). The last pillar, 'society or equity' emphasizes that every living organism should have equal access to resources (Hughes & Kroehler, 2008; Jucker, 2002). Human beings should allow other organisms and our offspring equal survival chances, like what indigenous people practice (Jucker, 2002).

Therefore, it is acceptable to generalize that sustainability links environmental, economic and societal aspects together (Pratt & Pratt, 2010) and it can be concluded that sustainability is the ability to maintain a high quality of life for all people, both now and in the future while maintaining the ecological processes (IEAust, 2014). This definition of 'sustainability' is used throughout this research.

2.2 Overview of Sustainability Education

Over the years, education was believed to be capable of achieving the goals of sustainability. There are higher chances that sustainability can be achieved if the knowledge is well conveyed among the people (Abdul-Wahab et al., 2003). As stated in the policy of Education for Sustainable Development and the Millenium Development Goals, education helps develop competent knowledge required for natural resources management, ecological sustainability and sustainable living practices (UNESCO, 2012). With adequate information on sustainability being imparted into the educational system, the future generation will possess the ability to think about new developmental solutions critically and promote sustainable production and consumption (UNESCO, 2012). UNESCO highlights that all three levels of education – primary, secondary and tertiary education are important in promoting sustainable development. Since the primary and secondary educations are not the focus of the current study, only tertiary education is addressed in the following sections.

The roles of tertiary education or Institutions of Higher Education (IHEs) in addressing sustainability knowledge are not substitutable. As commented by Carew & Mitchell (2006), IHEs play an operational, leadership and support role in sustainability education. Apart from providing developmental solutions, IHEs also play an active role in improving living standards and making sure that the students learn the necessary technical knowledge and moral values (Martinez et al., 2006; Segalàs et al., 2010; Segalàs et al., 2009). It is of utmost importance to make sure that the students are trained in sustainability knowledge before they graduate and make a significant impact on societal development.

Generally, various declarations and action plans with sets of principles have been outlined to address integration of sustainability education in IHEs. One of the most notable among them is Rio Declaration. The principles of sustainability stated in the Rio Declaration serve as a guide for the IHEs to achieve sustainability in the campus and infuse sustainability into the higher education system. UNESCO has defined essential characteristics of education for sustainable development (ESD) as follows.

"The education should be:

- Based on the principles and values that underlie sustainable development

- Dealing with the well being of all three realms of sustainability - environment, society and economy
- Promoting life-long learning
- Be locally relevant and culturally appropriate
- Be based on local needs, perceptions and conditions, but acknowledges that fulfilling local needs often has international effects and consequences
- Engaging formal, non-formal and informal education
- Accommodating the evolving nature of the concept of sustainability
- Addressing content, taking into account context, global issues and local priorities
- Building civil capacity for community-based decision-making, social tolerance, environmental stewardship, adaptable workforce and quality of life
- Be interdisciplinary. No one discipline can claim ESD for its own, but all disciplines can contribute to ESD
- Using a variety of pedagogical techniques that promote participatory learning and higher-order thinking skills."

(UNESCO, 2012)

The essential characteristics of ESD, as listed above describe how sustainability education should be like and the means through which sustainability education can be delivered. The listed characteristics are so comprehensive that they are globally relevant and there is no geographical or discipline boundary to the application of these characteristics. Generally, these characteristics are relevant for every country and every academic discipline.

2.2.1 World Declarations on Sustainability Education

Witnessing the destruction of environmental quality resulted from intensive global economic growth and digital revolution in the 20th century, many IHEs around the world have realized the needs for tertiary education to contribute to rectifying the worsening environmental condition around the world. The environmental issues, particularly the sustainability concerns have thus been a topic of discussion in several world-level meetings among the top management or academics from the IHEs around the world, leading to the generation of several world declarations that signify the commitments of the IHEs towards sustainable development. Most of these declarations mention sustainability education as a whole except for Barcelona Declaration, which has a distinct highlight on sustainability education for the engineering discipline. The following subsections discussed the relevant declarations.

2.2.1.1 The Talloires Declaration, 1990

Talloires Declaration, which is among the most discussed documents on sustainability education was composed in 1990 at an international conference held at Talloire, France (Haigh, 2005; ULSF, 1990). This is the first official statement made by the universities leaders on their commitment to sustainability in higher education (ULSF, 1990). Till 2012, it has more than 350 signatories from more than 40 countries (ULSF, 2012). As published on the webpage of ULSF (2012), most of the signatories of the Declaration are from the United States while the University of Malaya is the only signatory from Malaysia. According to a study done by Haigh (2005), until 2005, there had been a large number of IHEs which had committed themselves to the declaration, but only a few of them had a concrete implementation plan for sustainability education. There are no updated data in this context in the recent publications. Talloires Declaration outlined a 10-point action plan for incorporating sustainability and environmental education into various aspects of IHEs such as teaching, research, operations and outreach (ULSF, 1990). The themes of the 10-point action plan stated in the Declaration are as follows: "

1. Increase awareness of environmentally sustainable development
2. Create an Institutional Culture of sustainability
3. Educate for Environmentally Responsible Citizenship
4. Foster environmental literacy for all
5. Practice institutional ecology
6. Involve all stakeholders
7. Collaborate for interdisciplinary approaches
8. Enhance the capacity of primary and secondary schools
9. Broaden service and outreach nationally and internationally "

(ULSF, 1990)

Based on the document, the 2nd action plan reads

> "…all universities to engage in education, research, policy formation… to move towards sustainable development" (ULSF, 1990)

The 3rd action plan reads

> "… produce expertise in environmental management, sustainable economic development…all university graduates have the environmental literacy and awareness…" (ULSF, 1990)

The 7th action plan reads

> "… develop interdisciplinary approaches to curricula, research initiatives, operations and outreach activities to support an environmentally sustainable future…" (ULSF, 1990)

The 2nd, 3rd and 7th action plans are particularly related to sustainability education in the IHEs. They highlight the needs to have competent instructors to deliver the sustainability knowledge, which was also commented by Jones et al. (2008), Martin & Rigola (2001) and Warburton (2003). This declaration indicates the importance of institutional support and IHEs should produce graduates who are sustainability literate and empowered to make a real impact in the society.

2.2.1.2 The Halifax Declaration, 1991

The Halifax Declaration was the outcome of the meeting of the presidents or senior representatives of 33 universities from 10 countries at Halifax, Canada in December 1991 (Halifax, 1991). It highlighted the roles of universities on the environment and development, drawing the attention of the IHEs to the concerns summarized as follows:

1. The university should have a comprehensive and clear direction towards committing to sustainable development within the university, and at the local, national and global levels.
2. The university should utilize intellectual resources of the university to encourage a better understanding of sustainability.
3. The university should emphasize the ethical responsibilities of the present generation to overcome the impact of current anthropogenic activities on sustainability.
4. The university should further improve its teaching and practice of sustainable development principles to increase relevant knowledge among the faculties, students and the public.
5. The universities should cooperate among themselves and with the society to solve the issues of environmental degradation, South-North disparities and inter-generational inequity.

6. The universities should engage all possible means to communicate their relevant efforts to UNCED, governments and the public at large.

(Halifax, 1991)

Items 2, 3, and 4 again, coincide with the Talloires Declaration that there should be institutional support from the IHEs in terms of funding and other supports to aid in elevating instructors' literacy level in sustainability related knowledge and then the students'. As argued by Wright (2002) and Kumar et al. (2005), the top management from the IHEs should provide resources to drive the IHEs towards sustainability and guide the students to work towards sustainable development. Their reports have highlighted that institutional support is a critical factor for sustainability integration into the IHEs.

2.2.1.3 The Earth Summit, 1992

Agenda 21 was the outcome of the UN Conference on Environment and Development (UNCED), or widely known as the Earth Summit, 1992 at Rio De Janeiro, Brazil. It contains a non-binding and voluntarily detailed proposal for the actions in the social and economic areas with regards to sustainable development (UN, 1992). There are 38 chapters in Agenda 21 and sustainability education is included in Chapter 36, which highlights 2 areas for universities' attentions (UN, 1992). The two areas are

1. Reorient education towards sustainable development
2. Increase public awareness

Agenda 21 again highlights the critical role of education for sustainable development (Azapagic et al., 2005). The four pillars of education for the 21st century as stated in the UNESCO Report – Learning: the Treasure Within: Learning to Know, Learning to Do, Learning to Be and Learning to Live Together, support that students should be exposed to SD in various ways (Delors, 1996) and these four pillars correspond to the Agenda 21.

2.2.1.4 The Swansea Declaration, 1993

The Swansea Declaration was produced at Swansea in 1993 as a conclusion of the Association of Commonwealth Universities' (ACU) Fifteenth Quinquennial Conference. Upset by the general universities' commitment towards the Halifax and Talloires Declaration and overwhelmed by the worldwide concern on the degraded environmental quality, 400 representatives from 47 countries met and urged all IHEs to consider the following actions (Association of Commonwealth Universities' Fifteenth Quinquennial Conference, 1993): "

1. To urge universities of the ACU to seek, establish and disseminate a clearer understanding of sustainable development - "development which meets the needs of the present without compromising the needs of future generations" - and to encourage more appropriate sustainable development principles and practices at the local, national and global levels, in ways consistent with their missions.
2. To utilise resources of the university to encourage a better understanding on the part of governments and the public at large of the inter-related physical, biological and social dangers facing the planet Earth, and to recognize the significant interdependence and international dimensions of sustainable development.
3. To emphasize the ethical obligation of the present generation to overcome those practices of resource utilization and those widespread circumstances of intolerable human disparity which lie at the root of environmental unsustainability.

4. To enhance the capacity of the university to teach and undertake research in sustainable development principles, to increase environmental literacy, and to enhance the understanding of environmental ethics within the university and with the public at large.
5. To co-operate with one another and with all segments of society in the pursuit of practical and policy measures to achieve sustainable development and thereby safeguard the interests of future generations.
6. To encourage universities to review their own operations to reflect best sustainable development practices.
7. To request the ACU Council urgently to consider and implement the ways and means to give life to this declaration in the mission of each of its members and through the common enterprise of the ACU."

(Association of Commonwealth Universities' Fifteenth Quinquennial Conference, 1993)

Actions 2 and 4 highlight the institutional roles and the needs to have competent instructors for sustainability education. The instructors should plan their teaching and motivate students to learn effectively (Warburton, 2003). Even though sustainability education among students was not clearly highlighted in the Swansea Declaration, it is generally understood that students are part of the target populations whom the IHE should educate on sustainability awareness.

2.2.1.5 The Kyoto Declaration, 1993

Kyoto Declaration was produced by International Association of Universities (IAU) Ninth Round Table at Japan in November 1993 (IAU, 1993). It recommended the universities to seek to achieve the sustainability related goals in their actions plans. The suggested sustainability related goals are summarized as follows:

1. Commit to sustainable development at the institutional level within the academic platform and inform such commitment to its students, its staff and the public
2. Encourage sustainable consumption within the university's operations
3. Increase its academic staff's capabilities to teach environmental knowledge
4. Infuse environmental perspective into every field of study
5. Utilise the intellectual resources to establish strong environmental education programs
6. Promote interdisciplinary and collaborative research on sustainable development by conquering barriers between disciplines and departments
7. Stress and work on the ethical responsibilities of the university community with the students, faculty and staff to solve environmental degradation, North-South disparities, and the inter-generational inequities
8. Advocate interdisciplinary networks and research or academic collaboration at the local, national and international level to distribute relevant knowledge
9. Enable mobility of staff and students to encourage knowledge dissemination
10. Cooperate with the society in transferring innovative and appropriate technologies that further contribute to sustainable development.

(IAU, 1993)

Goals 2, 3, 4 and 5 highlight the institutional support, instructors' competence and the importance of integrating sustainability elements into every field of study. The highlights are the same as those in the Talloires and Halifax Declarations. Collectively, goals 2, 3, 4 and 5 are often discussed by researchers as strategies for encouraging sustainability in higher education.

2.2.1.6 The COPERNICUS Charter, 1994

The COPERNICUS is the abbreviation of 'Cooperation Programme in Europe for Research on Nature and Industry through Coordinated University Studies'. It is also known as The University Charter for Sustainable Development. This Charter, which was drafted in May 1994 at Geneva, Switzerland, highlighted the roles of university by stating

> "…It is consequently their duty to propagate environmental literacy and to promote the practice of environmental ethics in society, in accordance with the principles set out in the Magna Chart of European Universities and subsequent university declarations"(CRE-Copernicus, 1993)

COPERNICUS was sponsored by Conference of European Rectors, the association of European Universities (CRE-Copernicus, 1993), a non-governmental organization (NGO) which has more than 500 universities or equivalent IHEs from 36 countries as its members. The principles of the action of the COPERNICUS charter are : "

1. Institutional commitment
2. Environmental ethics
3. Education of university employees
4. Programmes in environmental education
5. Interdisciplinarity
6. Dissemination of knowledge
7. Networking
8. Partnerships
9. Continuing education programmes
10. Technology transfer"

(CRE-Copernicus, 1993)

The 1st, 4th and 5th principles are particularly relevant to sustainability education in the IHEs. The 1st principle is:

> "…real commitment…to environmental protection and sustainable development…" (CRE-Copernicus, 1993)

The 4th principle is:

> "…incorporate and environmental perspective in all their work…involving both teachers and researchers as well as students…irrespective of their field of study." (CRE-Copernicus, 1993)

The 5th principle is:

> "…interdisciplinary and collaborative education and research programmes related to sustainable development as part of the institution's central mission…" (CRE-Copernicus, 1993)

By definition, these principles share the main characteristics of the previously discussed declarations.

2.2.1.7 The Earth Charter 1997

The Earth Charter was launched in 1994 by Maurice Strong and Mikhail Gorbachev, the President of Green Cross International (Haigh, 2005). It was generated based on an open consultation involving a large number of stakeholders around the world and it proved that there was a growing global concern for a better future (Haigh, 2005). There are sixteen principles in the Earth Charter which are: "

1. Respect Earth and life in all its diversity
2. Care for the community of life with understanding, compassion and love

3. Build democratic societies that are just, participatory, sustainable and peaceful
4. Secure earth's bounty and beauty for present and future generations
5. Protect and restore the integrity of earth's ecological systems, with special concern for biological diversity and the natural processes that sustain life
6. Prevent harm as the best method of environmental protection and, when knowledge is limited, apply a precautionary approach
7. Adopt patterns of production, consumption, and reproduction that safeguard Earth's regenerative capacities, human rights, and community well-being
8. Advance the study of ecological sustainability and promote the open exchange and wide application of the knowledge required
9. Eradicate poverty as an ethical, social and environmental imperative
10. Ensure that economic activities and institutions at all levels promote human development in an equitable and sustainable manner
11. Affirm gender equality and equity as prerequisites to sustainable development and ensure universal access to education, health care and economic opportunity
12. Uphold the right of all, without discrimination, to a natural and social environment supportive of human dignity, bodily health, and spiritual well-being, with special attention to the rights of indigenous peoples and minorities.
13. Strengthen democratic institutions at all levels, and provide transparency and accountability in governance, inclusive participation in decision making and access to justice
14. Integrate into formal education and life-long learning the knowledge, values and skills needed for a sustainable way of life

15. Treat all living beings with respect and consideration
16. Promote a culture of tolerance, nonviolence and peace."

(International Earth Charter, 1992)

The Earth Charter, different from the previous declarations, does not directly emphasize the roles of education for sustainability. It, instead, highlights 'sustainability', which is the condition that should be achieved and can be assumed as a product of sustainability education. Out of the 16 principles, the 8^{th} and 14^{th} principle highlight the roles of sustainability education with the latter having an emphasis on the role of formal education for inculcating sustainability awareness, as also agreed by Clarke (2012) and Rich & Brown (2012).

2.2.1.8 Summary of The Relevant World Declarations

Based on the published documents of all these declarations, the similarities of these declarations can be concluded as follow. All of them have mentioned that there should be:

1. Institutional commitment towards overall sustainability implementation in the university;
2. Capacity development of staff and academics to teach sustainability-relevant subjects;
3. Knowledge development of students to increase their literacy competency in sustainability related areas;
4. Cultivation of awareness on ethical responsibilities to society;
5. Interdisciplinary approach for sustainability education by overcoming traditional barriers across disciplines;

A simple relationship among the IHEs, instructors and students can be developed according to the above information. It is interpreted that the IHEs need to provide the necessary resources to equip instructors with sustainability knowledge and the instructors should deliver such knowledge using an interdisciplinary approach to cultivate sustainability awareness among the students. The support of the IHEs in making sustainability education successful was also highlighted by Lidgren et al (2006) who reported that IHE should have the capacities to promote sustainability through various activities, such as research, capacity building, community outreach, curriculum greening and etc. The similarities of the above discussed declarations, presented conceptually in the form of relationships among the IHEs, instructors and students for sustainability education is shown in Figure 2.2. Accordingly, in an institutional environment, instructors play an important role in cultivating the students' knowledge and interest in sustainability. In order for an instructor to play this role, there must be relevant institutional policies, financial support and support from the management. Besides, the capacity building among the instructors, especially in terms of SD knowledge must also be in place to make sure that sustainability education is successful.

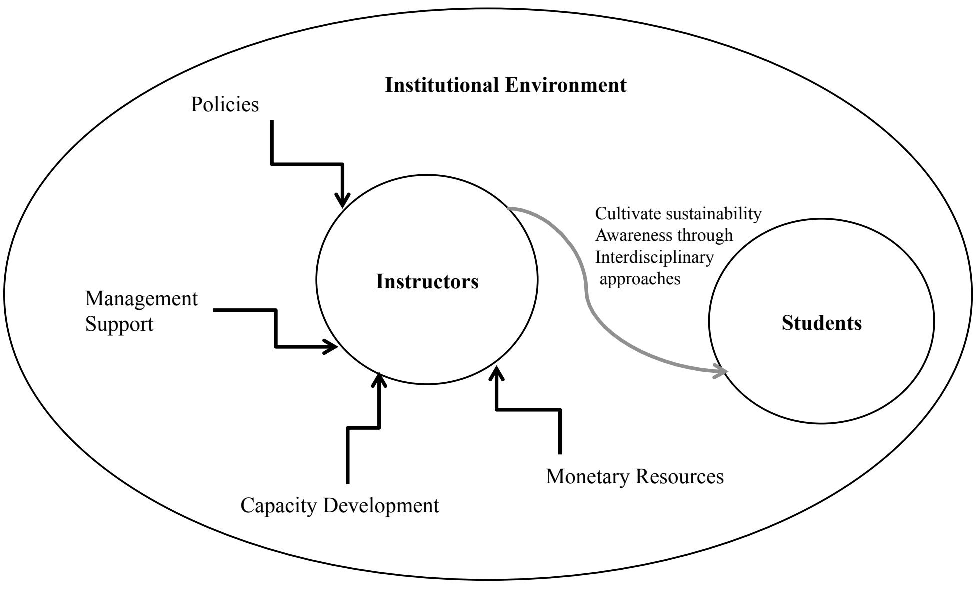


Figure 2.2: Summary of the relevant world declarations on sustainability education

2.2.2 World Declaration On Sustainability Education For Engineering - Barcelona Declaration, 2004

The declarations described in Section 2.2.1 were on general sustainability education. The Barcelona Declaration, which was specifically related to engineering education (Segalàs at al., 2008), is discussed in this section. The Barcelona Declaration was the outcome of the International Conference on Engineering Education for Sustainable Development held at Barcelona from 27 to 29 October 2004. This Declaration emphasized the importance of sustainability education in the engineering field at the higher educational level. It highlighted the characteristics the engineers today must possess towards achieving sustainable development. The declaration stated the following:

"The Engineers today must:

1. Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts.
2. Understand the contribution of their work in different cultural, social and political contexts and take those differences into account.
3. Work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management.
4. Apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts.
5. Participate actively in the discussion and definition of economic, social and technological policies, to help redirect society towards more sustainable development.

6. Apply professional knowledge according to deontological principles and universal values and ethics.
7. Listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures."

(EESD, 2004)

This Declaration did not specify the action plans for sustainability education, but it highlighted the roles of institutional support for sustainability education for engineers. It asked for transformation of the engineering educational process and urged a review into the course content, classroom teaching, teaching and learning techniques, research methods, capacity development of instructors, quality control and participation of external stakeholders in reviewing the engineering curriculum to make sure that engineering education is on the right path towards educating for sustainable development (EESD, 2004). It also suggested that the IHEs should redefine their mission to make sustainability a core concern and allocate sufficient support and funding for the transformation of engineering education (EESD, 2004). The should-be characteristics of engineers highlighted in this Declaration (as listed above), serve as a motivation and reminder to all IHEs that the engineers should be competent with sustainability knowledge and this can be achieved through education (Abdul-Wahab et al., 2003).

In short, the Barcelona Declaration flags the institutional roles and instructors' roles in sustainability education of engineering students. Figure 2.2 can be adapted for the Barcelona Declaration as this declaration, too, emphasizes that the IHEs need to provide the necessary resources to support engineering instructors in sustainability education.

2.3 Overview of Engineering Education and Sustainability

Engineering education, especially at the higher education level, should be oriented towards sustainability (EESD, 2010) based on the fact that engineering contribution is closely related to sustainable development (Downey & Lucena, 2004). As highlighted in the closing remark of the 2002 Engineering Education for Sustainable Development Conference, all engineers should be able to integrate the sustainability elements in their work and they should have a fair awareness on sustainability or SD (Fokkema et al., 2005). Rugarcia et al.(2000) also reported that many researchers had highlighted that engineers should be willingly concerned about the environment and contribute to the society. Since the IHEs are the main ground where engineering knowledge is acquired, the competency of the curricula at the IHEs are of high importance (El-Zein et al., 2008).

Integration of sustainability into the engineering curricula is not a new attempt. For example, Delft University of Technology (DUT) decided to integrate sustainability components into all of its engineering curricula starting from 1998 based on the rationale that all students should have basic knowledge on sustainability and be able to relate this component to their own engineering discipline (Quist et al., 2006).

The other examples include Michigan Technological University which offers sustainability related subjects to the Mechanical Engineering students in the university (Kumar et al., 2005) and the University of Cape Town that has developed a subject on sustainability, titled as Business, Society and Environment, which has successfully created satisfactory to good levels of sustainability knowledge and skills among its students (von Blottnitz, 2006). The same university has also recently included ‘natural foundations’ as a theme in its first-year Chemical Engineering curriculum (von Blottnitz et al., 2015). Chau (2007) also reported that Hong Kong Polytechnic had introduced specific projects in the Civil Engineering programmes to address sustainability.

In short, many IHEs have tried to include complex learning experiences to inculcate higher order of thinking among the students in order to successfully integrate sustainability into the engineering curricula (Kumar et al., 2005).

2.3.1 Transformation of Engineering Education

As a response to the global call for sustainable development, various efforts have been done in infusing sustainability knowledge into the engineering education. It was observed that there is a transformation in the core content of the engineering education from 1930 till present in order to meet the employers' needs (Clarke, 2012). As pointed out by Clarke, (2012), engineering education focused on business skills in the 1930s when open trading was the main driver of societal development. The focus was then shifted to design skills in the 1960s when there was an era of rapid development. In the 1980s when the digital revolution was the focus of the society, the engineering education was again transformed to highlight communication skills. In the early 2010s, it started focusing on employability skills. Knowledge of sustainability, deemed as the recent requirement by the employers, has therefore, become the core of the engineering education in this era. Overall, the engineering education has been or is being transformed accordingly from the industrialization era to the information era (Jowitt, 2004) and now the sustainability era.

The transformation of engineering education can be explained by the transition theory proposed by researchers such as Schlossberg (Forney & Guifo-DiBrito, 1998) and Kirk (1998). Schlossberg suggested that perception was important in any transitions and human beings adjusted themselves to adapt to the changes while Kirk (1998), in his definition of the demographic transition theory, explained that human beings progressed from pre-modernized to modernized era and there were societal, economic and developmental changes. The ‘progression’ and ‘adaptation’ explained in these two transition theories are similar to the transformation process observed in the engineering education to address new challenges and needs.

2.3.2 The Reasons Sustainability Education Is Needed For Engineering Students

Many researchers have articulated why knowledge on sustainability is important for engineers. Generally, they can be classified into four main reasons based on the literature, as discussed in the following sections.

2.3.2.1 Developmental Needs

Engineers are active in seeking solutions to meet the developmental needs. Technology advancement usually progresses at the expense of natural resources. In the modern world, there should be a balance among economic, environmental and societal development, which the engineers should address (de Graaff & Ravesteijn, 2001). The role of engineers in shaping a sustainable society is not negligible (Johnston, 1997) and it is essential that they are trained to address global, regional and local issues (Mihelcic et al., 2008). Engineers create technologies for people or stakeholders with the required outcomes and decisions (Brown & Elms, 2013; Mihelcic et al., 2008) and it should not be forgotten that technology is an important element of sustainability (Fokkema et al., 2005). Therefore, sustainability should be integrated into the engineering and science curricula so that sustainable solutions can be produced (Du et al., 2013).

2.3.2.2 Environmental Needs

Since engineers are one of the main drivers of technology advancement (Mihelcic et al., 2008; Prtichard & Baillie, 2006) and there is rapid depletion of important natural resources, there is a need to address sustainability knowledge in the engineering education so that the engineers may better relate themselves to the environmental well-being (Goldma et al., 2013; Köhler et al., 2013). The relationship between important natural resources and needs for sustainable development was further discussed by Tilton (2001) that engineers have the choices in their hands to select a more sustainable approach to express their technical expertise in designing solutions and products.

2.3.2.3 Societal needs

Other than technical contribution, there is also a call for engineers for exhibiting their social responsibilities (Pritchard & Baillie, 2006), which could be well learned if sustainability is integrated into the engineering education. Mihelcic et al. (2008) suggested that a broader view on the societal aspects of sustainability should be incorporated into the engineering education to address this global call.

2.3.2.4 Employer's Needs

In view of higher sustainability awareness among the industrial players nowadays, there is a pressing demand of engineers who are trained with sustainability knowledge with more and more employers believing that a workforce which is environmentally conscious may increase the productivity and improve the image of the companies (Clarke, 2012; Miller, 2014; Thomas & Nicita, 2002). Some industries are emphasizing green processes nowadays, looking at the profitability gained without harming the environment (Rugarcia et al., 2000; Wan Alwi et al., 2014). In fact, in the remarks by Duić et al. (2014) of the 8th Conference on Sustainable Development of Energy, Water and Environment, it was mentioned that the sustainability components were being gradually infused into the science and engineering curricula so that the technologies and innovations can become more sustainable. This shows the current demand of the employers for sustainable solutions.

Engineers, are thought to have knowledge in utilizing resources for innovating new technologies and thus their decisions have an impact on the global change and sustainability (Martin, et al., 2005; Miller, 2014). Instead of resource intensive technologies, engineers have the options to employ appropriate technologies to cope with the rising needs of the community (Mihelcic et al., 2008), which is only feasible if they are competent in the sustainability knowledge. Their competence in sustainability knowledge will also help to make sure that the solutions they propose match the cost, scale, technical complexity, sustainability, cultural acceptability and level of ownership demanded by the employer or the community (Johnston et al., 2007). Engineers from every discipline have the responsibility to tackle sustainability issues and contribute to sustainable development (Filipkowski, 2011). The engineering educators should therefore, design engineering curricula that make sure that future engineers can serve the society better (Galloway, 2007).

2.3.3 Suggested Characteristics for Good Sustainability Education for Engineering Students

Sustainability covers a wide range of components and higher education should be moving in the right direction towards sustainability (Gagnon et al., 2012). The importance of sustainability education has attracted the interest of many researchers and resulted in a wide array of approaches and concerns relevant to such contexts. For example, Cortese & Hattan (2010) suggested that sustainability education should be made available in the core classes and not only limited to electives or specialized subjects. There are also papers on the characteristics of effective sustainability education, which are discussed below.

2.3.3.1 Cultivate Intellectual Level

There are several perspectives pointed out by previous research on 'how sustainability education for engineering disciplines should be like.' Morris et al., (2007), for example, highlighted the cognitive aspects of sustainability education. They pointed out that an effective sustainability education should be one that can instill sustainability knowledge into the students' mindset deeply so that it affects their daily lives. Such a mind set is also the key to envision and to implement wise decisions in the solution-seeking process to solve any issues tasked to engineers. The level of depth the sustainability education is infused into the engineering education is important as the students grow up in a consumerist environment, under which they tend to design products without much thought on sustainable use of the resources (Morris et al., 2007). There should therefore be a systemic change in the educational approach and societal values held by the instructors to effectively deliver sustainability education (Huntzinger et al., 2007).

Besides, both Huntzinger et al. (2007) and Morris et al. (2007) agreed that sustainability education for engineers should encapsulate proper intellectual growth which involves deep learning. Deep learning involves understanding the underlying purposes of a practice which is always associated with critical thinking (Warburton, 2003). It requires students to have an adequate level of analytical skills, independent thinking and the ability to do cross-referencing. It is important as it is the impetus for the ‘intention to learn’ among the students, which is very much related to any types of knowledge acquirement (Marton & Saljo, 1999). The students should progressively move on from ignorantly accept the ideas of sustainability to critically evaluating information related to sustainability, as defined in the context of intellectual growth (Felder & Brent, 2004). Coupled with an active learning environment, deep-learning is essential for facilitating sustainability education (Marbach-Ad & Sokolove, 2000).

2.3.3.2 Cultivate Interest

Sustainability education should also be interesting so that students feel contented or happy for their possible individual contributions (Orr, 1992; Maniates, 2002). Brown & Kasser (2005) asserted that the student’s personal perceptions would directly motivate the students in contributing to sustainable development, which in a way is related to their interest in sustainability. Cap (2007) also stated based upon her research that the ability of an educational system to cultivate the interest level among the students is a key for success. Curricula that encourage effective learning should facilitate lifelong learning, which is very much related to the intrinsic interest within the students (Rugarcia et al., 2000). It is argued that when the students have the desire to learn and engage in sustainability, the learning is more efficient. This can also be related to the ‘intention to learn’ as discussed earlier (Marton & Saljo, 1999). Besides, sustainability education can also be more effective[2] when there are good teaching, study support, choices of content and study methods (Ramsden, 1997).

[2] Based on the discussion in Section 2.3.3.1 and 2.3.3.2, the descriptive term ‘effective’ is used to describe sustainability courses that can cultivate knowledge and interest among students towards sustainability. Therefore, this term is used throughout this thesis to describe a course that can cultivate knowledge and interest collectively.

2.4 Types of Approaches For Sustainability Integration Into the Engineering Disciplines

Based on the literature, many approaches have been proposed by previous researchers for integrating sustainability into education. However, the interdisciplinary approach, which was highlighted in the major world declarations and recommendations by some researchers (Bursztyn & Drummond, 2014; Mulder et al., 2012; Tomkinson, Tomkinson et al., 2008; Warburton, 2003) is not well-discussed in the existing literature. Nevertheless, there are other more defined approaches, which have been discussed extensively by the researchers in the relevant field, based on which, there are generally four approaches that could be used to incorporate sustainability into the engineering curricula, which are: a) some coverage of environmental issues in the existing module (Davis et al., 2003; Lozano, 2010; Mulder, 2006; Mulder et al., 2005; Thomas, 2004); b) a specific subject on sustainability (Cortese, 2003; Kumar et al., 2005; Mulder et al., 2005; Thomas, 2004); c) interweaving sustainability into existing regular subjects (Abdul-Wahab et al., 2003; Crofton, 2000; Kamp, 2006; Kumar et al., 2005; Mulder, 2006; Peet et al., 2004; Thomas, 2004); and d) develop a graduate specialization subject on SD (Crofton, 2000; Kamp, 2006; Kumar et al., 2005; Mulder, 2006).

The above approaches can be further categorized based on the suggestion of Ceulemans & de Prins (2010) who proposed that sustainability integration into curricula is through either the horizontal approach or a vertical approach. An integration approach is considered vertical when sustainability-based subjects are separated as individual subjects within the curriculum while an approach is considered horizontal when sustainability or environmental knowledge is intertwined into the existing subjects (Cuelemans & de Prins, 2010).

A comparison between the listed approaches and the ones by Ceulemans & de Prins (2010) suggested that (a) and (c) are horizontal approaches while (b) and (d) are vertical approaches. Therefore, further discussion on sustainability integration approaches could be continued based on the two categories by Ceulemans & de Prins (2010) to avoid confusion in the discussion. The categorization is illustrated in Figure 2.3.

Apart from the vertical and horizontal approaches, there could also be discussions on Singh's (2009)'s proposal that sustainability education can be achieved through formal, informal and non-formal curricula. There is relatively less literature in this perspective for sustainability education in the engineering disciplines compared to the vertical and horizontal approach. However, it was noticed that each of this educational types has an interesting role in sustainability education and thus an exploratory discussion was attempted. The approaches and educational types mentioned above were further elaborated in the following sub-sections.

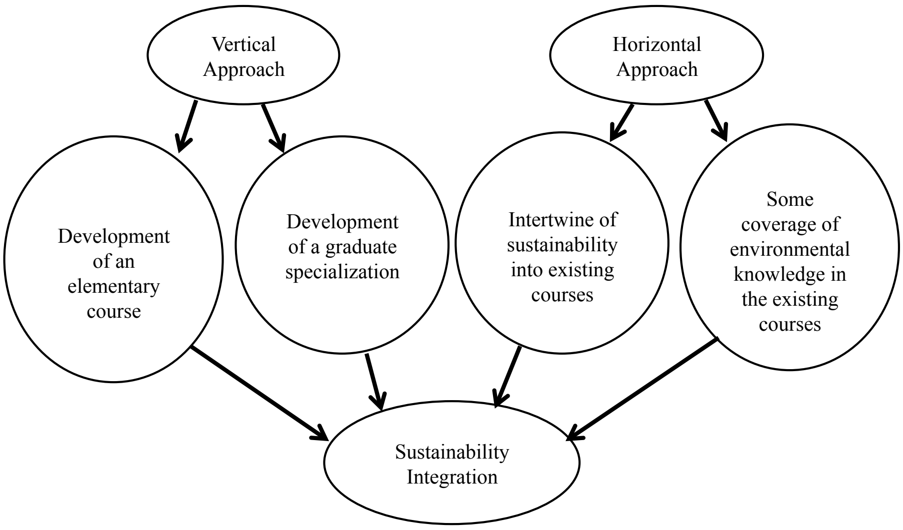


Figure 2.3: The vertical and horizontal approach to integrate sustainability into the engineering education (Chiong et al., 2014)

2.4.1 The Vertical Approach

As discussed earlier, an integration approach is considered vertical when sustainability-based subjects are separated as individual or stand-alone subjects within the curricula (Cuelemans & De Prins, 2010). It can also be a subject that is outside the formal engineering curricula which the engineering students can take, as suggested by Crofton (2000). It is a common approach at the initial stage of integrating sustainability into a curriculum, especially for the engineering curricula (Haigh, 2005; Kelly, 2008) and it is considered a traditional approach in the higher education system (Disterheft et al., 2013)

This approach has been supported by a few organizations such as the United Kingdom Government Sustainable Development Education Panel (SDEP). Azapagic et al. (2005) quoted that SDEP had suggested that sustainability knowledge is best to be integrated into specialist courses with learning activities and materials substantially different from the other subjects. The suggestion by SDEP was also supported by the Royal Academy of Engineering and the Institution of Chemical Engineers (IChemE) (Azapagic et al., 2005).

Rydhagen & Dackman (2011) also promoted this approach by commenting that a more in-depth view into sustainability is possible by applying the vertical approach as more sustainability specific examples can be given and this is especially important for sustainability education for engineers so that they have a well-founded knowledge on sustainability (Morris et al., 2007). Furthermore, this approach also allows instructors to develop the critical awareness needed for the key concepts, scopes and limitations of different disciplines which is found in sustainability education (Warburton, 2003). Some IHEs in the United Kingdom have used this approach by offering stand-alone courses on sustainable engineering or design (Morris et al., 2007). The School of Civil and Environmental Engineering of Geogia Institute of Technology in the United States also used the vertical approach by introducing two stand-alone subjects on sustainability into its curriculum (Watson et al., 2013)

However, since the subject is specific and stands alone, the instructors should provide practical examples, which can be related to the future profession of the students (Lundholm, 2004; Ramirez, 2006) to help the students see the interconnectedness between the specific subject and their core disciplines. In order to make this approach more efficient, an instructor who is competent in sustainability knowledge should be stationed permanently along the process of developing such subjects (Holmberg, 2008).

2.4.2 The Horizontal Approach

For the horizontal approach, sustainability is integrated within the existing modules in the curriculum (Ceulemans & de Prins, 2010). The students may better understand sustainability based upon this approach as the students no longer see sustainability as something that is irrelevant and alien. The ability to relate sustainability to the profession is important in order to raise the sustainability awareness among the learners. Similarly, motivating and relevant examples are important to help engineering students link sustainability to the engineering field (Mulder, 2006).

While there are strong supporters for the vertical approach, some researchers strongly believe in the horizontal approach as an efficient approach to integrate sustainability into education (Rydhagen & Dackman, 2011). University of Bath, UK uses the horizontal approach by integrating sustainability into some of the departmental subjects (Orr et al., 2014). Besides, Delft University of Technology also has a good example for the horizontal approach in integrating sustainability into engineering education whereas a subject named ‘Sustainable Entrepreneurship and Technology’ is offered. No studies have been done to evaluate the effectiveness of this approach but Cuelemans & de Prins (2010) suggested that the horizontal approach, which is more interdisciplinary and holistic better relates sustainability to the subject matter and therefore, is preferred. Mulder (2006) also suggested that sustainability elements should be embedded into the regular courses. The ‘interdisciplinary’ characteristics of this approach were also highlighted by Crofton (2000) for incorporating sustainability into engineering education. Osman et al. (2014) concluded by suggesting that interdisciplinary knowledge may help sustainability practitioners flourish.

2.4.3 The Vertical versus Horizontal Approach

Sustainability education requires students to learn other domains of knowledge apart from the traditional technical knowledge (Miller, 2014). As observed in the literature, both approaches are used.

The vertical approach is believed to exert less stress on the instructors and can enable knowledge delivery in an efficient way. However, by being separated from the core of the curricula and being mostly single disciplinary, the subject may be ineffective in cultivating the complex understanding needed for addressing sustainability and relating it to the future profession of the students (Disterheft et al., 2013; Thomas & Nicita, 2002), causing the students to understand it as something that is not related to their future profession. This problem may become more apparent if the class is attended by the students from different disciplines as it is difficult for educators to give discipline-specific examples. It is also challenging to introduce a new subject on environment or sustainability into the already packed engineering curricula (Abdul-Wahab et al., 2003; Pappas et al., 2013). Such addition may increase student’s workloads, exert pressures on the teaching-and-learning time allocation and cause potential reduction of the existing contents (Gillett, 2001).

On the other hand, although the horizontal approach bolsters interdisciplinary approach by integrating sustainability into the existing courses, there is a concern on whether sustainability elements could be addressed sufficiently in these courses that are already filled with other components. As pointed out by Haigh (2005), such subjects usually offer limited information on sustainability, defeating the purpose of integration. Besides, some researchers have also pointed out that the horizontal approach is more challenging for engineering education as there is the possible sacrifice of traditional knowledge which most engineering educators are opposed to (Hegarty et al., 2011). Some IHEs are also resistant towards revising the existing subjects to integrate the sustainability components into them (Pappas et al., 2013). A comparison between the vertical and the horizontal approach is summarized in Figure 2.4. It is obvious from the Figure that each of these approaches has advantages and limitations in addressing sustainability education. Neither is superior over the other.

Based on the literature, there is no definitive answer to which integration approach works better, although the horizontal approach is generally preferred. As long as the integration approach enables students to understand sustainability and at the same time actualize the concepts by behaving sustainably, the approach is considered appropriate (Perdan & Azapagic, 2000). The key point to remember is, the students should always be involved and appropriate examples should always be given to stimulate the students' thinking into the right direction by having an approach that strives to achieve a balance between the tradition and innovation in the engineering education (Clarke, 2012; Peet et al., 2004).

Besides, on a side note, it may be noteworthy that there are some shortcomings in such categorization. This categorization neither considers the level of a subject or whether a subject is an elective or a core subject nor does it seem to be applicable for non-formal and informal learning. It has therefore posed a limitation on proposing sustainability integration strategies solely based on these two approaches and it has indirectly indicated the needs to analyse the role of non-formal and informal learning in sustainability education.

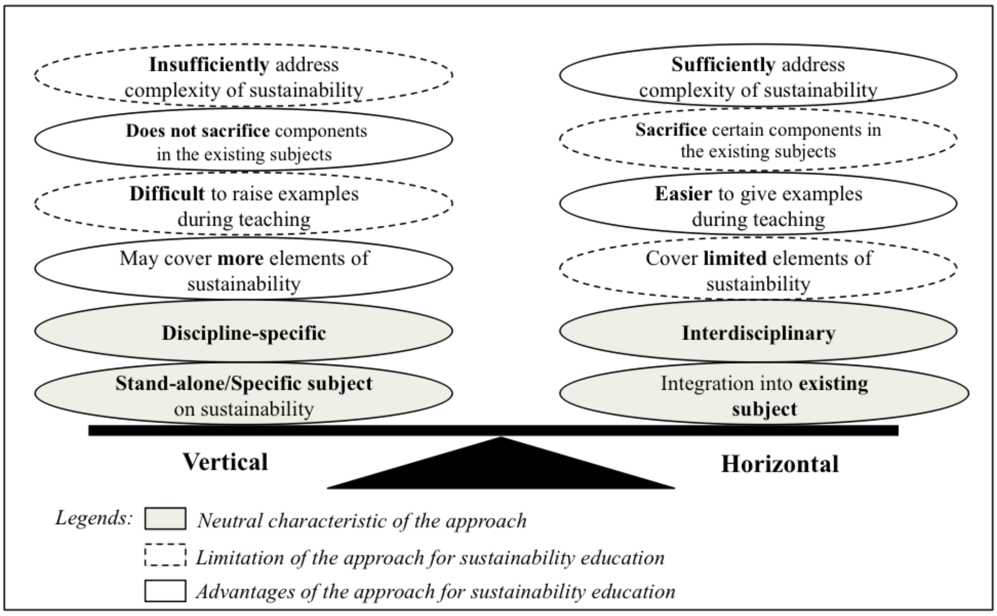


Figure 2.4: Comparison between the vertical and horizontal approach for integrating sustainability into the sustainability education

2.4.4 Formal, Non-Formal And Informal Approaches for Sustainability Integration Into the Engineering Education

As noted in the UNDESD, education for sustainable development can be done through formal, informal and non-formal curricula (Singh, 2009). Based on the literature, it was found that the definition of formal curricula is significantly different from the definitions of informal and non-formal curricula. The term 'informal' and 'non-formal' are often used interchangeably in the literature with some researchers perceive that non-formal is between formal and informal education (Hager & Hallisay, 2006). However, a deeper study into the literature suggested that there are some differences between the informal and non-formal education.

An evident difference among the three types of the education can be excerpted from the related official explanations by the European Guidelines for Validating Non-formal and Informal Learning (Cedefop, 2009). The guidelines state that

> "Formal learning is the learning that occurs in an organised and structured environment (e.g. in an education or training institution or on the job) and is explicitly designated as learning (in terms of objectives, time or resources). Formal learning is intentional from the learner's point of view. It typically leads to validation and certification.
>
> Non-formal learning is learning, which is embedded in planned activities not always explicitly designated as learning (in terms of learning objectives, learning time or learning support), but which contains an important learning element. Non-formal learning is intentional from the learner's point of view.
>
> Informal learning means a learning resulting from daily activities related to work, family or leisure. It is not organised or structured in terms of objectives, time or learning support. Informal learning is mostly unintentional from the learner's perspective." (Cedefop, 2009)

Ainsworth & Eaton (2010) further explained these three types of education in terms of their organizational types, availability of certificates and the motivating factors. They explained that formal education involves instructors as the motivators and certification is awarded; non-formal education is structured with objectives with no certification while informal education is self-motivated with no certification (Ainsworth & Eaton, 2010). Their definitions are commensurate with the dimensions explained by the European Guidelines for Validating Non-formal and Informal Learning. There has been intensive discussion on the non-formal education by the previous researchers, possibly due to its significant contribution to life-long learning (Wójcik, 2004). The characteristics of formal, non-formal and informal educational types, as explained above, are summarised in Figure 2.5.

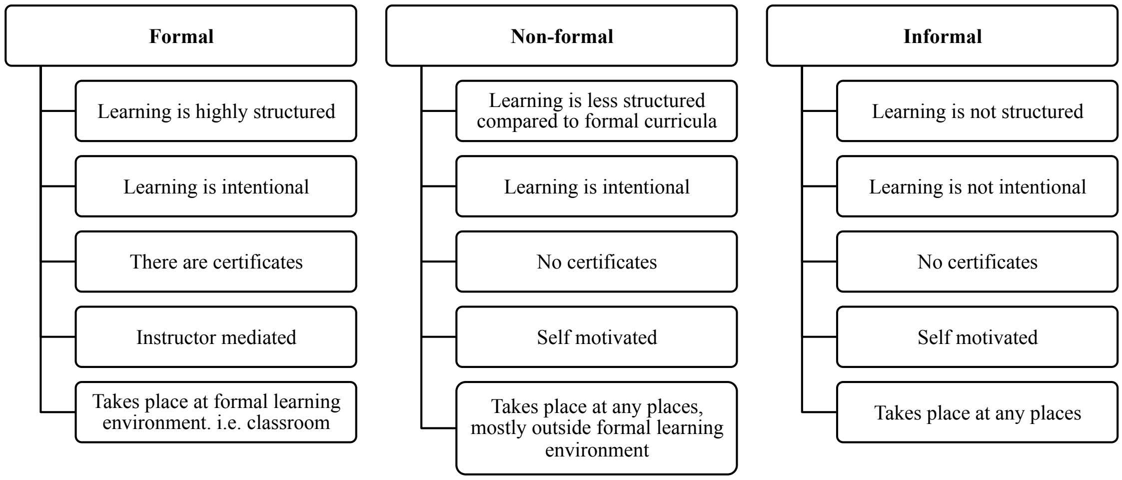


Figure 2.5: The characteristics of the formal, non-formal and informal education

2.4.4.1 Formal Education for Sustainability Integration Into the Engineering Education

Formal education is highly institutionalized, chronologically graded and hierarchically structured (Coombs & Ahmed, 1974). It is a transmission based educational type with the lecturers delivering knowledge to the students (Rich & Brown, 2012). This kind of education is instructor based, rather than student-based (Ainsworth & Eaton, 2010). Therefore, it mainly aims at creating a significant mass of students with certain level of literacy in a subject area (Cap, 2007). It is a traditional approach as formal education is normally conducted in classroom like environments. A typical formal education covers formal curricula, text books, teaching laboratories and classrooms (Cap, 2007).

According to Clarke, (2012), successful engineering education should encompass practical, peer learning and formal education which is more personalized. Formal education, in fact, has started to diversify to take care of the needs of various aspects in the society (Rogers, 2001) and this observation highlights that engineering education has been transforming in response to the needs of the society. Rich & Brown (2012) further explained that formal education is an important tool for subjects that require a breadth and depth of knowledge, which is applicable for sustainability education for the engineering disciplines where understanding of sustainability requires deep-learning (Huntzinger et al., 2007).

Formal education is also important in capacity building towards sustainable development (Agenda 21, 1995). Nevertheless, Cap (2007) pointed out that one of the short falls of formal education is it always ends up with delivery of information without connection to daily life examples, which is an essential component in sustainability education for the engineering disciplines (Glavič et al., 2009; Hall & Howe, 2010; Holmberg, 2008).

2.4.4.2 Non-Formal Education for Sustainability Integration Into the Engineering Education

The most widely used definition for non-formal education was proposed by Coombs & Ahmed (1974) which is 'any organized, systematic educational activity carried outside the framework of the formal system to provide selected types of learning to subgroups of the population, adults as well as children'. Non-formal education is an educational type through which essential knowledge and skills can be learned (Brennan, 1997). It involves all educational activities outside the campus (Singh, 2009; Wójcik, 2004), or highly structured and adaptable learning in any institutions or organizations outside the rigid framework of formal and informal education with personal motivation as the main driver (Eshach, 2006). It may take place at any place (Eshach, 2006).

In contrast with formal education, it is mostly student-based without much interference from the instructors (Rich & Brown, 2012). Non-formal education is always directly related to formal education as it aims at addressing the limitations of formal education (Brennan, 1997; Torres, 2001). Since non-formal learning is mainly student-led instead of instructor-led, it may prove effective to stimulate curiosity and critical analysis skills, which are needed for sustainability education, as quoted by Khalili et al. (2014) from the UNESCO 2012 report. However, care should always be taken while designing non-formal education so that it serves its purposes to address knowledge and skills that formal education cannot effectively deliver (Newman, 1979).

Though structured, non-formal education is flexible (Rogers, 2001). It includes activities, seminars and project-based activities which aim at complex issues outside the formal educational range (Cap, 2007). It may also include some games, through which sustainability education can be delivered, as suggested by Dieleman & Huisingh (2006). Such activities may also be included into the regular curricula to enable efficient learning (Cap, 2007). The projects undertaken by the University of Guadalajara in Mexico, as reported by Martinez et al. (2006) can be considered as an example of non-formal sustainability education whereby the students learned about sustainability in an out-of-classroom setting.

Brennan (1997) pointed out that non-formal education could be complementary, alternative or supplementary. The complementary type of non-formal education is more applicable for populations who are not exposed to formal education while the alternative type is for indigenous groups who have somehow lost their traditional customs or practices overtime. Neither of these types are applicable for the engineering education.

The supplementary type is deemed to be the most applicable for engineering education as it is designed to cope with the current developmental issue of a country which cannot be addressed fast enough by formal education (Brennan, 1997). It is also more knowledge or skill specific, with the capability of deepening the knowledge of students in a subject area (Cap, 2007). As agreed by Guilherme & Morgan (2009) and Rose (2001) too, non-formal education can be used to enhance basic education, cultural development and economy (Rose, 2001), which addresses some of the underpinning elements of sustainability. Besides, Wójcik (2004) reported that non-formal education is especially significant in environmental or sustainability education among young adults. Since it is always challenging to redesign engineering curricula to incorporate sustainability components (Hegarty et al., 2011), non-formal curricula plays an important role in this context to supplement the engineering students with necessary knowledge on sustainability to catch up with the global needs. In fact, in a study by Segalàs et al. (2012), they pointed out that most experts of engineering education for sustainable development suggested that project-based learning was the most effective in delivering sustainability education. Therefore, learning sustainability through non-formal curricula, which encapsulate project-based problems or case studies may prove effective for the engineering students.

Furthermore, non-formal education is also an impetus for communication among the students where students having the same interest will start communicating with each other, sharing and deepening their knowledge along the way (Cap, 2007). Based on the fact that there is a rapid change in the societal and technological demand which the formal curricula cannot respond to fast enough, non-formal curricula can be an alternative (Brennan, 1997). This approach may keep students' curiosity satisfied and stimulate self-learning. As long as the non-formal education is built upon a quality formal education, the students can benefit the most out of it (Cap, 2007).

2.4.4.3 Informal Education for Sustainability Integration Into the Engineering Education

Informal education is defined as learning that occurs in activities organized outside the classrooms with the learning motivation lies within the students themselves without much interference from the instructors (Gerber et al., 2001). It is small scale and personalized (Rogers, 2001). This type of education is less structured compared to formal and non-formal education and can be intentional or non-intentional (Singh, 2009). As argued by Eraut (2004), informal education can be purposeful if the body of knowledge to be learned is explicit and complex. Hands-on experience, which is normally associated with informal education reveals the complexity of situations and can serve as a better approach to problem-solving and complex learning. As mentioned in the EfS blueprint by Second Nature (2011), students can learn more about sustainability outside the formal curricula. The Ministry of Education of Japan actually engaged fourteen communities in Japan as the model cases for sustainability education from 2003-2006 (Nomura & Abe, 2010), which could been as an informal educational approach.

Besides, the motivation for informal education is always intrinsic where the students take initiatives to learn and cultivate an interest towards a subject area (Csikszentmihalya & Hermanson, 1995). Such intrinsic motivation is important as successful sustainability education very much relies on the emotional linkage students have towards the concept of sustainability (Dieleman & Huisingh, 2006). The effectiveness of informal education in cultivating sustainability awareness among the students should not be underestimated as it always leads to deeper learning and outcomes which are required for sustainability education (Huntzinger et al., 2007; Jahnke, 2012). As discussed earlier, a successful sustainability education is able to cultivate interest among the students and makes them inclined to participating in relevant activities (Brown & Kasser, 2005). Acknowledging the roles of informal education, sustainability is always integrated into the informal curricula of the Scottish education system (UK National Commission for UNESCO, 2013) which again proves that informal education can be feasible for sustainability education.

2.4.4.4 Comparison of Formal, Non-formal And Informal Education for Sustainability Integration Into the Engineering Education

As discussed, all formal, non-formal and informal education are relevant to sustainability integration into the engineering education. As recommended by Gerber et al., (2001) and Lehmann et al.(2008), sustainability education must be integrated into the engineering curricula through project-based learning, which falls into the categories of formal and non-formal education. They are not the only researchers who reported that. Kumar et al. (2005) also mentioned that more hands-on or real-world learning experience should be integrated into the engineering curricula to complete the sustainability education. Apart from the formal education, which is capable of conveying engineering knowledge in-depth, the parts played by non-formal and informal education are equally important. As discussed by Nomura & Abe (2010), community-based education should be encouraged for successful sustainability education, which can be well achieved through community activities in informal and non-formal education. A successful example of enhancing sustainability awareness among the engineering students has been demonstrated by the University of Calgary that has developed a large-scale hands-on training programme named as "Engineers Without Borders" (Johnston et al., 2007).

Generally, there is no consensus on which educational type works the best for sustainability education for the engineering discipline. While Jahnke (2012) and Ryan et al. (2010) suggested that a combination of formal and informal education can result in better learning outcomes, Newman (1994) and Sterling, (1996) suggested that non-formal education, when going hand-in-hand with formal education, will yield greater success in sustainability integration into education. Brennan (1997), who conducted a review on the non-formal education and how it could complement the other two educational types commented that effective combinations of formal, non-formal and informal education to integrate sustainability knowledge into the education system may contribute to sustainable development.

2.5 Obstacles In Sustainability Integration Into The Engineering Education

Based on the literature review, the process of integrating sustainability into the engineering discipline is not always smooth. There are a few obstacles that have been pointed out by the researchers, including reluctance to change, lack of interdisciplinary approaches, lack of information and knowledge, dilemma with career and personal interests, bureaucracy or lack of institutional support, lack of financial support, lack of time, lack or peer participation and lack of support from the lecturers or the management. All of the obstacles are summarised in Figure 2.6.

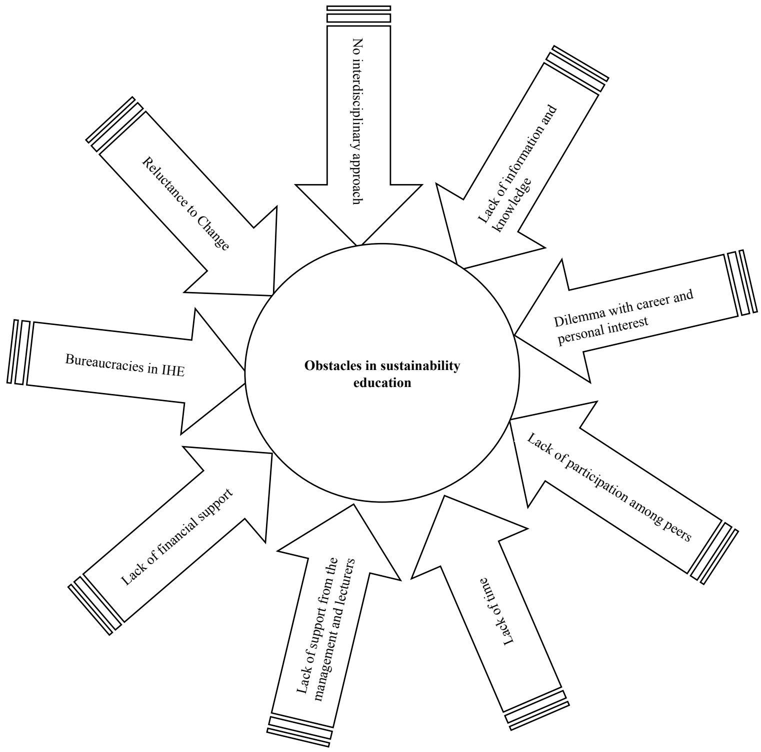


Figure 2.6: Obstacles that prevent sustainability integration into education

2.5.1 Reluctance to Change

According to a study done by Rydhagen & Dackman (2011), some of the engineering instructors involved in their study expressed their reluctance to integrate sustainability into the engineering education and they believed that technical training is more important. They were not willing to give up technical knowledge by allowing issues on 'social competence' to be inserted into the subjects (Emilsson & Lilje 2008). Besides, most of the engineering instructors were confined to their own disciplines due to institutional requirements, leading to almost zero cross-cooperation among different disciplines (Bursztyn & Drummond, 2014). Besides, the worry to face skepticism for adding new elements into the existing curricula also hinders the instructors from integrating sustainability into the existing educational system (Lidgren et al., 2006). Most of their activities and researches are self-centered and this is contrary to the sustainability integration approach highlighted by many researchers that there should be cross-disciplinary co-operation (Creighton, 1998; Toyne, 1993).

2.5.2 Lack of Interdisciplinary Approach

Haigh (2005) and Jones et al (2010) pointed out another obstacle by reporting that the discipline-specific delivery style is a hindrance to sustainability education. Their finding was in agreement with an earlier research by Johnston et al. (2007) who reported that the engineering curricula mainly focused on traditional knowledge and it was delivered in depth rather than in breadth (Morris et al., 2007). In another word, the traditional engineering education always teaches undergraduates single-discipline knowledge without linking this knowledge with other streams of information and skills. This contradicts with the interdisciplinary approach recommended for sustainability education (Bursztyn & Drummond, 2014; Johnston et al., 2007; Murray et al., 2013; Tomkinson et al., 2008; Warburton, 2003). Besides, the institutional pressure on the instructors which requires them to be experts in a single discipline also affects sustainability education (Pearson, Honeywood, & O'Toole, 2005). What makes things worse is most of the scientists are defensive, self-centered and decline knowledge or activities not relevant to their fields (Lélé & Norgaard, 2005). A failure to improvise rigorous connections among different disciplines and subjects will definitely lead to the failure of sustainability education within the engineering education (Lozano, 2010).

2.5.3 Lack of Information and Knowledge

The engineering educational system was mainly oriented around traditional disciplinary-based subjects (Warburton, 2003). As a result, the engineering students always find that the concept of sustainability is fuzzy (Rydhagen & Dackman, 2011). They find themselves having difficulty to 'adapt to' sustainability information. As argued by Filho (2000), the concept of 'sustainability' is too abstract and broad. It is difficult in defining the 'development', 'well-being' and 'future needs' in the context of sustainability and there are unknown long term effects of sustainable practice (Gagnon et al., 2012). Therefore, maybe the students should not be blamed for being confused.

Furthermore, the adaptation to sustainability related subjects could also be more challenging if the subject is specific or stand-alone because the delivery style of this type of subject may differ distinguishably from the conventional engineering subjects (Rydhagen & Dackman, 2011). Failing to see the potential benefits of sustainability-knowledge and overwhelmed with the perceivably fuzzy concepts, the students were just afraid that their educational quality would be compromised if the traditional knowledge was to be replaced with some components of sustainability (Rydhagen & Dackman, 2011). Worse still, such a situation may worsen if the sustainability specific course is introductory, which offers limited information necessary to understand the concept (Haigh, 2005). For example, a student may know that burning wood for electricity is bad but perceive that burning fossil fuel to obtain energy is acceptable (Wemmenhove & Groot, 2001). Peet et al. (2004) also suggested that unless the students see the greater perspectives in sustainability education, it is difficult to change a student's mindset towards sustainability education.

Apart from the students, some instructors are also confused and do not have sufficient knowledge in sustainability (Rydhagen & Dackman, 2011). This may possibly be the root cause for the 'fuzzy concept' in the eyes of the students. Most of the instructors have received limited training on sustainability and environmental issues (Boyle, 1999). Instructors are actually teaching and learning sustainability or sustainable development at the same time (Velazquez et al., 2005) which can result in less effective teaching of sustainability. Such a condition does not portray a positive impact on sustainability integration as it is the instructors' responsibilities to create situations that motivate students to develop a personal interest towards sustainability and the instructors' competence is the key to successful sustainability integration (Warburton, 2003). The sustainability literacy of the instructors must therefore, be addressed first to increase the effectiveness of sustainability education (Sterling, 2004).

2.5.4 Dilemma With Career And Personal Interests

As discussed earlier, personal interest has a relationship with the success in sustainability education (Brown & Kasser, 2005; Steiner & Laws, 2006). Therefore, a successful sustainability education should be able to cultivate the interest among the students and vice versa. However, worldviews differ and it is unavoidable that different interest groups emphasize different aspects of sustainability (Hughes & Kroehler, 2008; Miller, 2014). Most of the time, such interests contradict one another. For example, if the student is more concerned about personal interest, she/he can be more egoistic and may have diminished interest towards sustainable practice (Hughes & Kroehler, 2008; Stern, 2000). On the other hand, if an engineer has a primary focus on the well-being of living organisms, he is deemed to be biocentric and may design a technical solution to the interest of both the client and the environment (de Groot, 2008; Stern, 2000).

It is important to make the students see clearly the defined moral values to which they commit themselves to enable efficient learning (Podger, 2010). In this case, the students must become acquainted with the interconnectedness between their personal values and sustainability so that they will be committed to sustainability education and sustainability practice.

Additionally, the consumerist mindset among the engineering students nowadays is also hindering sustainability education as they are already used to utilizing resources to meet the current needs of the society, failing to look into the economic, societal and environmental aspects of sustainability (Morris et al., 2007; Byrne & Fitzpatrick, 2009; Goldman et al., 2013). At the end, they see a conflict between sustainable practice and their expertise (Miller, 2014). This interpretation is in agreement with the research findings of Rydhagen & Dackman (2011) who found that students generally isolated sustainable practice at the initial stage of product design.

2.5.5 Bureaucracies or Lack of Institutional Support

The bureaucratic resistance to change also affects sustainability integration into engineering education (Steiner & Laws, 2006). Bird (2001) commented that institutional culture still resists against the interdisciplinary approach that is much recommended for sustainability integration into education. Besides, the lack of institutional trust in the IHEs in effectively executing policies and plans for sustainability education also negatively affects the commitment of staff and students towards sustainability related activities (Evangelinos & Jones, 2009). As argued by Carew & Mitchell (2006) too, integration of sustainability into the institutional policies or codes of practices are directly related to delivering sustainability education to the engineering graduates.

Besides, the protocols involved in an organization, which is always procedural and time-consuming is not friendly for sustainability education. According to the study done by Viebahn (2002), effective decisions must be made on time to achieve the goal of sustainability education because the enthusiasm towards SD may dampen over time when there are no quick responses from the management (Thomas, 2004). This simply means that when the instructors or students have shown interest in sustainability education or put forward proposals relevant to sustainability, the management must respond and gives its support in time.

2.5.6 Lack of Financial Support

Based on the literature, financial constraint is also one of the obstacles for facilitating sustainability education (Dahle & Neumayer, 2001). High implementation costs in creating a conducive environment for sustainability education can be discouraging at times (Evangelinos & Jones, 2009). For example, a university at Northern England has opted to use non-recycled papers instead of recycled papers as the former is cheaper than the latter (Filho, 2000).

Limited funding also affects the implementation, planning, and level of participation in sustainability related activities, which is often related to the informal and non-formal educational types of sustainability integration (Gerber et al., 2001; Pike et al., 2003; Velazquez et al., 2005; Zimmerman & Halfacre-Hitchcock, 2006).

2.5.7 Lack of Time

Instructors and students are most of the time loaded with their own work. Consequently, they are reluctant to allocate their time to support the sustainable development initiatives in the IHEs (Lozano, 2006; Thompson & Green, 2005). In a study done by Jones et al. (2008), it was also found that time was a limiting factor for successful implementation of sustainability education. Normally, only those who volunteer will stay to complete the initiatives or plans (Velazquez et al., 2005) and participate in the sustainability related activities. Since considerable time is needed for sustainability-related activities, such activities may fail eventually due to time constraints (Reid & Petoca, 2006; Velazquez et al., 2005).

2.5.8. Lack of peer support

A dense social network is important for collective activities for the common good and individual well-being (Coleman, 1990) which is connected to sustainable development (Pretty, 2003). Social network serve as a way to spread knowledge. Evangelinos & Jones (2009) pointed out that social networks can actually influence the flow of information and promote sustainable development within a campus.

Sustainability education can be initiated through training of community members (von Oelreich, 2004), which are relevant with the formal and informal approaches of sustainability education. Eagerness and commitment from all members within a community will significantly facilitate environmental management initiatives (Price, 2005),

2.5.9 Lack of Support From The Lecturers And Management

A lack of senior management consciousness towards environmental issues and gaps between academicians, administrators and students are the other inhibiting factor of sustainable development in the IHEs (Nicolaides, 2006). The IHEs should provide necessary resources to guide students towards sustainability (Kumar et al., 2005). There must be a leader responsible for organization and coordination of the SD plans (Shriberg, 2003).

It should be noted that lecturers carry equal weight as the management in incorporating sustainability education in the IHEs. According to Lozano (2006), some of the university members have done nothing to integrate the concepts or components into their courses, research and outreach due to many reasons such as lack of relevant information, although they are aware of sustainable development. Therefore, as many visible supports as possible should be obtained from both the management. The more support there is, the more likely that a sustainable approach can be implemented (Thompson & Green, 2005) in the institution to facilitate sustainability education.

2.6 Efforts of Various IHEs And Organizations At A Glance

In view of the fact that integration of sustainability in engineering education is a determining factor for shaping a sustainable future, many engineering organisations and IHE have started responding to sustainability related contexts (Lucena & Schneider, 2008). There is also a rising establishment for the relevant journals, educational programmes and media of professional engineering organizations (Lucena & Schneider, 2008; Miller, 2014). In fact, Velazquez et al. (1999) foresaw that sustainability education would be incorporated into the engineering education at the end of the 21st century, as mentioned in one of their publications in 1999. Based on the literature search, some of the significant efforts demonstrated by these organisations were briefly discussed below.

2.6.1 The North American Countries

In the United States (US), American Society of Engineering Educators (ASEE) was among the first to release an official statement on sustainability education for engineering disciplines by announcing their 'Statement on Sustainable Development Education' (Lucena & Schneider, 2008). Besides ASEE, American Society of Civil Engineers (ASCE), American Institute of Chemical Engineers, The Institute of Electrical and Electronic Engineers of the United States have also issued statements that emphasize roles of engineers for sustainable development and addressed sustainability or environmental concern in their codes of practice (Carew & Mitchell, 2006; Lucena & Schneider, 2008; Miller, 2014). The University of Sonora, Mexico also joined the quest by developing 'Sustainable Development Group' in 1992 (Velazquez et al., 1999). This

Group has created an educational model that oversees sustainability education for the engineering disciplines. Canada has also introduced sustainable engineering as a general concept into their engineering education and it is generally defined as integration of sustainability into engineering activities or practice (Gagnon et al., 2012).

2.6.2 The European Countries

The United Kingdom (UK) is one of the European countries that are active in sustainability integration into the engineering education. The Higher Education Funding Council for England (HEFCE) has a sustainable development strategy for higher education (Martin et al., 2005). The Engineering Education for Sustainable Development (EESD) and The Observatory and The Alliance for Global Sustainability have also been established to monitor integration of sustainability into engineering education (Glavič et al., 2009; Filho, 2014). Relevant effort has also been observed in Ireland. Engineers Ireland has specified sustainable development relevant programme outcomes which have to be abode by all accredited engineering programmes in Ireland (Nicolaou & Conlon, 2012).

Besides the UK, the Swedish government has also promoted sustainability integration into engineering education by stating that sustainable development would be integrated into the engineering education under the Swedish Act for Higher Education (Rydhagen & Dackman, 2011). Integration of sustainability into engineering education has also been proposed in Latvia and Netherlands starting from 1990 (Haigh, 2005; Lucena & Schneider, 2008).

In the Netherlands, The Delft University of Technology (TUD) has adopted an environmental policy containing a set of guidelines for sustainability integration into the engineering curricula (Mulder, 2006). The policy highlights that sustainability should be introduced into the engineering curricula and research within three years from the date the policy is effective, following which, a subject named as Sustainable Entrepreneurship and Technology which combines entrepreneurship, sustainability and project education has been introduced into the Chemical Engineering Programme (Bonnet et al., 2006). The effort of TUD has paid off as significant sustainability literacy level has successfully been cultivated among its staff and students (Köhler et al., 2013).

The other example is in Spain. Jorge et al. (2014) reported that the Conference of Rectors of Spanish Universities had also established a special working group on SD to issue guidelines on integrating sustainability components into curricula. On top of that, the Spanish government has new imposed legislations on sustainability integration into higher education such as the Organic Law 4/2007 (Jorge et al., 2014).

2.6.3 The Asia-Pacific Countries

The Australian and New Zealand professional organizations have adopted a much similar approach as the European and North American organizations. The Institution of Engineers of Australia has stated 'sustainability' as a criterion for accreditation of an engineering baccalaureate (Carew & Mitchell, 2002).

Ministry of Education of Japan also responded to the UNDESD by establishing a programme entitled 'Environmental Leadership Initiatives for Asian Sustainability' in 2008 to highlight its commitment towards sustainability education (Nomura & Abe, 2010). In fact, the Japanese government already created the Japanese National DESD Plan Implementation Plan in 2006 which serves as the main policy for promoting sustainability education (Nomura & Abe, 2010). The University Tokyo also established a system named as "Integrated Research System for Sustainability Science" (IR3S) in 2005 to focus on relevant research (Abd-Razak et al., 2011).

The Taiwanese government has responded to the urge of Agenda 21 by creating Taiwan Sustainable Campus Programme (TSCP), which aims at sustainability integration into the campus as a whole and into the curriculum (Su & Chang, 2010). A number of Taiwanese governmental agencies have allocated funding for sustainability integration into the curriculum across the campus through formal and non-formal education (Su & Chang, 2010), recognizing that enough funding is needed for driving sustainability education.

Apart from that, India, which has the second highest population in the world, recognizes the needs for sustainability education too. The Indian government has made it mandatory to teach environmental subjects to all undergraduates (Chhokar, 2010) by instructing the University Grants Commission to ensure delivery of environmental related subjects at all universities as the step to facilitate sustainability education (Chhokar, 2010). One of the top IHEs in India, Indian Institutes of Technology has introduced SD into its Environmental Engineering Programme while the Civil Engineering Department offers a subject named as 'Technology and Sustainable Development' (Chhokar, 2010). The other main IHEs in India have also integrated sustainability education into their undergraduate curricula to certain level.

China, the most populated country in the world that faces challenges in terms of geographical size, is making an effort to address sustainability education through National Green Campus Project, a plan launched to improve sustainability knowledge within the learning institutions (Niu et al., 2010). Sustainability education has been incorporated in different programmes at various levels in the Chinese IHEs since 1997. For example, Tongji University at China launched the United Nations Decade of ESD in 2005 (Niu et al., 2010).

As observed above, the Asian countries have generally demonstrated clear effort in integrating sustainability into their higher education curricula and IHEs. The available literature mainly discussed such integration and commitment as a whole without a detailed discussion in the engineering context. However, all these efforts and commitments, as discussed in the available literature, spanned across the respective nation and applied to all types of curricula. It is therefore, suggested that the relevant framework and policies suggested by these nations are also applicable to the engineering disciplines within their countries.

2.6.4 Research On Effectiveness Of Sustainability Integration Into Engineering Disciplines

Based on the literature, there is an array of research on sustainability education in a general context but there are relatively less publications on sustainability education in relation to the engineering curricula. Most of the research discusses the general approaches, experiences, factors and obstacles associated with campus greening efforts based on the specific experience of an individual IHE. There are very limited publications relevant to the themes of this research.

Based on the literature that has been reviewed, previous studies, which discuss similar themes as this research's were conducted by Azapagic et al., (2005), Carew & Mitchell (2008), Segalàs et al., (2008) and Nicolaou & Conlon (2012) . Some of this research used questionnaires as the main data collection tool while others used conceptual maps. The recent relevant studies by these researchers are summarized in the following paragraphs.

The study by Carew & Mitchell (2002) at the University of Sydney was one the earliest of its kind. They used Structure of Observed Learning Outcome (SOLO) to analyse their engineering students' understanding on sustainability. They used a matrix of principles of sustainability to assist their study. Their result showed that the students understood sustainability broadly and the majority of the students either did not know what sustainability was or provided a non-specific response. In their conclusions, they argued that there should be improvement in the engineering curricula in order to facilitate learning on sustainability.

Azapagic et al. (2005) conducted a research internationally using a questionnaire, which was completed over two years. The designed questionnaire aimed at assessing the students' knowledge on SD through questions on environmental issues; legislations; policy and standards and tools related to SD. In their research, they identified the engineering students' knowledge and level of understanding on SD and the knowledge gap. Their research showed that the students' knowledge and understanding on SD was low and there was a knowledge gap on SD legislation, policy, social issues and some environmental issues. They suggested that engineering education should be improved to close the abovementioned knowledge gaps.

Another similar research was conducted in Ukraine, Spain and the The Netherlands by Segalàs et al. (2008) using a conceptual map. The conceptual map was suggested by Lourdel et al. (2007) as a tool to measure knowledge on sustainability. Conceptual maps were used in their study to measure the effectiveness of a specific subject on sustainability to deliver sustainability knowledge. It was conducted by comparing the students' literacy level in sustainability before and after they attended the target subject in their study. Their results showed that the students related sustainability to mainly environmental components before taking the subject and such scenario did not differ much upon completing the subject. There was also a knowledge gap on the societal acpects. They argued that there was a need to emphasize social, institutional and other knowledge related to sustainability.

A research was performed by Nicolaou & Conlon (2012) to study the engineering undergraduate's knowledge and understanding on SD in an Irish IHE. Similar to the abovementioned researchers, they used a questionnaire as the main data collection tool. They designed the questionnaire based on the one designed by Azapagic et al. (2005) and Carew & Mitchell (2008). They assessed the student's knowledge on SD through questions on legislations; environmental issues; SD tools and organizations that promote SD. Their results showed that most of the students had poor or vague understanding of SD. They identified that there was a knowledge gap with regards to the SD principles, SD legislations and societal aspects of SD among the students. Their results also showed that the knowledge level may be discipline-led, which suggested that the student's knowledge level in sustainability may vary according to the engineering disciplines.

2.7 The Scenario in Malaysia

While there is a plethora of activities, declarations and efforts in addressing sustainability education in the IHEs or into the engineering education in the European, American and Australian Countries, Malaysia seems to be lagging behind. Based on the literature search and other published sources, no major commitments specifically on sustainability education have been reported in Malaysia.

In terms of governmental policies, there are no similar policies such as 'Learning for Change' in Scotland, and 'Sustainability in Exchange' in the UK (UK National Commission for UNESCO, 2013) in Malaysia in response to the call of the UNDESD. The most relevant one, which involves participation of the IHEs at the national level is Schneider Electric's University Challenge, which is an inter-university competition aimed at inspiring engineering students to propose creative solutions for solving energy issues (Chua & Oh, 2011).

In terms of national developmental plans, a look into the Ninth (2006-2010) (EPU, 2006) and Tenth Malaysian (2011-2015) Plans (EPU, 2010) revealed that the government is aspiring to improve its human capital through various stages of education to achieve its goal to become a developed nation by 2020. The plans, especially the Tenth Malaysian Plan has a higher focus on sustainable development compared to the ninth Malaysian Plan, but still, it does not outline any action plans for sustainability integration into the IHEs or in the engineering disciplines.

Nevertheless, individual IHE in Malaysia is found to show encouraging efforts corresponding to major world declarations on sustainability education. For example, *Universiti Sains Malaysia* (USM) has a mission statement articulating its commitment towards sustainability and establishment of a sustainable campus (Sanusi & Khelgat-Doost, 2008). It has established the Centre for Global Sustainable Studies which mainly takes care of the transformation of the campus into a sustainable campus (CGSS, 2012) and it is aspired to be the Regional UNDESD Centre of Expertise (Sanusi & Khelgat-Doost, 2008). The University of Malaya (UM) has established UMCares which is a centre focusing on promoting sustainable lifestyle among the students and some target communities (UMCares, 2014). *Universiti Teknologi Malaysia* (UTM) has established Unit of Sustainability which aims at promoting sustainable campus (UTM, 2014). *Universiti Kebangsaan Malaysia* (UKM) has also created Institute for Environment and Development at UKM that serves as a platform for sustainability related research (UKM, 2013).

Generally, there are no concrete national actions plans on incorporation of sustainability into the the higher education system in Malaysia, particularly the engineering education at the national and institutional level. Perhaps, the most active and relevant organization in addressing sustainability education for the engineering students is the Board of Engineers of Malaysia (BEM). BEM has made an effort to make sure that the sustainability components are integrated into the engineering education in Malaysia by making it an accreditation criteria (BEM, 2012). The latest EAC manual has outlined 12 programme outcomes for engineering degree programmes and the 7th programme outcome states:

> "Environment and Sustainability - Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development." (BEM, 2012)

Any accredited engineering programme in Malaysia should therefore, make sure that sustainability knowledge is incorporated into the curricula.

2.8 Summary

There is a dire call for sustainable development around the globe in view of the mounting environmental and societal problems. A number of world declarations, as a result of meetings among top global leaders, experts and management from the IHE have been produced in the hope to achieve sustainable development through tertiary education, a key tool to sustainable development (Thomas, 2004). By figure, more than a thousand IHEs in total have become the signatories to these world declarations and committed themselves to shape a more sustainable future through institutional effort (Corcoran et al., 2004). Some of them have realized their promise and actively promoted sustainable development through tertiary education while some have not.

As highlighted in the world meetings, sustainability knowledge must be instilled into the curricula of tertiary education to produce a future workforce who is competent with the knowledge. Engineering education has since become one of the most active disciplines in seeking to integrate sustainability into its engineering curricula. Based on the research done on sustainability education, it was found that sustainability knowledge could be incorporated into the curricula through the vertical or horizontal approach, with the former involving sustainability-specific subject and the latter orienting around sustainability integration into existing subjects. Another dimension of the integration approaches is built on the formal, informal and non-formal types of education. There are pros and cons for all of the approaches and the educational types. Generally, there is no consensus among the researchers on which approach works the best though there is an indication that the horizontal approach which is usually more interdisciplinary; and the non-formal education which always involves communities should be appropriate for sustainability integration into the engineering curricula. However, some researchers have highlighted that there is no one-fit-all approach as every engineering discipline is unique.

Based on the literature, a few constrains that hinder sustainability integration into the engineering education were identified. They included reluctance to change, lack of interdisciplinary approach, lack of relevant knowledge, contradicts personal interest, lack of institutional support, lack of financial support, lack of time, lack of peer participation and lack of support from lecturers and management.

In order to make sustainability education more effective, many IHEs, governmental agencies and professional organizations have detailed policies, action plans, guidelines and frameworks as an institutional guidance and motivation. Among all, the European and North American IHEs, together with the Australian IHEs seemed to have the most established policies and plans to promote integration of sustainability knowledge into the engineering education. Most of the engineering professional bodies in these countries, including the one in Malaysia have highlighted 'knowledge on sustainability' as an accreditation criterion for the engineering programmes in the IHEs. Some Asian countries such as Japan, Taiwan, India and Japan have also made substantial effort to drive sustainability education at the national level by having certain policies or providing sufficient funding.

Corresponding to various efforts done by the IHEs in cultivating a sustainable culture within the campus and improving the engineering curricula with sustainability components, plenty of research has been conducted in evaluating the relevant efforts. Most of this research has focused on the individual IHE's effort, commitment and policies towards sustainability integration into the campus in a wider perspective, without specifically discussing the engineering disciplines. Some have particular research interest in the relationship between sustainability and engineering outcomes such as ‘sustainability and products’, ‘sustainability and future’. There is limited research on the effectiveness of the current sustainability education strategy in producing engineering students who are literate and interested in sustainability. Besides, there is limited information on the applicable theories and methodologies suitable for this kind of research, as reported by some researchers. It was found that questionnaires and conceptual maps were the most common tools used for evaluating the student’s understanding level in sustainability.

Generally, the literature review showed that most of the relevant studies in the context of sustainability education have been widely established for the European, North American, and Australian IHEs. The developments of such research in the Asian countries are slow, as agreed by Ryan et al. (2010).

The effectiveness of the current approach adopted by the Malaysian IHEs for integrating the sustainability knowledge into the engineering curricula to cultivate the sustainability literacy and interest among the engineering students is unknown. Nevertheless, it is believed that Malaysia has been involved in such efforts for a while, it should now be the time to examine the student’s knowledge level and propose an improvement plan. There is a need to examine if the students’ knowledge and interest level in sustainability are sufficient under the current educational approach. Besides, it is necessary to identify the educational approach and type that are appropriate for the engineering education in Malaysia as a continual improvement effort for sustainability integration into the engineering disciplines, which has never been researched before, to my knowledge.

CHAPTER 3: METHODOLOGY

This research focused only on engineering disciplines because it is the most active profession in integrating sustainability in its education, and engineers are the main solution providers for technology advancement (Fien, 2002; Glavič et al., 2009). It is therefore, meaningful to study the approaches that can enhance sustainability integration into the engineering curricula in order to produce engineers who are competent with the sustainability knowledge. The data were built on the information from five research-based public IHEs in Malaysia.

The research methodologies were divided into three parts, which were collection of background information of the targeted engineering disciplines from the selected IHEs in Malaysia, collection of information from the respective final-year engineering undergraduates through a questionnaire and statistical data analyses.

The targeted engineering disciplines were Chemical, Civil, Mechanical and Electrical Engineering, which are the traditional engineering disciplines that have the longest existence among all the engineering disciplines. The selected research based IHEs were anonymously known as IHE A, B, C, D and E. Research based IHEs were chosen as they always serve as a point of reference for the other IHEs in the country and they have higher research components through which sustainability education can be promoted (Fien, 2002; ULSF, 2012). It is believed that since the research based IHEs are the major innovation providers, their policies on sustainability integration into the education should be more significant compared to the other IHEs. Besides, the selected IHEs are the oldest IHEs in Malaysia and they have an established history of offering undergraduate engineering programmes.

The units of analysis in this study were curricula content, student's knowledge and interest level in sustainability and formal, non-formal and informal educational tactics used for the sustainability education for engineering undergraduates.

Generally, there were very limited publications on similar research and well-documented methodology to collect relevant information needed for this study. Besides, there was a lack of theoretical support to the existing data collection methods (Corcoran et al., 2004). Most of the previous studies, if concerned with sustainability integration, focused on sustainability integration into the campus as a whole (Axelsson et al., 2008; Cusick, 2008; Holmberg et al., 2012) and sustainability assessments in the campus (Beringer, 2006; de Castro & Jabbour, 2013; Moldan et al., 2012; Waheed et al., 2011). There was relatively less research on measuring the student's level of understanding and interest on sustainability, as an indicator of the effectiveness of the integration. Some of the recent similar research studies were conducted by Azapagic et al. (2005), Carew & Mitchell (2002) and Nicolaou & Conlon (2012) who used questionnaires primarily in their research to evaluate how much engineering students knew about sustainability. Their research goal coincides with one of the themes of this research and therefore their research methodology was used as the foundation for the questionnaire used in this research.

3.1 The Analytical and Conceptual Framework

Based on the literature, an effective sustainability incorporation strategy enhances students' knowledge level and interest level in sustainability (Felder & Brent, 2004; Orr et al., 2014). Therefore, the term 'effective' is used throughout this thesis to describe an educational system, which is able to enhance students' knowledge level and interest level in a subject matter. Sustainability incorporation into the engineering education can generally be completed through the vertical and horizontal approaches within the formal curricula together with the informal and non-formal curricula (Cuelemans & De Prins, 2010; Haigh, 2005). Therefore, there is a relationship between the incorporation strategy with the student's knowledge and the interest level in sustainability.

These approaches are different from one another. However, they are known to have an influence on sustainability integration into the engineering education (Brennan, 1997). Given the tight schedule in an undergraduate engineering programme, it can be time consuming and impractical to try to implement all the approaches at one time.

It should be noted that a typical undergraduate engineering programme in Malaysia is built upon a one-hundred-and-forty-credit-hour course content. Although well above the minimum requirement by the Engineering Accreditation Council (EAC) of one hundred and twenty credit hours, those extra credit hours are usually allocated for compulsory national courses, english courses, university courses and other engineering related courses which are deemed helpful in enhancing the students' competency in the field (Chiong et al., 2014). Sustainability, which is deemed to be non-technical, may be sidelined. There is therefore, a need to identify a possible strategy for effectively integrating sustainability into the engineering education without further loading the already compact engineering curricula. The proposed strategy should also differ with the engineering disciplines as sustainability education should be tailored according to disciplines (Parkin et al., 2004).

The first part of this research analysed the curricula content of the respective engineering disciplines from the five selected IHEs. Then, the current knowledge and interest level of the engineering students from the respective engineering disciplines were analysed. The third part of the research accessed and identified the formal, non-formal and informal educational tactic which had the highest influence on the students' knowledge and interest level in sustainability. This was done through determining the correlation of each of the tactics in each educational type (formal, informal, non-formal) with the students' knowledge and interest level. The analytical framework of this study is summarized in Figure 3.1.

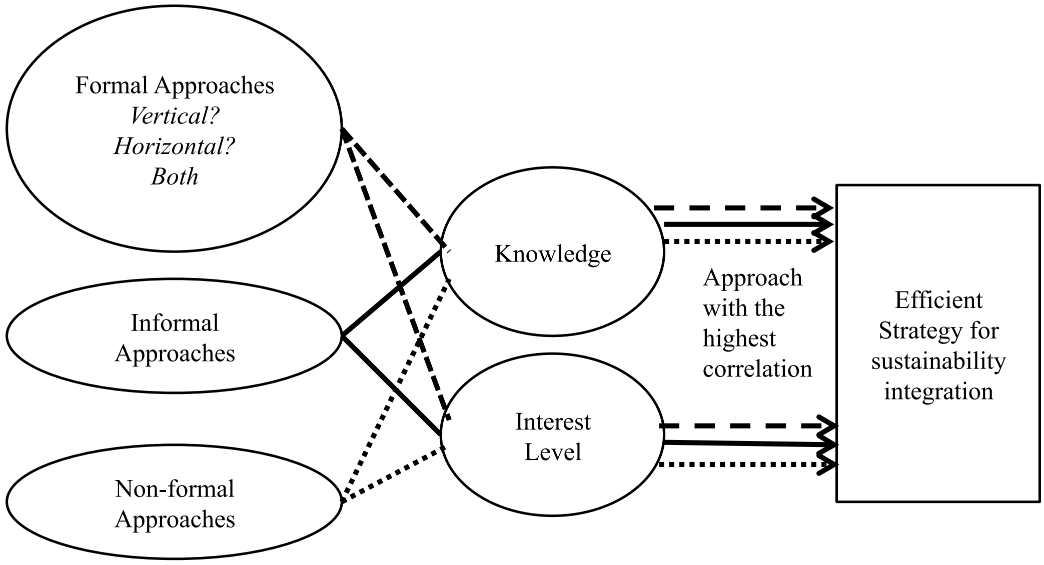


Figure 3.1: The developmental process of the proposed strategy for effective integration of sustainability into the engineerin education

Other than identifying the tactics which had the highest influence on/ correlation with the students' knowledge and interest level, further categorization on whether the proposed strategy was inclined towards the horizontal or vertical approach was explained. The definition of the horizontal and vertical approaches is already summarized in Figure 2.2. Categorization of the approach will be useful for the curriculum development unit in updating the engineering curricula in the future since such categorization is easily understandable and can serve as the core of the integration strategy. Since no two disciplines are alike in nature (Corcoran et al., 2004), the conducted analyses were discipline-specific, which means that the scenario for each engineering discipline was analysed and discussed separately. Additionally, the factors that reduced the students' interest on sustainability were also identified in this study. This information is meant to complement the proposed strategy. The identified issue could be addressed during the curricula update exercise to improve the overall effectiveness of sustainability incorporation into the curricula.

3.2 Selection of Target Institutions of Higher Education (IHEs)

Data were collected from the targeted engineering disciplines, namely Chemical, Civil, Mechanical and Electrical Engineering from five public Institutions of Higher Education (IHEs) in Malaysia, anonymously known as A, B, C, D and E. The selected IHEs have the same characteristics as follows:

- Research-based IHE
- Offer the engineering programmes targeted in the study
- Have a significant history (more than fifteen years) in offering undergraduate engineering programmes
- Have almost the largest student population size in undergraduate engineering programmes

The other IHEs in Malaysia, which offer the targeted undergraduate engineering programmes, were not included in this study to avoid potential bias in the resulting data due to different institutional characteristics (the other IHEs did not share the same characteristics listed above).

3.3 Background Information Collection

The background information of the selected engineering disciplines, including the programme outlines and information on the number of final-year engineering undergraduates was gathered from the academic unit of the respective IHE. The information on the number of students was obtained directly through tele-conversation with the academic unit of the respective IHEs.

3.4 Analyses of the Engineering Curricula

The outlines or synopsis of each subject for the respective engineering curricula from the selected IHEs were analysed. Text analysis was performed on the outlines and synopsis based on the key terms to identify subjects which are relevant to sustainability. The list of the key terms relevant to sustainability can be found in Appendix A. The key terms were derived according to the components of the Sustainability Triangle for Engineering in the Developing World established by Fuchs and Mihelcic (2006), as reported by Mihelcic et al. (2008) and the work by researchers such as Fenner et al. (2005).

3.4.1 Categorization of Courses

Then, the relevant subjects were categorized accordingly under the horizontal (existing courses within which sustainability knowledge is intertwined) or the vertical (stand-alone courses) approach. A subject which covers only the environmental knowledge or sustainability knowledge, regardless of the discipline, is categorised under the vertical approach (Kumar et al., 2005). A subject is considered under the category of the horizontal approach when its core content is not on the environment or sustainability components but its sub themes cover some relevant contents such as energy efficiency, efficient use of natural resources, efficient energy use, mitigation and prevention of pollution, mitigation of climate change, application of sustainability in engineering (Fenner et al., 2005) and others as listed in Appendix A. Further analyses were performed to identify if a subject was compulsory or elective for the statistical analysis purpose, which would be explained later. The categorization analysis provided information on the approaches engaged by each engineering discipline for sustainability education.

3.4.2 Percentage of Overall Sustainability Integration Into the Curricula

The integration percentage of sustainability related subjects into the engineering curricula was calculated using the following formula, modified from the formula proposed by Chiong et al. (2014).

$$\frac{\text{Total number of compulsory subjects related to sustainability}}{\text{Total number of compulsory subjects of the programme}} \times 100\%$$

It should be noted that only compulsory subjects were considered in the integration percentage. It was because compulsory subjects are subjects that students must take and therefore play a direct role in delivering sustainability education. Electives, on the other hand, are subjective to students' choice and the exposure of students to extra sustainability knowledge (apart from the existing in compulsory courses) may depend on whether the students have opted to choose sustainability-related electives from that long list of electives offered by the faculty. This has posed mathematical concern as there is a need for probability analysis on 'chances sustainability related electives will be chosen from the electives list', 'chances students will fulfil all the allocated slots for electives with sustainability related electives' and 'how many of the allocated slots for electives will be used for sustainability related electives'. This mathematical concern will potentially lead to statistical error that will compromise the result analysis at a later stage. Therefore, electives were omitted in the calculation of the integration percentage.

3.5 The Questionnaire

The questionnaire was the main data collection tool in this research. It provided information on the following:

1. Student's knowledge and interest level in sustainability

2. The formal, informal and non-formal approaches which were the most effective in delivering sustainability education

The questionnaire collected the relevant information from the target population from the respective engineering disciplines. The target population was the final-year engineering undergraduates from 4 engineering disciplines at the selected IHEs. The personal data of the respondents were not reported to protect the anonymity of the individuals (Jones et.al., 2008). The questionnaire was distributed, in the form of hardcopy, by student helpers and the researcher herself, to increase the response rate and to make sure that the respondents received the same set of instructions (Berglund et al., 2014). Systematic random sampling was conducted, with random sampling conducted within each targeted engineering discipline at the selected IHE. An example to explain the sampling method is illustrated in Figure 3.2. The figure shows that the questionnaire was distributed randomly among the final-year Chemical Engineering students at IHE A and the same procedure was repeated at IHE B, C, D and E. Accordingly, the same procedures were repeated for the other targeted engineering disciplines. Since 'random' sampling was conducted within a confined boundary – specific IHEs and respondent groups, it was considered systematic random sampling.

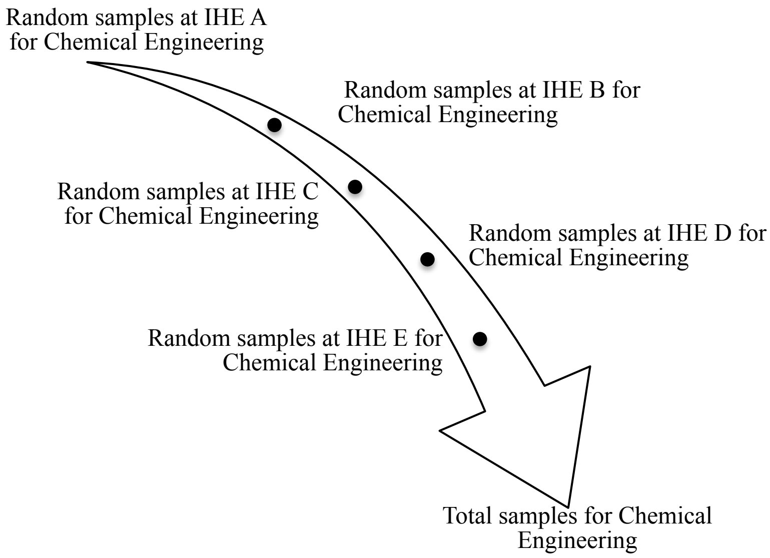


Figure 3.2: Illustration of the systematic random sampling method used in distributing the questionnaire

3.5.1 Structure of the Questionnaire

The questionnaire was built by referring to the similar research conducted by Azapagic et al. (2005), Carew & Mitchell (2002) and Nicolaou & Conlon (2012) which aimed at measuring students' knowledge and level of awareness. Carew & Mitchell (2002) used a qualitative-analysis based questionnaire in their study while the others mainly used a quantitative-analysis based questionnaire. As the targeted respondents in the study were the final-year students who had limited time to spend on the survey, the quantitative-analysis based questionnaires used by Azapagic et al. (2005) and Nicolaou & Conlon (2012) were used as the framework based on which the questionnaire for this study was developed.

However, the questionnaire developed for this study was not identical with the ones used by them. It was made more complex with a list of formal, non-formal and informal educational tactics which the respondents had to respond to in order to achieve the objectives of this study despite it contained similar items that were found in the questionnaire used by the abovementioned researchers, such as definitions of sustainable development and importance of sustainability as perceived by the respondents.

The questionnaire was divided into five parts: Part A - Knowledge on sustainability/ sustainable development; Part B - Integration of sustainability into formal curricula; Part C – Integration of sustainability into non-formal curricula; Part D – Integration of sustainability into informal curricula (extra-curricular activities) and Part E – Interest towards sustainability. Ten to fifteen minutes were needed by the respondents to complete the questionnaire.

Two terms –'sustainability' and 'environment' were used in the questionnaire to avoid discouraging respondents who may not be familiar with the term 'sustainability', as suggested by Azapagic et al., (2005). In fact, the term -'environmental' can appear more acceptable and 'appealing' in the subject titles compared to the term - 'sustainability' and thus a subject with 'environmental' in its title also addresses sustainability (Thomas, 2004).

A likert scale was used throughout the questionnaire as this questionnaire aimed at measuring the opinions and perceptions of the respondents towards a series of statements, which is measurable by Likert scale (Bowling, 1997). A 5-point Likert scale was used with 1=Yes, strongly agree; 2= Yes, agree; 3=Not sure; 4=No, disagree and 5=No, strongly disagree. A 5-point Likert scale was used because it can create more scale variance for the measurement purpose (Netemeyer et al., 2003). All the statements in this questionnaire were in positive terms to avoid possible confusions caused by double negative statements (Bowling, 1997). A sample of the questionnaire is attached in Appendix B.

A) Part A of the questionnaire

Part A of the questionnaire contains a total of seven items which are all oriented around statements on sustainability such as the definition of sustainability. This part aims at determining the perception and knowledge level of the respondents towards sustainability. These seven items were decided based on the underlying definitions of sustainability except for Item 1 and 2 which evaluated the student's experience with the term to give a general understanding on the student's exposure to the term. The 5-point Likert scale in this part was assigned scores accordingly with Likert scale 1 = 5 marks; 2= 4 marks; 3 = 3 marks; 4= 2 marks ; 5 =1 mark for analytical purposes. The total marks obtained from this were averaged and the obtained marks were then interpreted and translated into the knowledge level according to the mark interpretation shown in Table 3.1

B) Part B of the questionnaire

Part B of the questionnaire contains a total of ten items which are all related to sustainability or environmental integration into the formal curricula, designed based on the characteristics of the vertical and horizontal approaches. The items related to the vertical approach are Item B1(1), B1(4), B(2) and B2(4) which ask if the subjects are specific on sustainability. The rest of the items are built upon the horizontal approach and ask if sustainability is incorporated into the existing subjects. An illustration of this categorization is shown in Figure 3.3. These items were decided based on the literature definitions and background information collected from the respective IHE. Each item in this Part is considered and discussed as a tactic in Chapter 4 Results and Discussion. Similar to Part A of the questionnaire, the 5-point Likert scale in this part was assigned scores accordingly with Likert scale 1 = 5 marks; 2= 4 marks; 3 = 3 marks; 4= 2 marks ; 5 =1 mark for analytical purpose. The total marks obtained from this part were averaged and the obtained marks were then interpreted and translated into the interest level according to the mark interpretation shown in Table 3.1 below.

Table 3.1: Marks Categorization of the Questionnaire

Average Score	Interpretation
1.0 -1.8	Very Low
1.9 – 2.6	Low
2.7 – 3.4	Moderate
3.5 – 4.2	High
4.3 – 5.0	Very High

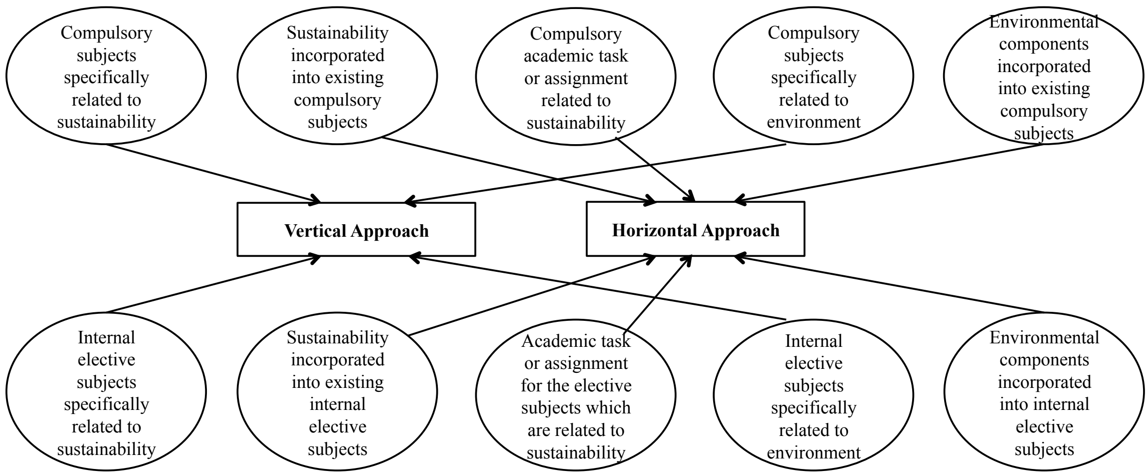


Figure 3.3: Categorization of Part B of the questionnaire

C) Part C of the questionnaire

Part C of the questionnaire contains a total of two items related to non-formal curricula or out-of-classroom activities on sustainability or environment. Each item in this Part was discussed as a tactic in Chapter 4. Part C aims at identifying which non-formal educational tactic was more relevant to sustainability education based on the students' experience or perception.

D) Part D of the Questionnaire

Part D of the questionnaire contains a total of eight items which are related to the informal curricula or extra-curricular activities organized by the university, faculty or department/ school. The items were decided based on the literature and background information collected from the respective IHEs. Each item in this Part was considered as a tactic in Chapter 4. Part C aims at identifying which informal curricula tactic was more relevant to sustainability education based on the students' experience or perception.

E) Part E of the questionnaire

Part E of the questionnaire contains a total of fourteen items focusing on whether the respondents are interested in sustainability related activities or willing to take part in the relevant activities voluntarily. One of the items (Item 12) in this Part prompts the respondents to choose the main factors that cause them to have lower interest level towards sustainability related activities. However, only respondents who answered 'No' to 'willing to take part in the activity voluntarily' (Item 11) needed to respond to Item 12. The respondents could choose from the list of predetermined factors identified based on the finding of literature review. There is also a free text comment column where the respondents could add the other factors other than the ones listed. Free text comment was allowed in hopes to obtain more data for future development of the questionnaire (Polgar & Thomas, 1995).

3.5.2 Sample Size

Since the population of the targeted final-engineering undergraduates was large, it was not possible to collect responses from one hundred percent of the population. Therefore, instead of a descriptive study, which involved one hundred percent of the target population, an inferential study, which involved random sampling from the population was conducted.

The minimum sampling size or number of responses that was collected from each engineering discipline was determined using the widely used sample size calculation formula shown below. The formula was introduced by Krejcie & Morgan (1970), who developed a well-known sample size reference table.

$$s = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)}$$

Where, s is the sample size, X^2 is the chi square value for 1 degree of freedom at the desired confidence level (3.841 at df=1 and 95% confidence level), *N* is the population size, *P* is the population proportion (assumed to be .50 as it would provide the maximum sample size) and *d* is the degree of accuracy expressed as a proportion (.05).

3.5.3 Pilot Study

A pilot study was conducted to test the reliability of the questionnaire. A pilot-test is used to pre-test the questionnaire to identify potential logistical issues (Baker, 1994; Simon, 2011) and make sure that the obtained information is consistent. The questionnaire was distributed to a group of final-year engineering undergraduates at an IHE which was not among the studied IHEs to avoid biased responses when the real study was conducted. All the respondents participating in the pilot study responded and the findings of the pilot study were reported in Chapter 4. The sample size for the pilot study was ten to twenty percent of the sample size needed for the actual study (Baker, 1994).

3.5.4 Reliability Analysis

The reliability of a questionnaire is important to make sure that the data collected from the questionnaire are valid. It ensures repeatability, internal consistency and stability of the questionnaire (Jack & Clarke, 1998). Cronbach's alpha reliability test was used in this research to test the reliability of the questionnaire. It is one of the most common tests used for reliability analysis (Berglund et al., 2014; Bowling, 1997)

The Cronbach's alpha reliability analysis of this questionnaire was conducted using the Cronbach's alpha reliability test function in the Statistical Package for Social Sciences (SPSS). A minimum Cronbach's alpha value of .65 is needed to prove that the reliability of the questionnaire is satisfactory (Chua, 2012). The preferred range of the Cronbach's alpha value is .65- .95. according to Chua (2012) but the limits depend on the underlying construct of the questionnaire (Field, 2013). A value smaller than .65 indicates that the items in the questionnaire are not able to evaluate the desired target while a value larger than .95 indicates that the items in the questionnaire are similar to each other and may be overlapping (Chua, 2012). The data collected from the pilot study was used for the reliability analysis.

3.6 Data Analyses

The collected data from the questionnaire were statically analyzed using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel. The Spearman rho's correlation function in the SPSS was used to correlate each tactic under the formal (Part B of the questionnaire), non-formal (Part C of the questionnaire) and informal curricula (Part D of the questionnaire) with the students' knowledge (Part A of the questionnaire) and students' interest level in sustainability (Part E of the questionnaire). The Multiple Response function in the SPSS was used to analyse Item 12 of Part E to identify the main factors contributing to low interest level towards sustainability related activities among the respondents. Microsoft Excel was used for simple analysis such as frequencies.

3.6.1 Correlation Analysis

Since the data collected from the questionnaire were ordinal and non-parametric, Spearman's rho correlation was used in this study (Chua, 2008). A Spearman's rho correlation coefficient *(r_s)* is constrained within $-1 \leq r_s \leq +1$. r_s of +1 indicates positive correlation while -1 indicates negative correlation. The closer the r_s value to .00, the weaker the correlation is (Chua, 2008). The strength of the correlation can be interpreted based on Table 3.2. The significance level (p-value, p) of the correlation was also evaluated and such value was generated automatically by SPSS along with the correlation coefficient. Generally, a p-value smaller than .05 indicates that the correlation is significant while a larger p-value indicates that there is no strong evidence for the correlation (Chua, 2008). Both the r_s and the significance level of a correlation between the studied variables were reported in Chapter 4.

Table 3.2: Strength of Correlation

Correlation coefficient (r_s) +ve or -ve	Correlation Strength
.91 – 1.00	Very strong
.71 - .91	Strong
.51 - .70	Average/ medium
.31 - .50	Weak
.01 - .30	Very Weak
.00	No correlation

Source: (Chua, 2008)

3.7 Engineering Discipline As A Research Context

Engineering profession started in the 19th century, with Civil Engineering as the first engineering branch (Jørgensen, 2007). Over the years, engineering education has transformed accordingly in order to cater for the developmental and societal needs. However, engineering education also suffers from 'devolution' during the transformation stages, with more emphasis being put on the technical aspects but negligence on the other critical aspects which concern safety, health and welfare (Galloway, 2007). It was once packed with sophisticated theoretical knowledge and only until recently it has refocused on practical knowledge, which is required by the employers nowadays (Jørgensen, 2007). Engineering education has been transformed from being business skills oriented in the 1930s, design skills oriented in the 1960s, information technology oriented in the 1980s and environmental knowledge oriented in the 2000s (Clarke, 2012; Rugarcia et al., 2000). Its transformation corresponds to the ever changing employers' needs (Miller, 2014) and therefore, many IHEs have modified their engineering curricula to stress environmental and social concern (El-Zein et al., 2008).

As pointed out by Galloway (2007), there should be cooperation between engineering educators and engineering practitioners so that the curriculum is always up-to-date and able to fulfill the current needs of a society. A review through the existing literature revealed that there is a collection of publications on engineering education but almost all of them discuss engineering education as a whole without being discipline specific. There are more publications related to the Chemical and Civil Engineering education compared to the other engineering disciplines.

Thus far, there has not been any clear indication on the difference in the education strategies for different engineering disciplines. Generally, the existing publications discuss problem-based or project-based learning as two pedagogical approaches for the engineering education (Mills & Treagust, 2003). Often, the research on these two pedagogical approaches for the engineering education is extended to sustainability education such as the research by Dobson & Tomkinson (2012), Huntzinger et al. (2007)

and Lehmann et al (2008). However, pedagogical approaches were not the focus of this study and thus they were not elaborated in detail in this research.

Although there is no distinguished difference among the four engineering disciplines in terms of their educational strategies, they can be differentiated by their expertise and potential contribution to sustainable development of the society.

3.7.1 Chemical Engineering

Chemical Engineering is about transformation of raw materials into end products in a safe and cost effective way (Institute of Chemical Engineers, 2015). It is involved in a wide range of industrial applications, including food, pharmaceutical, chemical, electronic manufacturing and etc. (Gillet, 2001). This engineering discipline contains the general engineering subjects but is usually with more courses on advanced chemistry in its curricula compared to the other engineering disciplines (Prados et al., 2005). As Chemical Engineering is directly involved in industrial processes, it is crucial that chemical engineers are well equipped with the sustainability knowledge so that this part of knowledge may be blended into the design of industrial processes to minimize the impacts of these industrial applications on the society and environment. In fact, this engineering discipline has addressed the needs for sustainable development through its educational system since as early as 1990 (von Blottnitz et al., 2015).

3.7.2 Civil Engineering

Civil Engineering is involved in the design and building of facilities such as bridges, roads, tunnels, buildings, train stations and etc. (ICE, 2015). It can be branched out into different majors including coastal, earthquake, environmental, structural, transport, urban and water resources engineering (ICE, 2015), which are all relevant to the continuous development of a country. They have a direct relation to the use of natural resources for the benefits of the society and it is therefore, essential to incorporate the sustainability concept into the Civil Engineering education and practice (Chau, 2007). Civil engineers make sure that our beaches are protected from erosion, buildings can withstand earthquakes, wastes are properly treated, building structures are safe, the transport system is efficient, urban amenities are safe, water resources distribution system is sufficient etc. (ICE, 2014). Therefore, their decisions on the respective engineering designs may directly determine if a nation is progressing towards sustainable development. Lambropoulos et al. (2014) suggested elements such as leadership behavior, management and environment etc. should be added into the Civil Engineering curricula so that the future civil engineers may address the needs of the current society and employer. The element-'environment' should be noted here as it indirectly highlights the roles played by civil engineers in supporting sustainable development.

3.7.3 Mechanical Engineering

Mechanical Engineering is about developing mechanical systems utilizing the knowledge on force, energy and motion (ASME, 2015). Mechanical engineers design equipment and machineries such as sports equipment, medical devices, engines, computers and manufacturing machines that produce these equipment (ASME, 2015). It is most likely if an item moves or utilizes energy, mechanical engineers are involved in the design and production of the product (ASME, 2015). In fact, a significant coverage of the mechanical and thermal systems is usually found in the Mechanical Engineering curricula (Prados et al., 2005). The additional knowledge in the mechanical and thermal systems make sure that mechanical engineers readily contribute to aerospace, biotechnology, robotic, construction, electronic and other industries where machineries aid are needed. Their contribution to sustainable development lie within their capability to blend in the sustainability knowledge, into the design of machineries.

3.7.4 Electrical Engineering

Electrical Engineering deals with the technology of electricity and the contribution of Electrical Engineering can be seen in power generation, power transmission, batteries, control system, telecommunication, remote sensing, electrical circuits, digital devices and others (Bureau of Labour Statistics, 2015; Lucas, 2014). As observed, their design and engineering solutions are always related to electricity consumption and therefore, electrical engineers have significant contribution to sustainable development by making sure that the electrical and electronic devices that they design are energy and resource efficient.

3.7.5 Summary

Based on the collected information, it is obvious that each engineering discipline plays its own roles on the pathway towards sustainable development. Engineers definitely have the choice on whether they just want to deliver profit-centric engineering solutions or solutions that strive to achieve a balance between the socio-economic development and environmental conservation. As noted by ASME (2015), engineers are involved in the design and production of almost everything we see and use daily. Therefore, it is essential to address sustainability knowledge in the engineering education so that the engineers may better relate themselves to the environmental well-being and contribute to global sustainable development (Goldma et al., 2013; Köhler et al., 2013).

CHAPTER 4: RESULTS AND DISCUSSION

The analytical results of the engineering curricula, pilot study, statistical analyses of the collected data from the questionnaire and the main findings of this research are discussed in detail in the following subsections.

4.1 General Analysis of the Engineering Curricula

Syllabi of the studied engineering disciplines from the selected IHE were collected and analysed to identify sustainability related courses. The following sub-sections discussed the results in detail. As explained earlier in Chapter 3, only compulsory subjects were taken into account for the calculation of sustainability integration percentage into the engineering curricula. The colored values in Table 4.1, 4.2, 4.3 and 4.4 were the information used to compute the integration percentage by using the formula shown in Chapter 3. However, the total number of sustainability related subjects available for each engineering discipline was inclusive of both compulsory and elective courses to give an insight on the emphasis placed on the sustainability education by each engineering discipline.

4.1.1 Chemical Engineering

Based on the analyses, it was found that on average, nine point nine percent of the compulsory subjects of Chemical Engineering were infused with sustainability components, as shown in Table 4.1. Please refer to Appendix C for the list of the sustainability related subjects.

On average, there were eight sustainability related subjects, inclusive of both compulsory and elective subjects, which were available in the Chemical Engineering curricula. Out of them, thirteen percent were stand-alone subjects (the vertical approach) while the remaining were subjects within which sustainability was integrated (the horizontal approach), as shown in Figure 4.1.

This finding showed that the horizontal approach was the main approach used to integrate sustainability into the Chemical Engineering curricula and apart from the core subjects, electives were also used as a means of delivering sustainability education. Intertwining sustainability components into the elective subjects can be seen as an alternative aiming at minimizing the disruption on the existing curricula which is already packed with traditional engineering knowledge (Jørgensen, 2007) and since electives are normally subjects derived from research, sustainability components may be more effectively delivered through the elective subjects (Gillett, 2001; Lozano, 2006; Second Nature, 2011). Besides, since Chemical Engineering is involved in a wide range of industrial processes (Gillett, 2001), horizontal approach may be preferred as it fits into the interdisciplinary learning characteristics of Chemical Engineering.

Table 4.1: Sustainability related subjects (Chemical Engineering)

IHE	No. of Programme Subjects			No. of Sustainability Related Subjects				Integration % (comp. subjects only)
	Comp.	Elec.	**Total**	Hor.	Ver.	**Total**	***Remarks***	
A	52	4	56	6 *(4 elec.)*	1	7	*3 comp.* *4 elec.*	5.8
B	51	2	53	8 *(1 elec.)*	1	9	*8 comp.* *1 elec.*	15.7
C	47	4	51	6 *(4 elec.)*	0	6	*2 comp.* *4 elec.*	4.3
D	39	4	43	9 *(3 elec.)*	2 *(1 elec.)*	11	*7 comp.* *4 elec.*	18
E	52	4	56	7 *(4 elec.)*	1 *(1 elec.)*	8	*3 comp.* *5 elec.*	5.8
Average				7	1	8	*5 elec.* *3 elec.*	9.9

Legend - Comp.: Compulsory; Elec.: Elective; Hor.: Horizontal; Ver.: Vertical

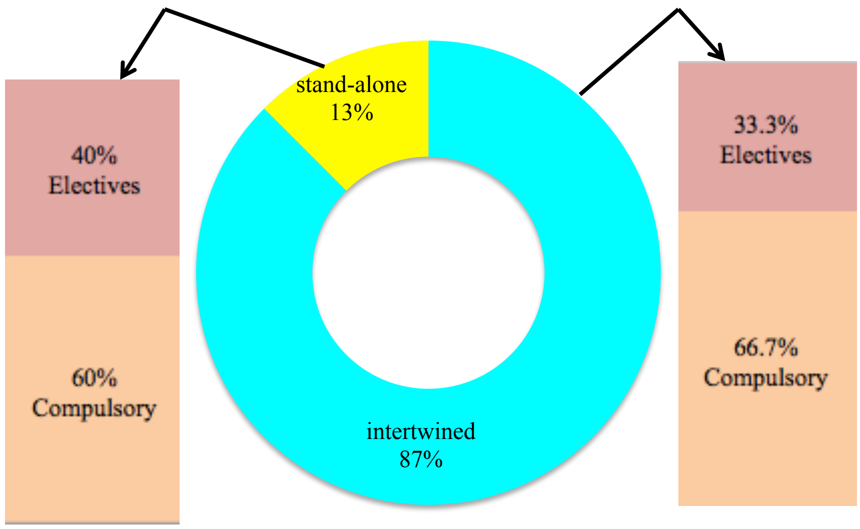


Figure 4.1: Categorization of sustainability related subjects (Chemical Engineering)

4.1.2 Civil Engineering

Based on the analyses, it was found that on average, nineteen point one percent of the compulsory subjects of Civil Engineering were infused with sustainability knowledge, as shown in Table 4.2. Please refer to Appendix D for the list of the sustainability related courses.

On average, there were thirteen sustainability related subjects, inclusive of both compulsory and elective subjects, which were available in the Civil Engineering curricular structure. Out of them, eight percent were stand-alone subjects (the vertical approach) on sustainability while the remaining were subjects within which sustainability knowledge was integrated (the horizontal approach), as shown in Figure 4.2.

This result showed that the horizontal approach was the main approach used to embed sustainability into the Civil Engineering curricula. Civil Engineering is closely relevant to infrastructure development such as water resources planning, transport system, irrigation and energy supply (ICE, 2014), which equally highlights the needs for interdisciplinary approach for sustainability education. It may explain why the horizontal approach that supports interdisciplinary learning (Cuelemans & de Prins, 2010) was preferred as a sustainability integration strategy in Civil Engineering. Similar to Chemical Engineering, elective subjects were used as a means to deliver sustainability education and it is believed that this strategy is a solution to minimize disruption in the existing curricula.

Table 4.2: Sustainability related subjects (Civil Engineering)

IHE	**Programme Subjects**			**Sustainability Related Subjects**				**Integra-tion % (comp. subjects only**
	Comp.	Elec.	**Total**	Hor.	Ver.	**Total**	***Remarks***	
A	52	2	54	7 *(4 elec.)*	2 (*1 elec.)*	9	*4 comp.* *5 elec.*	7.7
B	51	4	55	3 *(1 elec.)*	2 (*1 elec.)*	5	*3 comp.* *2 elec.*	5.9
C	47	4	51	13 *(2 elec.)*	1	14	*12 comp.* *2 elec*	25.5
D	39	3	42	24 *(6 elec.)*	1 (*1 elec.)*	25	*18 comp.* *7 elec*	48.7
E	52	3	55	13 *(10 elec.)*	1	14	*4 comp.* *10 elec*	7.7
Average				12	1	13	*8 comp.* *5 elec*	19.1

Legend - Comp.: Compulsory; Elec.: Elective; Hor.: Horizontal; Ver.: Vertical

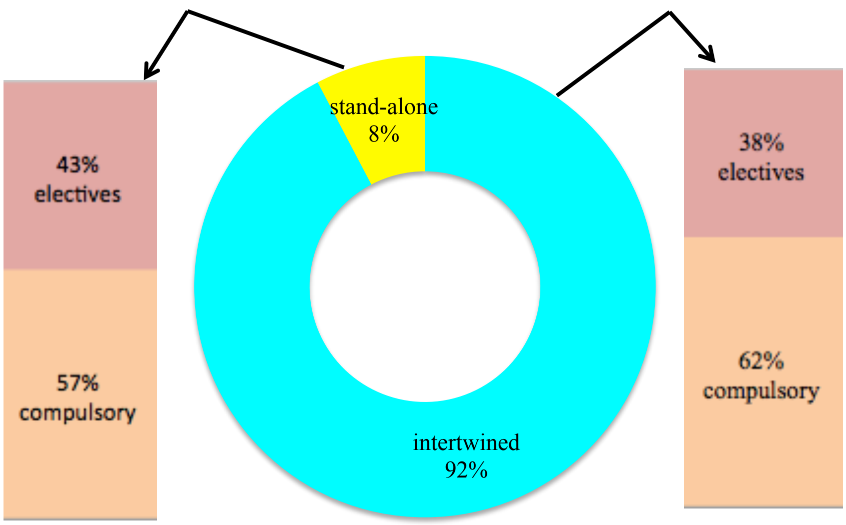


Figure 4.2: Categorization of sustainability related subjects (Civil Engineering)

4.1.3 Mechanical Engineering

Based on the analyses, it was found that on average, only four point nine percent of the compulsory subjects of Mechanical Engineering were infused with the sustainability knowledge, as shown in Table 4.3. It should be noted that the relevant subject outlines from IHE D were not analysed as the Head of the School of Mechanical Engineering of IHE D had refused to participate in this part of the study. The list of the sustainability related subjects from the rest of the IHEs is appended in Appendix E.

The analyses showed that the horizontal approach was the only approach engaged by Mechanical Engineering to deliver the sustainability education, as shown in Figure 4.3. This engineering discipline also did not use elective subjects to deliver sustainability knowledge. The preference of the horizontal approach over the vertical approach in this case can be explained by the interdisciplinary characteristic of the horizontal approach, which is recommended by some of the researchers for the sustainability education (Rydhagen & Dackman, 2011). However, there is no well explanation for the lack-of-use of electives in this case since this piece of information is not well established in the existing literature. Nevertheless, Galloway (2007)'s suggestion that sustainability components such as culture and diversity should be made the core engineering content may appear relevant for this case. Mechanical Engineering's involvement in motion, energy and force utilization may have made sustainability integration into core subjects necessary. Besides, its core subjects that were already oriented around efficient use of force, energy and motion may readily serve as the right platform for sustainability integration. In this case, electives that are often derived from research to address additional and advanced knowledge of a relevant subject matter may not be necessary for Mechanical Engineering.

Table 4.3: Sustainability related courses (Mechanical Engineering)

IHE	Programme Subjects			Sustainability Related Subjects				Integra-tion % (comp. subjects only
	Comp.	Elec.	**Total**	Hor.	Ver.	**Total**	***Remarks***	
A	50	4	54	1	0	1	*1 comp.* *0 elec.*	1.9
B	44	5	49	5	1 *(1 elec.)*	6	*5 comp.* *1 elec.*	11.4
C	42	5	47	2	0	2	*2 comp.* *0 elec*	4.3
D				**N/A**				
E	50	3	53	1	0	1	*1 comp.* *0 elec*	1.9
Average				2	0	2	*2 comp.* *0 elec*	4.9

Legend - Comp.: Compulsory; Elec.: Elective; Hor.: Horizontal; Ver.: Vertical

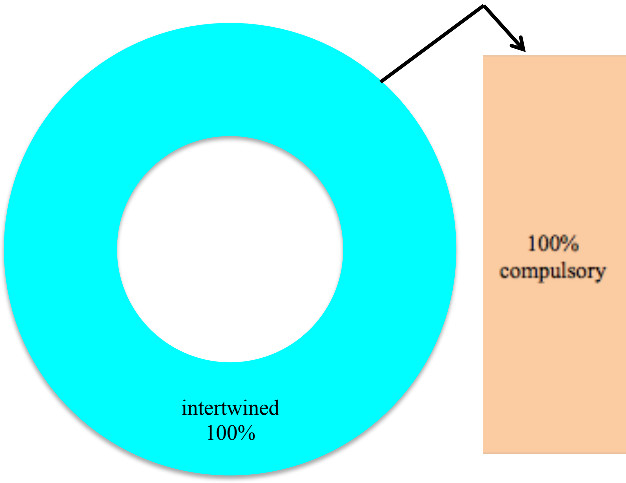


Figure 4.3: Categorization of sustainability related subjects (Mechanical Engineering)

4.1.4 Electrical Engineering

Based on the analyses, it was found that on average, eight point six percent of the compulsory subjects of Electrical Engineering were infused with the sustainability knowledge, as shown in Table 4.4. The list of the sustainability related subjects is appended in Appendix F.

It was also found that the horizontal approach was the only approach engaged by Electrical Engineering to deliver sustainability education, as shown in Figure 4.4. This engineering discipline also did not use elective subjects to deliver sustainability knowledge. Again, the preference of the horizontal approach over the vertical approach can be explained by the interdisciplinary characteristics of the horizontal approach. Similar to the case of Mechanical Engineering, Galloway's (2007) suggestion that has been explained earlier may be used to explain this case. Furthermore, as mentioned in Chapter 3, Electrical Engineering is always related to engineering designs that involve electrical and energy consumption and thus the core subjects are already oriented around efficient use of energy and they readily serve as a right platform for sustainability integration. Therefore, electives are not necessarily a means to deliver sustainability knowledge in Electrical Engineering.

Table 4.4: Sustainability related courses (Electrical Engineering)

IHE	**Programme Subjects**			**Sustainability Related Subjects**				**Intergra -tion % (comp. subjects only**
	Comp.	Elec.	**Total**	Hor.	Ver.	**Total**	***Remarks***	
A	52	4	53	1	0	1	*1 comp. 0 elec.*	1.9
B	51	3	50	2	0	2	*2 comp. 0 elec.*	4
C	47	4	47	2	0	2	*2 comp. 0 elec.*	4.3
D	39	3	42	13	0	13	*13 comp. 0 elec.*	31
E	52	2	49	1	0	1	*1 comp. 0 elec.*	2
Average				4	0	4	*4 comp. 0 elec.*	8.6

Legend - Comp.: Compulsory; Elec.: Elective; Hor.: Horizontal; Ver.: Vertical

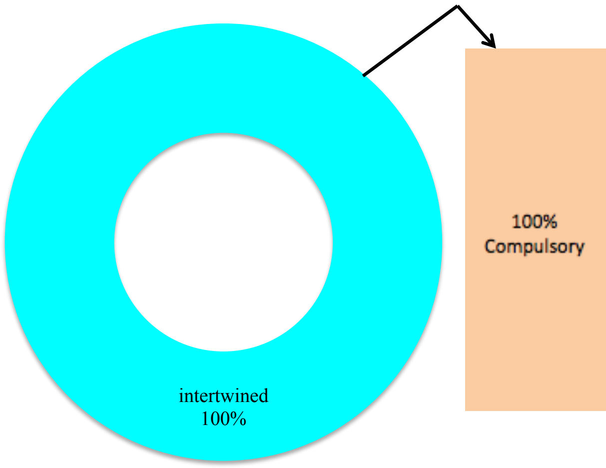


Figure 4.4: Categorization of sustainability related subjects (Electrical Engineering)

4.1.5 Summary of Analyses of the Engineering Curricula

Based on the above analyses, it was found that Civil Engineering had the highest sustainability integration percentage into its curricula. It also had the highest number of sustainability subjects within which sustainability knowledge was intertwined (the horizontal approach). It was also found that, generally, sustainability-intertwined subjects (the horizontal approach) was preferred in all the studied engineering diciplines, as shown in Figure 4.5.

The reason sustainability integration percentage was the highest in Civil Engineering may be attributed to that fact it is the oldest engineering profession which has direct involvement in the infrastructure development for the country (Jørgensen, 2007). Since the impact of infrastuctural construction on the socio-economy and environment is direct and obvious (Tardieu et al. 2015), Civil Engineering educators may have an early realization on the needs for sustainable development. Besides, most of the subjects for Civil Engineering are directly related to environment, such as the water systems, construction methods etc., which may make integration percentage of sustainability components in this engineering discipline higher in nature compared to the other engineering disciplines.

The preference of the horizontal approach over the vertical approach can be due to its interdisciplinary characteristic which is prefered for the sustainability education, as suggested by some reserchers such as Cuelemans & de Prins (2010). The horizontal approach for sustainability integration is not new as it has been used by some IHEs such as the University of Bath and Delft University of Technology, as discussed earlier.

On the other hand, the sustainability integration percentage into chemical and Mechanical Engineering was lower compared to Civil Engineering as these two engineering disciplines contained less subjects which can closely be related to the environment. The Chemical Engineering is more chemical sciences oriented while the Mechanical Engineering is more machineries oriented.

In short, it can be concluded that the horizontal approach was the main sustainability integration approach used for the respective engineering disciplines in Malaysia and Civil Engineering had the highest sustainability integration percentage into its curricula compared to the other engineering disciplines. Besides, apart from the core subjects, electives were used by both chemical and Civil Engineering as a means to deliver sustainability knowledge. The information obtained from the curricular analyses showed the current integration strategy used by the IHEs and the information may be used to further explain the other findings of this study.

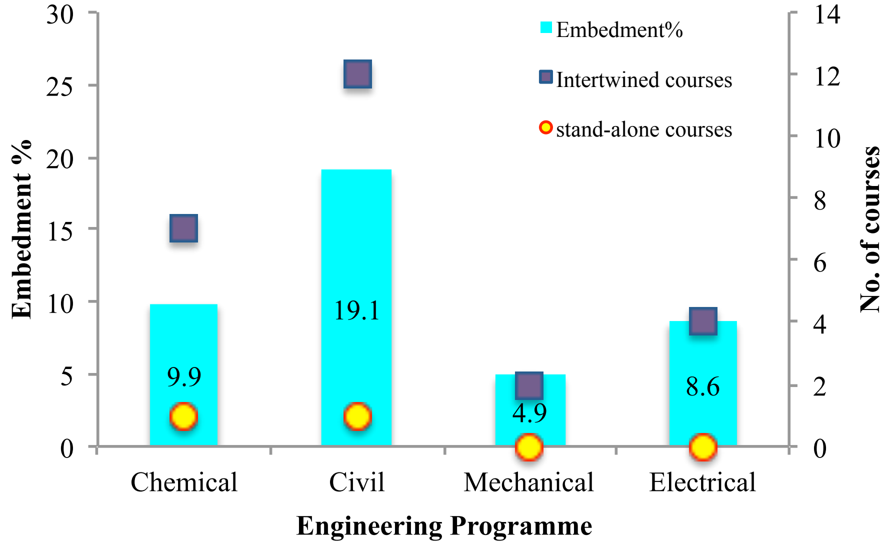


Figure 4.5: Percentage of sustainability related subjects for each engineering discipline

4.2 Analyses of the Questionnaire

The questionnaire was a data collection tool in this study to collect information on students' knowledge on sustainability. The following subsections discussed the results of the questionnaire analyses in detail.

4.2.1 Pilot Study

A pilot study was conducted to analyse the reliability of the questionnaire. The pilot study was conducted in an IHE other than the targeted IHE in this study to avoid biased response when the study was conducted. The following subsections discussed the results of the pilot study in detail.

4.2.1.1 Reliability Test

Cronbach's alpha test was used to determine the reliability of the questionnaire. A total of seventy questionnaires were distributed for the pilot test. This met the minimum sample size suggested by Baker (1994) that a sample size of ten to twenty percent of the sample size for actual study is sufficient for the pilot study. Based on the sample size calculation suggested by Krejcie & Morgan (1970), the suggested minimum sample size for the actual study was six hundred and seventy three. Therefore, a pilot-study sample size of seventy, which is more than ten percent of the suggested minimum actual study sample size is sufficient. All of the seventy questionnaires were completed and returned by the respondents. It was found that the Cronbach's alpha reliability coefficient for all Sections was more than .65, which was satisfactory (Chua, 2012). The Cronbach's alpha value for each of the sections of the questionnaire is summarised below.

Section A: Knowledge on Sustainability/ Sustainable Development

All seventy respondents filled up Section A. There are seven questions (known as items in statistical studies) in Section A targeting at measuring student's knowledge level towards sustainability or sustainable development. Based on the analysis, the Cronbach's Alpha reliability coefficient for Section A was .963, well above the minimum reliability requirement of .65. The Cronbach's Alpha value for this section was slightly high because there were many items in this section which were used to measure the same theme with all of them posing similar meanings based on the underlying elements of sustainability (Berglund et al., 2014; Field, 2013). All the seven items were kept in the questionnaire since the reliability coefficient was sufficient. The Cronbach's Alpha reliability coefficient for all the seven items in Section A is appended in Appendix G.

Section B: Integration of Sustainability into the Formal-Curricula (compulsory subjects)

There were ninety one point four percent of the respondents who filled up Section B. There are ten items in Section B targeting at measuring Sustainability integration into the compulsory subjects in the formal curricula. Based on the analyses, the Cronbach's alpha reliability coefficient for this section was .935, well above the minimum requirement of .65. Therefore, all of the items were considered reliable and all the ten items were maintained in the questionnaire. The Cronbach's alpha reliability coefficient for all the ten items is appended in Appendix H.

Section C: Integration of Sustainability into the Non-formal Curricula

All of the respondents filled up Section C. There are two items in Section C targeting at measuring sustainability integration into non-formal curricula. Based on the analysis, the Cronbach's alpha reliability coefficient for this section was .872, well above the minimum requirement for reliability of .65. Therefore, all of the items were considered reliable and the two items were maintained in the questionnaire. Please refer to Appendix I for the Cronbach's alpha reliability coefficient for all the items.

Section D: Integration into Informal Curricula

There were ninety two point nine percent of the respondents who filled up Section D. There are eight items in Section D targeting at measuring sustainability integration into informal curricula. Based on the analysis, the Cronbach's alpha reliability coefficient for this section was .949, well above the minimum requirement for reliability coefficient of .65. Therefore, all of the items were considered reliable and thus the questionnaire used contained all the eight items then. The Cronbach's alpha reliability coefficient for all items is appended in Appendix J.

Section E: Interests towards sustainability

There were ninety one point four percent of the respondents who filled up Section E. There are fourteen items in Section E targeting at measuring the interests level towards

Sustainability. It should be noted that Item 12 was excluded from the analysis as it is a multiple-response and non-compulsory question. The respondents have the option to answer Item 12 if the answer for Item 11 is negative. Based on the analysis, the Cronbach's alpha reliability coefficient for this section was .951, well above the minimum requirement for reliability coefficient of .65. Therefore, all of the items are deemed reliable and thus the questionnaire used contained all the fourteen items then. The Cronbach's alpha reliability coefficient for all the items is appended in Appendix K.

4.2.2 Sample Size

The suggested sample size calculated based on the sample size calculation formula proposed by Krejcie & Morgan (1970) and the actual sample size are shown in Table 4.5. It was found that the actual sample size for all the targeted engineering disciplines exceeded the minimum suggested size, and thus the sample size was considered sufficient and representative of the population.

Table 4.5: Sample Size

Engineering Disciplines	Suggested Sample Size	Actual Sample Size
Chemical	151	173
Civil	174	270
Mechanical	172	204
Electrical	176	224

4.3 The Students' Current Knowledge and Interest Level in Sustainability

The current students' knowledge and interest level in sustainability was evaluated in this study based on the students' response in Section A (Student's knowledge on sustainability) and Section E (student's interest level towards sustainability) of the questionnaire. The 'Frequency' function in the SPSS was used for this analysis.

4.3.1 Chemical Engineering

Figure 4.6 shows that forty six percent of the final-year Chemical Engineering students had a high knowledge level in sustainability. Only an insignificant percentage or two percent of the students had very low sustainability literacy.

The analysis also showed that majority or fifty five percent of the students had high interest level towards sustainability related knowledge. Only one percent from the respondents had very low interest level for sustainability related knowledge, as shown in Figure 4.7.

Figure 4.8 shows that the mean score for the knowledge level and interest level was three point eight three and three point eight seven respectively, which suggested that the Chemical Engineering students, on average, had a high knowledge and interest level towards sustainability. It reflected that sustainability education in the Chemical Engineering discipline was fairly successful. The result may be attributed to high integration percentage of the sustainability elements into the formal curricula of this engineering discipline, as shown in Table 4.1. Besides, the core element in Chemical Engineering - ‘optimised industrial process’ may have also promoted sustainability education as it encapsulates sustainability in a way (Gillet, 2001). The use of electives, through which sustainability knowledge can be sufficiently delivered (Second Nature, 2011) may have also contributed to high level of knowledge and interest on sustainability among the Chemical Engineering students. Therefore, it is not surprising that the Chemical Engineering students had high knowledge and interested level in sustainability. The detailed information of this part can be found in Appendix L.

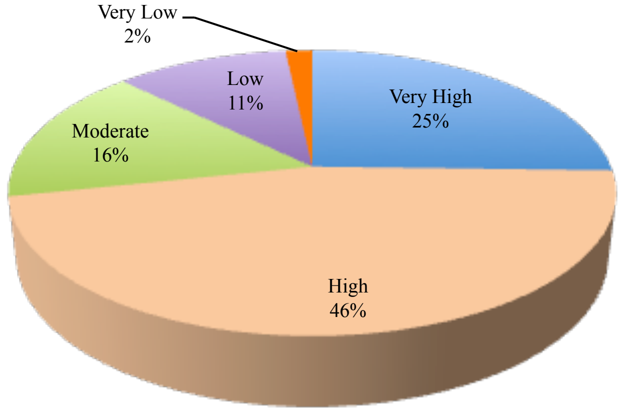


Figure 4.6: The knowledge level in sustainability (Chemical Engineering students)

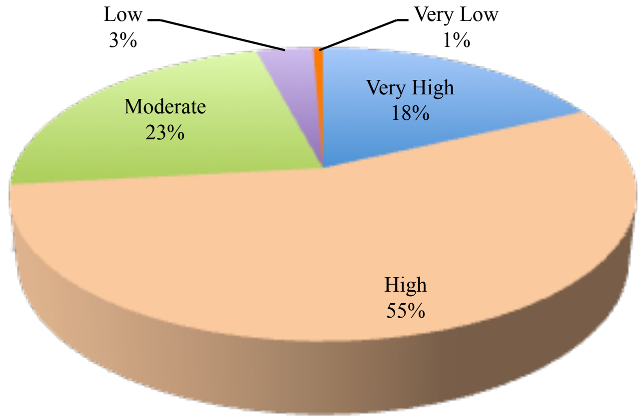


Figure 4.7: The interest level in sustainability (Chemical Engineering students)

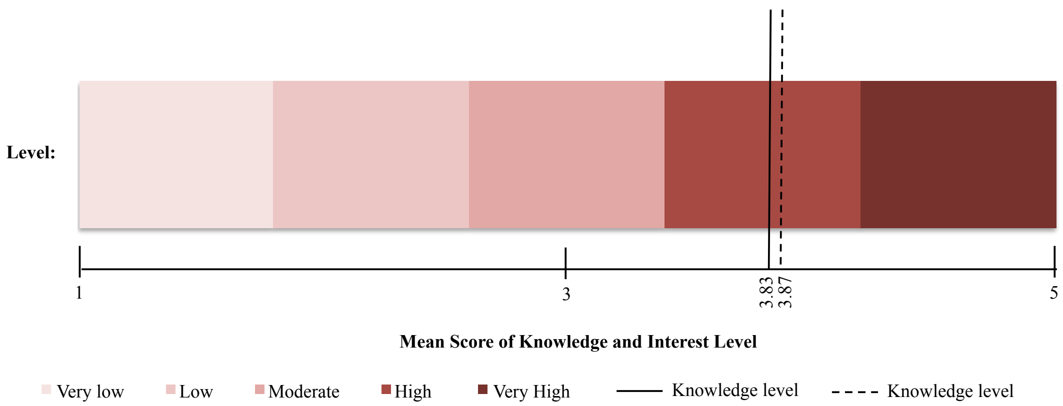


Figure 4.8: Mean score for the knowledge and interest level in sustainability (Chemical Engineering students)

4.3.2 Civil Engineering

Based on Figure 4.9, it was found that forty nine percent of the final-year Civil Engineering students had a high knowledge level. Only a very small percentage or three percent of the respondents had very low sustainability literacy.

Figure 4.10 presents that majority or fifty five percent of the students had high interest level towards sustainability related activities. Only one or zero point four percent from the respondents had very low interest level in sustainability related activities.

Figure 4.11 shows that the mean score for the knowledge level and interest level was four point zero four and four point zero nine respectively, which suggested that the Civil Engineering students, on average, had high knowledge and interest level towards sustainability, which indicated that the current sustainability education in the Civil Engineering discipline was good. The transformation history of this oldest engineering discipline has led to certain maturity in the sustainability education for Civil Engineering. Besides, as discussed earlier, direct involvement of Civil Engineering in the infrastructure construction, which are closely related to national development has naturally led to high integration of sustainability knowledge into this discipline, which may have contributed to high knowledge and interest level among the Civil Engineering students. The detailed information of this part can be found in Appendix M.

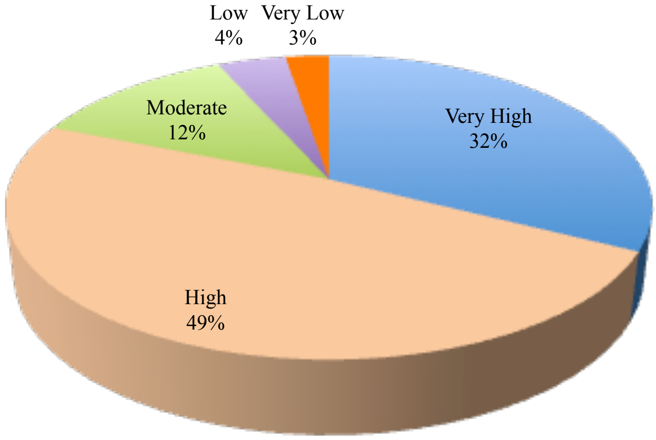


Figure 4.9: The knowledge level in sustainability (Civil Engineering students)

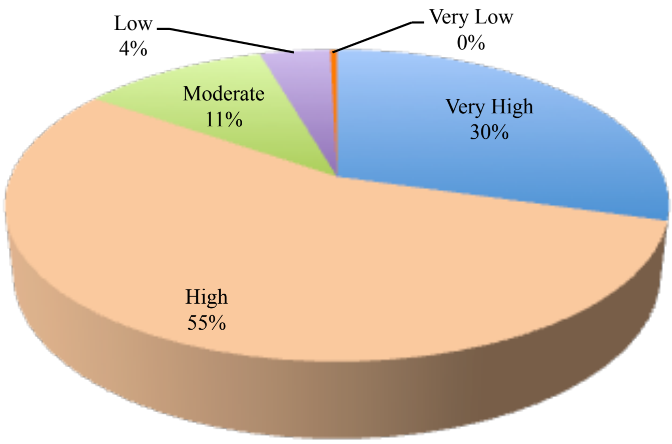


Figure 4.10: The interest level in sustainability (Civil Engineering students)

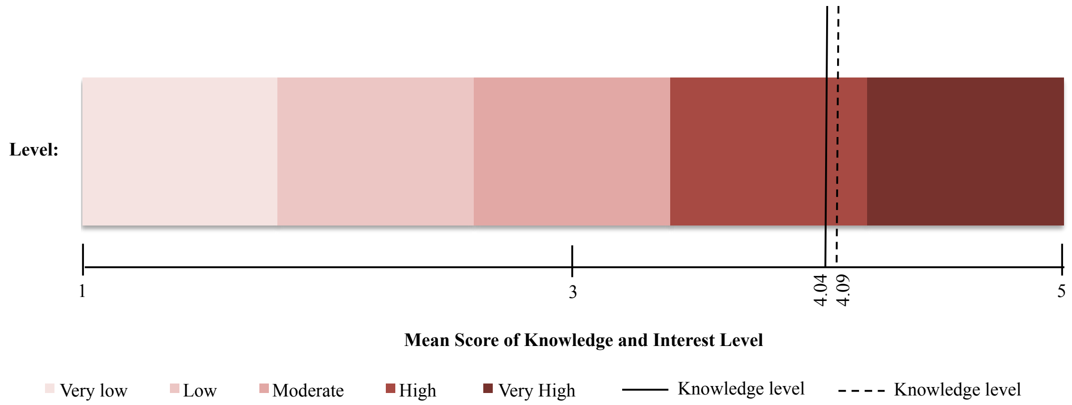


Figure 4.11: Mean score for the knowledge and interest level in sustainability (Civil Engineering students)

4.3.3 Mechanical Engineering

Figure 4.12 shows that forty four percent of the final-year Mechanical Engineering students had a high knowledge level in sustainability. Only a very small percentage or three percent of the respondents had very low sustainability literacy.

It was also observed that majority or fifty one percent of the students had high interest level towards sustainability related activities. There was no student who had very low interest level in sustainability related activities. Only one or seven percent from the respondents had a low interest level in sustainability related activities, as shown in Figure 4.13.

The mean score for knowledge level and interest level was three point six six and three point seven nine respectively, which suggested that the Mechanical Engineering students, generally had a moderately high knowledge and interest level in sustainability. The result is illustrated in Figure 4.14. The finding reflects that the current sustainability education for the Mechanical Engineering students may be effective in cultivating knowledge and interest on sustainability. The needs for understanding efficient thermal and mechanical systems, which are required for the Mechanical Engineering education (Prados et al., 2005) are believed to have unknowingly cultivated a higher knowledge and interest level in sustainability among the Mechanical Engineering students.

As shown earlier in Table 4.3, although the sustainability integration percentage into the Mechanical Engineering curricula was lower compared to those in Chemical and Civil Engineering. The sustainability components were mainly integrated into the compulsory subjects in Mechanical Engineering, a strategy that makes sure that every student is exposed to the sustainability component. Apart from that, the recent industrial emphasis on green manufacturing and renewable energy designs as suggested by many researchers (Dincer, 2000;Sezen & Çankaya, 2013) may have increased the sustainability components in the current Mechanical Engineering curricula, leading to higher sustainability knowledge among the students. This finding, which showed moderately high knowledge and interest level among the Mechanical Engineering students supported the suggestion by Cuelemans & de Prins (2010) and Galloway (2007) that sustainability education is best delivered through the the horizontal approach and core subjects.

The detailed information of this part is appended in Appendix N.

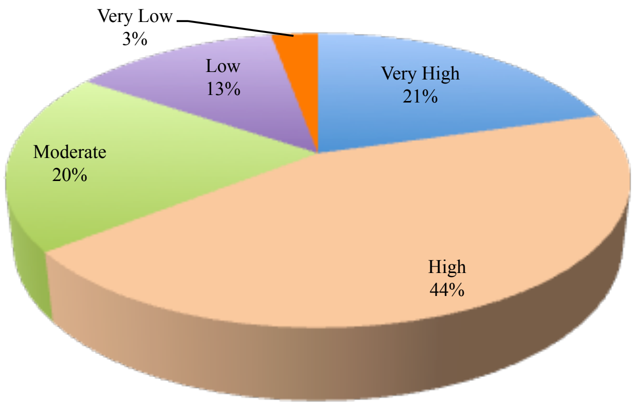


Figure 4.12: The knowledge level in sustainability (Mechanical Engineering students)

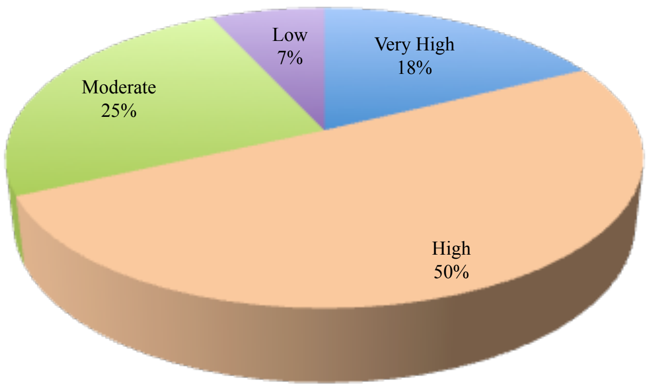


Figure 4.13: The interest level in sustainability (Mechanical Engineering students)

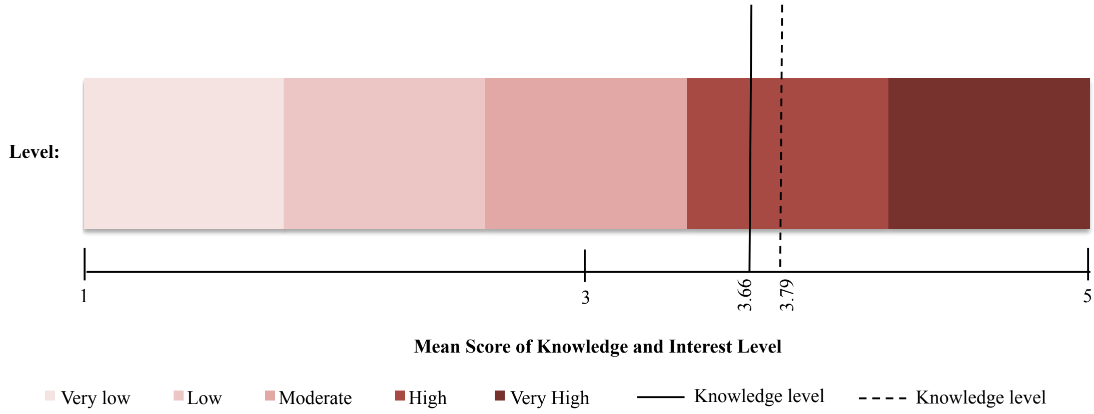


Figure 4.14: Mean score for the knowledge and interest level in sustainability (Mechanical Engineering students)

4.3.4 Electrical Engineering

The analyses showed that forty eight percent of the final-year Electrical Engineering students had a high knowledge level in sustainability. Only a very small percentage or one percent of the respondents had very low sustainability literacy. The result is illustrated in Figure 4.15 to facilitate comparison.

It was observed that majority or fifty seven point one percent of the students had high interest level towards sustainability related activities. None of the respondents had very low interest level in sustainability and only one percent of the respondents had a low interest level in sustainability related activities, as illustrated in Figure 4.16.

The analyses showed that the mean score for knowledge level and interest level was three point five eight and three point nine two respectively, as shown in Figure 4.17. The results showed that the Electrical Engineering students generally had moderately high knowledge and interest level in sustainability.

As shown earlier in Table 4.4, Electrical Engineering, similar to Mechanical Engineering, only integrated sustainability components into the existing compulsory subjects, which boasts both the interdisciplinary learning characteristics highlighted by the horizontal approach and compulsory learning. Cuelemans & de Prins (2010)'s statement that the horizontal approach can lead to more efficient learning of sustainability education can be used to explain this finding.

The detailed information of this part is appended in Appendix O.

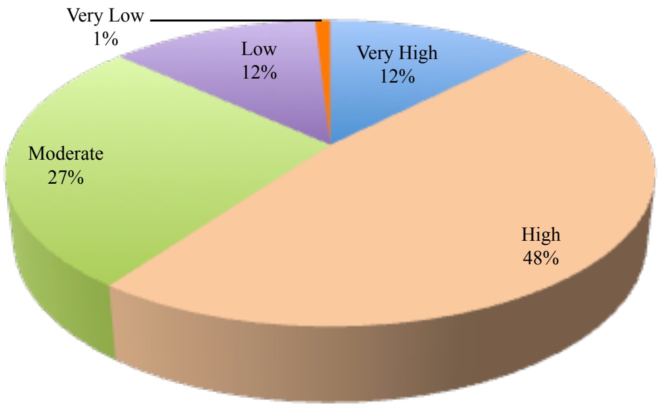


Figure 4.15: The knowledge level in sustainability (Electrical Engineering students)

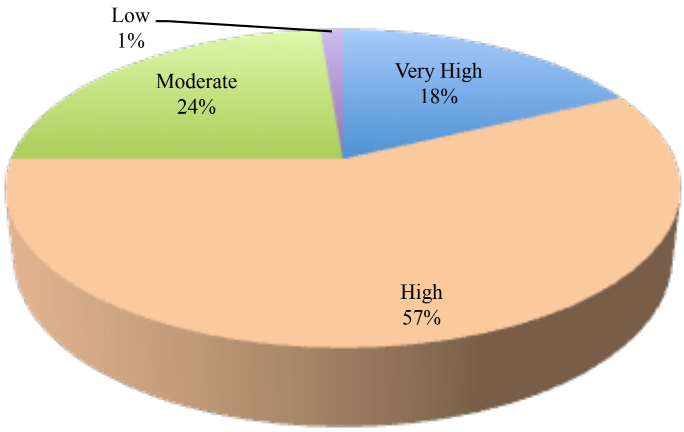


Figure 4.16: The interest level in sustainability (Electrical Engineering students)

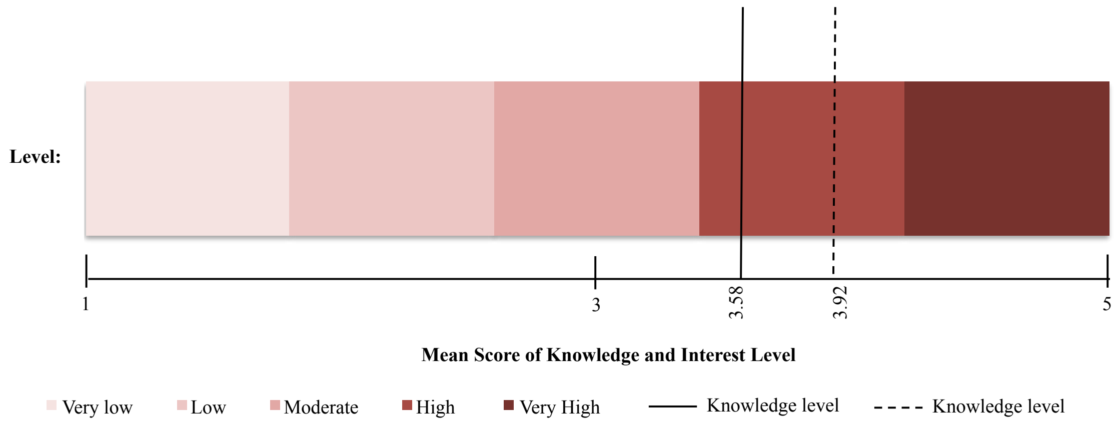


Figure 4.17: Mean score for the knowledge and interest level in sustainability (Electrical Engineering students)

4.3.5 Summary of the Knowledge and Interest Level in Sustainability Among the Engineering Students

It was observed that the average mean score for the knowledge and interest level in sustainability among the Malaysian engineering students from the four engineering disciplines was between three to four, which indicated moderately high to high level of knowledge and interest level in sustainability.

A comparison on the knowledge level and interest level in sustainability among the four disciplines gives the following trend, in a descending order. The comparison is also illustrated in Figure 4.18.

(A) Knowledge level : Civil > Chemical > Mechanical > Electrical

(B) Interest level : Civil > Electrical > Chemical > Mechanical

It should be noted that the trends are not the same between the two. Although the Electrical Engineering students had the lowest knowledge level in sustainability, they had a higher interest level in sustainability compared to the Chemical and Mechanical Engineering students. This may be attributed to a variety of factors such as the delivery style of instructors, availability of other learning strategies such as informal and non-formal learning (Cap, 2007; Warburton, 2003; Wójcik, 2004) that can affect the interest level among students. However, the contributing factors can be complex, with one factor affecting another. The literature has revealed some of the factors that may reduce students' interest towards sustainability, as discussed earlier in Chapter 2. Section E in the questionnaire may help identify the factors that had the highest influence on the students' interest towards sustainability and Section E are discussed in detail in another section of this Chapter.

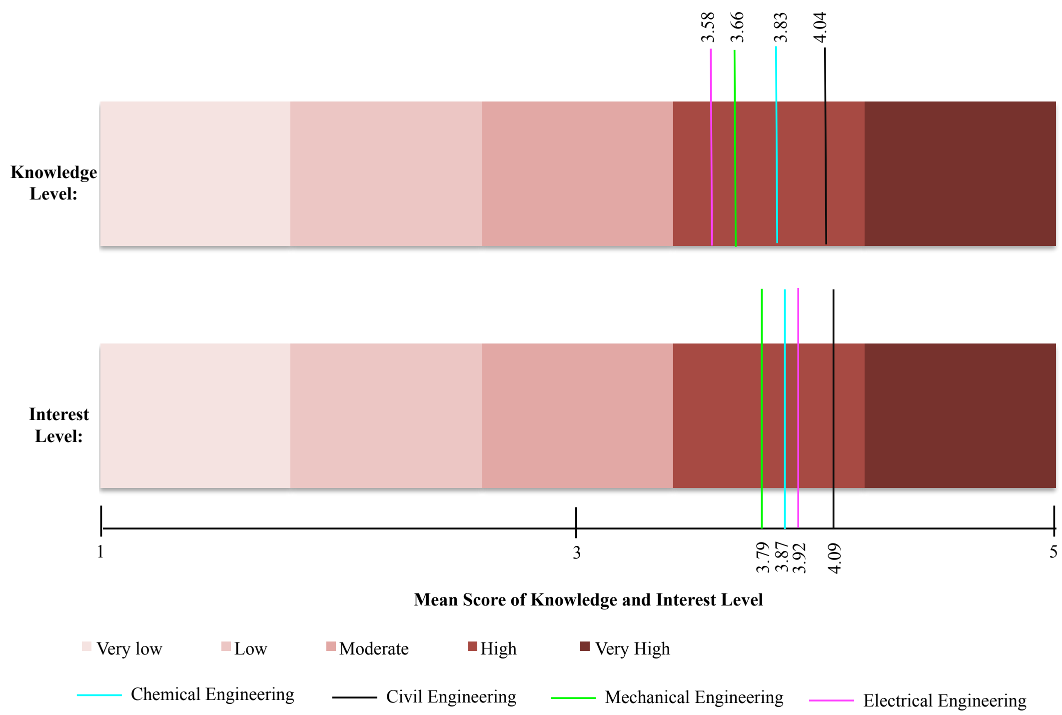


Figure 4.18: Comparison of the knowledge and interest level in sustainability among the engineering disciplines

By comparing Figure 4.5 (pg. 103) which shows the number of sustainability related subjects for each engineering discipline to the result of this Section, it was found that apart from Civil Engineering, the level of sustainability integration in the other engineering disciplines did not seem to directly affect the knowledge and interest level of the students of the respective discipline. The level of sustainability integration into the engineering curricula in a descending order, according to Figure 4.5, is as below:

(C) Level of sustainability integration : Civil > Chemical > Electrical > Mechanical

The differences between the trends of the knowledge and interest level (A and B) show that there is opportunity to further strengthen students' knowledge and interest on sustainability, especially for chemical, mechanical and Electrical Engineering because effective sustainability education should be able to cultivate both knowledge and interest towards sustainability among the students (Maniates, 2002; Morris et al., 2007) and that the trends on the knowledge and interest level should therefore be parallel.

At the same time, the difference between the sustainability integration level (C) and the other two trends suggests that apart from the formal curricula, there are other factors, such as the non-formal and informal learning that influence the sustainability knowledge and interest level among the students. The following sections attempt to identify and propose possible sustainability integration strategies for each engineering discipline by combining the formal, non-formal and informal educational types.

4.4 The Correlation between the Formal Curricula with the Students' Knowledge and Interest Level in Sustainability

The correlation between the integration of sustainability components into the formal curricula with the students' knowledge and interest level in sustainability was evaluated in this study by using the data collected from Section A (Student's knowledge on sustainability), Section B (Integration of sustainability into the formal curricula) and Section E (Student's interest towards sustainability) of the questionnaire.

There were ten items (discussed as 'tactic' in the following parts) of the formal curricula that were correlated with the students' knowledge level in sustainability (known as Category A) and students' interest level in sustainability (known as Category B). The tactics that had the highest correlation coefficient in Category A and Category B, respectively were the most effective tactics in cultivating the students' knowledge and interest in sustainability. The Spearman's rho correlation function in the SPSS was used throughout the analyses.

4.4.1 Chemical Engineering

There was a population of two hundred and forty nine final-year Chemical Engineering students at the selected IHEs when the study was conducted. A total of one hundred and seventy three responses or samples were collected from this population, which exceeded the minimum required sample size of one hundred and fifty one as suggested by Krejcie & Morgan, (1970). Therefore, the collected data were considered significant and representative.

Based on Table 4.6, for Category A (correlation between different tactics of the formal curricula with the students' knowledge level in sustainability), it was found that all tactics had a positive correlation with the students' knowledge level in sustainability. Generally, there were weak to moderate correlations, with the r_s values ranging from .318 to .568 for all the tactics. All the correlations were considered significant with $p<.05$. Amongst all, 'compulsory subjects specifically related to sustainability' had the strongest correlation with the students' knowledge on sustainability compared to the other tactics with $r_s=.568$; $p<.05$. This approach is a vertical approach (refer to Figure 3.3, page 87).

For Category B (correlation between different tactics of the formal curricula with the students' interest towards sustainability), it was found that all the listed tactics had a positive correlation with the students' interest towards sustainability. Generally, there were weak to moderate correlations with the r_s values ranging from .293 to .492. All the correlations were considered significant with p<.05. Amongst all, 'compulsory subjects specifically related to environment' had the strongest correlation with the students' interest towards sustainability compared to the other tactics with r_s =.492; p<.05. This approach is a vertical approach (refer to Figure 3.3, pg. 85).

The finding showed that the vertical approach had the highest influence on the Chemical Engineering students' knowledge and interest level in sustainability. It may be attributed to that fact that the vertical approach is more capable of establishing an in-depth knowledge on sustainability compared to the horizontal approach (Morris et al., 2007). For Chemical Engineering, which is involved in a wide range of industrial process, the vertical approach which allows more sustainability specific examples to be raised in the class (Rydhagen & Dackman 2011) may have helped the students to learn better.

Table 4.6: The correlation analysis for the formal curricula (Chemical Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Compulsory subjects specifically related to sustainability	Correlation Coefficient	.568**	.400**
	Sig. (2-tailed)	.000	.000
	N	173	173
Sustainability incorporated into existing compulsory subjects	Correlation Coefficient	.445**	.424**
	Sig. (2-tailed)	.000	.000
	N	173	173
Compulsory academic task or assignment related to sustainability	Correlation Coefficient	.546**	.440**
	Sig. (2-tailed)	.000	.000
	N	173	173
Compulsory subjects specifically related to environment	Correlation Coefficient	.544**	.492**
	Sig. (2-tailed)	.000	.000
	N	173	173
Environmental components incorporated into existing compulsory subjects	Correlation Coefficient	.460**	.475**
	Sig. (2-tailed)	.000	.000
	N	169	169
Internal elective subjects specifically related to sustainability	Correlation Coefficient	.397**	.399**
	Sig. (2-tailed)	.000	.000
	N	165	165

Table 4.6: Continued

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability incorporated into existing internal elective subjects	Correlation Coefficient	.318**	.293**
	Sig. (2-tailed)	.000	.000
	N	165	165
Academic task or assignment for the elective subjects which are related to sustainability	Correlation Coefficient	.337**	.308**
	Sig. (2-tailed)	.000	.000
	N	162	162
Internal elective subjects specifically related to environment	Correlation Coefficient	.412**	.380**
	Sig. (2-tailed)	.000	.000
	N	165	165
Environmental components incorporated into internal elective subjects	Correlation Coefficient	.340**	.379**
	Sig. (2-tailed)	.000	.000
	N	164	164

**. Correlation is significant at the 0.05 level (2-tailed).

4.4.2 Civil Engineering

There was a population of three hundred and nineteen final-year Civil Engineering students at the selected IHEs when the study was conducted. A total of two hundred and seventy responses or samples were collected from this population, which exceeded the minimum required sample size of one hundred and seventy four. Therefore, the collected data were considered significant and representative.

Based on Table 4.7, for Category A (correlation between different tactics of the formal curricula with the students' knowledge level in sustainability), it was found that all tactics had a positive correlation with the students' knowledge level in sustainability. Generally, there were weak to moderate correlations, with the r_s values ranging from .267 to .463 for all the tactics. All the correlations were considered significant with $p<.05$. Amongst all, 'environmental components incorporated into existing compulsory subjects' had the strongest correlation with the students' knowledge level in sustainability compared to the other tactics with r_s =.463; $p<.05$. This approach is a horizontal approach (refer to Figure 3.3, pg. 85).

For Category B (correlation between different tactics of the formal curricula with the students' interest towards sustainability), it was found that all the tactics had a positive correlation with the students' interest towards sustainability. Generally, there were weak to moderate correlations between them, with the r_s values ranging from .261 to .420. All the correlations were considered significant with p<.05. Amongst all, both 'environmental components incorporated into existing compulsory subjects' and 'compulsory subjects specifically related to environment' had the strongest correlation with the students' interest towards sustainability compared to the others. These two tactics had the same correlation coefficient of r_s =.420; p<.05. The former approach is a horizontal while the latter is a vertical approach (refer to Figure 3.3, pg. 85).

The results suggested that the horizontal approach had the highest influence on the students' knowledge level while both the horizontal and the vertical approach affect the students' interest towards sustainability. It reflects that the horizontal approach that encompasses interdisciplinary characteristics may have worked well for the sustainability education for the Civil Engineering students in Malaysia. Compared to the vertical approach which delivers sustainability knowledge in a stand-alone manner that possibly makes the students feel detached from their profession, the horizontal approach, which helps students to relate sustainability to their profession appeared to be more effective for the Malaysian Civil Engineering students (Cuelemans & de Prins, 2010; Thomas & Nicita, 2002).

Table 4.7: The correlation analysis for the formal curricula (Civil Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Compulsory subjects specifically related to sustainability	Correlation Coefficient	.433**	.377**
	Sig. (2-tailed)	.000	.000
	N	270	270
Sustainability incorporated into existing compulsory subjects	Correlation Coefficient	.383**	.375**
	Sig. (2-tailed)	.000	.000
	N	268	268

Table 4.7: Continued

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Compulsory academic task or assignment related to sustainability	Correlation Coefficient	.411**	.320**
	Sig. (2-tailed)	.000	.000
	N	268	268
Compulsory subjects specifically related to environment	Correlation Coefficient	.447**	.420**
	Sig. (2-tailed)	.000	.000
	N	271	271
Environmental components incorporated into existing compulsory subjects	Correlation Coefficient	.463**	.420**
	Sig. (2-tailed)	.000	.000
	N	269	269
Internal elective subjects specifically related to sustainability	Correlation Coefficient	.245**	.261**
	Sig. (2-tailed)	.000	.000
	N	266	266
Sustainability incorporated into existing internal elective subjects	Correlation Coefficient	.267**	.341**
	Sig. (2-tailed)	.000	.000
	N	265	265
Academic task or assignment for the elective subjects which are related to sustainability	Correlation Coefficient	.275**	.315**
	Sig. (2-tailed)	.000	.000
	N	266	266
Internal elective subjects specifically related to environment	Correlation Coefficient	.247**	.338**
	Sig. (2-tailed)	.000	.000
	N	266	266
Environmental components incorporated into internal elective subjects	Correlation Coefficient	.294**	.361**
	Sig. (2-tailed)	.000	.000
	N	266	266

**. Correlation is significant at the 0.05 level (2-tailed).

4.4.3 Mechanical Engineering

There was a population of three hundred and twelve final-year Mechanical Engineering students at the selected IHEs when the study was conducted. A total of two hundred and four responses or samples were collected from this population, which exceeded the minimum required sample size of one hundred and seventy two. Therefore, the collected data were considered significant and representative.

Based on Table 4.8, for Category A (correlation between different tactics of the formal curricula with the students' knowledge level in sustainability), it was found that all tactics had a positive correlation with the students' knowledge level in sustainability. Generally, there were weak to moderate correlations, with the r_s values ranging from .258 to .492 for all the tactics. All the correlations were considered significant with p<.05. Amongst all, 'compulsory academic task or assignment related to sustainability' had the strongest correlation with the students' knowledge on sustainability compared to the other tactics with r_s =.492; p< .05. This is a horizontal approach (refer to Figure 3.3, pg. 85).

For Category B (correlation between different tactics of the formal curricula with the students' interest towards sustainability), it was found that all the tactics had a positive correlation with the students' interest towards sustainability. Generally, there were weak correlations with the r_s values ranging from .211 to .369. All the correlations were considered significant with p<.05. Amongst all, 'compulsory academic task or assignment related to sustainability' had the strongest correlation with the students' interest towards sustainability compared to the other tactics with r_s =.369; p<.05. This tactic was also the tactic that had the strongest with the students' knowledge level in sustainability.

The results suggested that the horizontal approach had the highest influence on the Mechanical Engineering students' knowledge and interest level in sustainability. More specifically, incorporation of academic task or assignment into the subjects affected the knowledge and interest level the most. This is in agreement with the suggestion by Gerber et al. (2001) and Lehmann et al. (2008) that sustainability education must be integrated into the engineering curricula through projects or other hands-on activities, which were academic task or assignment in this case.

Table 4.8: The correlation analysis for the formal curricula (Mechanical Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Compulsory subjects specifically related to sustainability	Correlation Coefficient	.366**	.264**
	Sig. (2-tailed)	.000	.000
	N	204	204
Sustainability incorporated into existing compulsory subjects	Correlation Coefficient	.462**	.347**
	Sig. (2-tailed)	.000	.000
	N	204	204

Table 4.8: Continued

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Compulsory academic task or assignment related to sustainability	Correlation Coefficient	.492**	.369**
	Sig. (2-tailed)	.000	.000
	N	204	204
Compulsory subjects specifically related to environment	Correlation Coefficient	.297**	.259**
	Sig. (2-tailed)	.000	.000
	N	203	203
Environmental components incorporated into existing compulsory subjects	Correlation Coefficient	.465**	.292**
	Sig. (2-tailed)	.000	.000
	N	203	203
Internal elective subjects specifically related to sustainability	Correlation Coefficient	.258**	.211**
	Sig. (2-tailed)	.000	.002
	N	203	203
Sustainability incorporated into existing internal elective subjects		.307**	.332**
	Sig. (2-tailed)	.000	.000
	N	203	203
Academic task or assignment for the elective subjects which are related to sustainability	Correlation Coefficient	.372**	.271**
	Sig. (2-tailed)	.000	.000
	N	202	202
Internal elective subjects specifically related to environment	Correlation Coefficient	.317**	.297**
	Sig. (2-tailed)	.000	.000
	N	203	203
Environmental components incorporated into internal elective subjects	Correlation Coefficient	.362**	.285**
	Sig. (2-tailed)	.000	.000
	N	202	202

**. Correlation is significant at the 0.05 level (2-tailed).

4.4.4 Electrical Engineering

There was a population of three hundred and twenty three final-year Electrical Engineering students at the selected IHE when the study was conducted. A total of two hundred and twenty four responses or samples were collected from this population, which exceeded the minimum required sample size of one hundred and seventy six. Therefore, the collected data were considered significant and representative.

Based on Table 4.9, for Category A (correlation between different tactics of the formal curricula with the students' knowledge level in sustainability), it was found that all tactics had positive correlation with student's knowledge on sustainability. Generally, there were weak to moderate correlations, with the r_s values ranging from .200 to .413 for all the tactics. All the correlations were considered significant with *p*<.05. Amongst all, ‘compulsory academic task or assignment related to sustainability’ had the strongest correlation with student’s knowledge on sustainability compared to the other tactics with $r_s = .413$; $p < .05$. It is a horizontal approach (refer to Figure 3.3, pg. 85).

For Category B (correlation between different tactics of the formal curricula with the students’ interest towards sustainability), it was found that all the listed tactics had a positive correlation with the students’ interest towards sustainability. Generally, there were very weak to weak correlations between them, with the r_s values ranging from .126 to .315. All the correlations were considered significant with $p<.05$ except for ‘compulsory subjects specifically related to environment’ with $r_s = .126$; $p = .06$. A p-value larger than .05 indicates that there is no strong evidence for the correlation. Amongst all, ‘compulsory academic task or assignment related to sustainability’ had the strongest correlation with student’s interest towards sustainability compared to the others with $r_s = .315$; $p < .05$. This is also the same approach highlighted for Category A.

The results suggested that the horizontal approach had the highest influence on the Electrical Engineering students’ knowledge and interest level in sustainability. More specifically, incorporation of the relevant academic task or assignment into the courses played a bigger role in cultivating the intellectual and interest level in sustainability among the Electrical Engineering students, a finding that is in agreement with the suggestion by Gerber et al., (2001) and Lehmann et al.(2008).

Table 4.9: The correlation analysis for the formal curricula (Electrical Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Compulsory subjects specifically related to sustainability	Correlation Coefficient	.217**	.249**
	Sig. (2-tailed)	.001	.000
	N	224	224
Sustainability incorporated into existing compulsory subjects	Correlation Coefficient	.352**	.302**
	Sig. (2-tailed)	.000	.000
	N	224	224
Compulsory academic task or assignment related to sustainability	Correlation Coefficient	.413**	.315**
	Sig. (2-tailed)	.000	.000
	N	224	224
Compulsory subjects specifically related to environment	Correlation Coefficient	.200**	.126
	Sig. (2-tailed)	.003	.060
	N	224	224
Environmental components incorporated into existing compulsory subjects	Correlation Coefficient	.299**	.166**
	Sig. (2-tailed)	.000	.013
	N	222	222
Internal elective subjects specifically related to sustainability	Correlation Coefficient	.250**	.204**
	Sig. (2-tailed)	.000	.002
	N	222	222
Sustainability incorporated into existing internal elective subjects	Correlation Coefficient	.340**	.182**
	Sig. (2-tailed)	.000	.007
	N	222	222
Academic task or assignment for the elective subjects which are related to sustainability	Correlation Coefficient	.403**	.294**
	Sig. (2-tailed)	.000	.000
	N	222	222
Internal elective subjects specifically related to environment	Correlation Coefficient	.209**	.137**
	Sig. (2-tailed)	.002	.042
	N	222	222
Environmental components incorporated into internal elective subjects	Correlation Coefficient	.258**	.185**
	Sig. (2-tailed)	.000	.006
	N	222	222

**. Correlation is significant at the 0.05 level (2-tailed).

4.4.5 Summary (Formal Curricula)

For Category A (students' knowledge level in sustainability), three approaches – i) 'compulsory subjects specifically related to sustainability'; ii) 'environmental components incorporated into existing compulsory subjects' and iii) 'Compulsory academic task or assignment related to sustainability' were identified to have the strongest with the students' knowledge on sustainability. Approach (i) and (ii) had the strongest with the chemical and Civil Engineering students' knowledge level in sustainability, respectively. Approach (iii) was found to highly correlate to both the mechanical and Electrical Engineering students' knowledge level in sustainability, as shown in Table 4.10. The first approach is a vertical approach while the latter two are horizontal approaches.

For Category B (students' interest level in sustainability), three approaches – i) 'compulsory subject specifically related to environment'; ii) 'environmental components incorporated into existing compulsory subjects' and iii) 'compulsory academic task or assignment related to sustainability' were identified to have the strongest with the students' interest level in sustainability. Approach (i) highly correlated to Chemical Engineering students' interest level in sustainability. However, it was interesting to observe that both approach (i) and (ii) had the same correlation coefficient and the strongest with the Civil Engineering students' interest level in sustainability. Meanwhile, approach (iii) had the strongest correlation with both the Mechanical and Electrical Engineering student's interest level in sustainability, as shown in Table 4.10. The first approach is a vertical approach while the latter two are horizontal approaches.

A comparison among the identified tactics showed that 'compulsory academic tack or assignment related to sustainability' appeared to be the most related to the students' knowledge level in sustainability (category A) while both 'compulsory subjects specifically related to environment' and 'compulsory academic task or assignment related to sustainability' appeared to be the most related to the students' interest level in sustainability (Category B). The results indicated that use of assignment and projects for the engineering education, which has long been a practice for effective engineering education (Mills & Treagust, 2003), seems to apply to the sustainability education for the engineering students as well. Besides, the horizontal approach that encompasses interdisciplinary learning, which was supported by Cuelemans & de Prins (2010) and

Osman et al. (2014) was applicable for the engineering students in our case. It may also be noteworthy to mention that compulsory subjects appeared to be more effective in delivering the sustainability knowledge for the engineering students, as shown in Table 4.6 to 4.9.

Table 4.10: Tactics (formal curricula) with the highest correlation coefficient with the students' knowledge and interest level in sustainability

Tactics	Chemical Engineering	Civil Engineering	Mechanical Engineering	Electrical Engineering
Category A – Student's Knowledge Level in Sustainability				
Compulsory academic task or assignment related to sustainability			✓	✓
Compulsory subjects specifically related to sustainability	✓			
Environmental components incorporated into existing compulsory subjects		✓		
Category B – Student's Interest Level in Sustainability				
Compulsory academic task or assignment related to sustainability			✓	✓
Compulsory subjects specifically related to environment	✓	✓		
Environmental components incorporated into existing compulsory subjects		✓		

4.5 The Correlation between the Non-Formal Curricula to Students' Knowledge and Interest Level in Sustainability

The correlation between the integration of sustainability into the non-formal curricula with the students' knowledge and interest level in sustainability was evaluated in this study by using the data collected from Section A (Student's knowledge on sustainability), Section C (Integration of sustainability into the non-formal curricula: out-of-classroom activities required by the programme) and Section E (Student's interest towards sustainability) of the questionnaire.

There were two items (discussed as 'tactic' in the following parts) of the non-formal curricula that were correlated with the students' knowledge level in sustainability (known as Category A) and students' interest towards sustainability (known as

Category B). The tactics that had the highest correlation value in Category A and Category B, respectively were the most influential tactics on the students' knowledge and interest level in sustainability. The Spearman's rho correlation function in the SPSS was used throughout the analyses.

4.5.1 Chemical Engineering

Based on Table 4.11, for Category A, it was found that both the tactics - 'sustainability related activities for the subjects' and 'environmental related activities for the subjects' had a very weak positive correlation with student's knowledge on sustainability with $r_s = .174$; $p < .05$ and $r_s = .074$; $p > .05$ respectively. It should be noted that the correlation of the latter in Category A is of low significance level with $p = .333$ because a p-value larger than .05 indicates there is no strong evidence for the correlation (Chua, 2008). On the other hand, the former had a higher correlation with the students' knowledge on sustainability compared to the latter.

For Category B, it was found that both the tactics -'sustainability related activities for the subjects' and 'environmental related activities for the subjects' had a significant and weak positive correlation with the students' interest towards sustainability with $r_s = .241$; $p < .05$ and $r_s = .268$; $p < .05$ respectively. The latter had a higher correlation with the students' interest towards sustainability compared to the former.

The finding showed that sustainability related activities, which were not only environmental based, had a higher correlation with the students' knowledge level in sustainability. It may be because sustainability themed activities or assignments have a more holistic coverage of all the sustainability components and therefore have a more significant influence on the overall students' knowledge level in sustainability, as assessed by the questionnaire (Note: the questionnaire assessed the students' knowledge on sustainability by covering the three underpinning elements of sustainability). At the same time, environmental themed activities seemed to be more effective in cultivating interest in sustainability among the Chemical Engineering students. It was possibly due to the fact that the students perceived 'environment' as a simple term which appears to be more acceptable and therefore, environmentally themed activities had a higher correlation with their interest towards sustainability (Brown & Kasser, 2005; Thomas, 2004).

Table 4.11: The correlation analysis for the non-formal curricula (Chemical Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities for the subjects	Correlation Coefficient	.174**	.241**
	Sig. (2-tailed)	.022	.001
	N	172	172
Environmentally related activities for the subject	Correlation Coefficient	.074	.268**
	Sig. (2-tailed)	.333	.000
	N	172	172

**. Correlation is significant at the 0.05 level (2-tailed).

4.5.2 Civil Engineering

Based on Table 4.12, for Category A, it was found that both the tactics - 'sustainability related activities for the subjects' and 'environmentally related activities for the subjects' had a significant and weak positive correlation with the students' knowledge on sustainability with $r_s = .244$; $p < .05$ and $r_s = .260$; $p < .05$ respectively. The latter had a higher correlation with the students' knowledge on sustainability compared to the former.

Similarly, for Category B, it was found that both the tactics -'sustainability related activities for the subjects' and 'environmentally related activities for the subjects' had a weak positive correlation with the students' interest on sustainability with $r_s = .303$; $p < .05$ and $r_s = .326$; $p < .05$ respectively. The latter, which was also the highlighted parameter in Category A, had a higher correlation with the students' interest towards sustainability compared to the former.

The finding showed that environmental themed activities worked better for the Civil Engineering students. It may be due to the nature of the programme, which is closely related to the environment and subsequently leading to more environmental themed activities or assignments. Besides, the term 'environment' can also appear to be more appealing and acceptable to the students.

Table 4.12: The correlation analysis for the non-formal curricula (Civil Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities for the subjects	Correlation Coefficient	.244**	.303**
	Sig. (2-tailed)	.000	.000
	N	267	267
Environmentally related activities for the subject	Correlation Coefficient	.260**	.326**
	Sig. (2-tailed)	.000	.000
	N	270	270

**. Correlation is significant at the 0.05 level (2-tailed).

4.5.3 Mechanical Engineering

Based on Table 4.13, for Category A, it was found that both the tactics - 'sustainability related activities for the subjects' and 'environmental related activities for the subjects' had a significant and weak positive correlation with student's knowledge on sustainability with $r_s = .303$; $p < .05$ and $r_s = .270$; $p < .05$ respectively. The former had a higher correlation with students' knowledge on sustainability compared to the latter.

Similarly, for Category B, it was found that both the tactics -'sustainability related activities for the subjects' and 'environmentally related activities for the subjects' had a weak positive correlation with the students' interest on sustainability with $r_s = .306$; $p <$

.05 and $r_s = .227$; $p < .05$ respectively. The former, which was also the highlighted parameter in Category A, had a higher correlation with student's interest towards sustainability compared to the latter.

The reason that sustainability related activities had a higher influence on both the knowledge and interest level of the Mechanical Engineering students towards sustainability may be due to the holistic coverage of sustainability themed activities, which covers all economy, environment and society. The holistic coverage may help the Mechanical Engineering students to see their possible contributions to all the three assets, making them feeling fulfilled and having the intention to learn, which is the impetus to knowledge gaining and interest grooming (Marton & Saljo, 1999; Orr, 1992), especially when their engineering contribution is mainly related to energy usage and machineries efficiency, that have direct relation with manufacturing cost and environmental quality.

Table 4.13: Correlation analysis for Mechanical Engineering (non-formal curricula)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities for the subjects	Correlation Coefficient	.303**	.306**
	Sig. (2-tailed)	.000	.000
	N	202	202
Environmentally related activities for the subject	Correlation Coefficient	.270**	.227**
	Sig. (2-tailed)	.000	.001
	N	201	201

**. Correlation is significant at the 0.05 level (2-tailed).

4.5.4 Electrical Engineering

Based on Table 4.14, for Category A, it was found that both the tactics - 'sustainability related activities for the subjects' and 'environmentally related activities for the subjects' had a significant and weak positive correlation with student's knowledge on sustainability with $r_s = .255$; $p < .05$ and $r_s = .215$; $p < .05$ respectively.

The former had a higher correlation with the students' knowledge in sustainability compared to the latter.

For Category B, it was found that both the tactics -'sustainability related activities for the subjects' and 'environmentally related activities for the subjects' had a significant and very weak positive correlation with the students' interest in sustainability with $r_s = .220$; $p < .05$ and $r_s = .231$; $p < .05$ respectively. Based on the analysis, the latter had a higher correlation with the students' interest in sustainability.

The finding showed that both sustainability and environmental themed activities had an influence on the Electrical Engineering students' knowledge and interest level in sustainability. There is no established literature to explain this case. However, it is suggested that this may be due to the nature of the programme, which focuses on circuits or electrical systems, within which environmental components can be one of the design elements of an electrical device (Bureau of Labour Statistics, 2015; Lucas, 2014).

Table 4.14: The correlation analysis for the non-formal curricula (Electrical Engineering)

		Knowledge on sustainability/ SD	Interests towards sustainability
Sustainability related activities for the subjects	Correlation Coefficient	.255**	.220**
	Sig. (2-tailed)	.000	.001
	N	223	223
Environmentally related activities for the subject	Correlation Coefficient	.215**	.231**
	Sig. (2-tailed)	.001	.001
	N	223	223

**. Correlation is significant at the 0.05 level (2-tailed).

4.5.5 Summary (Non-formal Curricula)

Generally, it was found that 'sustainability related activities for the subjects' had the strongest correlation with the students' knowledge level in sustainability and interestingly, it was the other approach - 'environmentally related activities for the subjects' that had the strongest correlation with the students' interest level in sustainability, as shown in Table 4.15. It can be deduced from the results that sustainability activities which have a more holistic coverage of all the three underpinning elements played a more important role for the cognitive learning of the students towards sustainability, making sure that they acquire the complex knowledge on sustainability. On the other hand, environmentally themed activities which appeared to be more acceptable (Thomas, 2004) among the students were able to attract students to sustainability as students' perception is an important factor for effective sustainability education since it creates the intention to learn. Furthermore, as suggested by Brown & Kasser (2005), 'perception' is important for learning and interest grooming.

Table 4.15: Tactics (non-formal curricula) with the highest correlation coefficient with the students' knowledge and interest level in sustainability

Category A – Student's Knowledge Level in Sustainability				
Tactics	Chemical Engineering	Civil Engineering	Mechanical Engineering	Electrical Engineering
Sustainability related activities for the subject	✓		✓	✓
Environmental related activities for the subject		✓		
Category B – Student's Interest Level in Sustainability				
Sustainability related activities for the subject			✓	
Environmental related activities for the subject	✓	✓		✓

4.6 The correlation Between the Informal Curricula with the Students' Knowledge And Interest Level In Sustainability

The correlation between integration of sustainability into the informal curricula with the students' knowledge and interest level in sustainability was evaluated in this study by using the data collected from Section A (Student's knowledge on sustainability), Section D (Integration of sustainability into the informal curricula) and Section E (sthe tudent's interest towards sustainability) of the questionnaire.

There were eight items (discussed as tactics in the following parts) of informal curricula that were correlated with the students' knowledge level in sustainability (known as Category A) and students' interest level in sustainability (known as Category B). The tactics that had the highest correlation coefficient in Category A and Category B, respectively were the most influential tactics on the students' knowledge and interest level in sustainability. The Spearman's rho correlation function in the SPSS was used throughout the analyses.

4.6.1 Chemical Engineering

Based on Table 4.16, for Category A (the correlation between different tactics of the informal curricula with the students' knowledge on sustainability), it was found that all the tactics had a positive correlation with the students' knowledge on sustainability. Generally, there were very weak to weak correlations, with the r_s values ranging from .029 to .390 for all the tactics. All the correlations were considered significant with $p<.05$ except for 'the department makes participation in sustainability/ environmental activities compulsory' and 'the university makes participation in sustainability/ environmental activities compulsory'. Amongst all, 'sustainability activities organized by the university' had the strongest correlation with the students' knowledge on sustainability compared to the other tactics with $r_s = .390$; $p< .05$.

For Category B (the correlation between different tactics of informal education with student's interest towards sustainability), it was found that all the tactics had a positive correlation with the students' interest towards sustainability. Generally, there were very weak to moderate correlations between them, with the r_s values ranging from .194 to .434. All the correlations were considered significant with $p<.05$. Amongst all, 'environmental related activities organized by the department' had the strongest correlation with the students' interest towards sustainability compared to the others with $r_s = .434$; $p < .05$.

The results showed that sustainability activities that have a more holistic coverage of sustainability knowledge had a higher influence on the students' knowledge. This finding was in agreement with the finding in the non-formal curricula. This result also showed that the activities should be organized by the University in order to encourage sustainability learning. This is because commitment from a larger community will facilitate sustainability learning (Price, 2005) and students are motivated to learn when there are enough supports from the institution (Wright, 2002).

At the same time, environmentally themed activities which the students found more acceptable (Thomas, 2004) were found to highly influence the students interest' in sustainability. This finding was in agreement with the findings for the non-formal curricula earlier. Interestingly, instead of activities organized by the university, departmental activities seemed to be more effective in cultivating students' interests towards sustainability. It may be due to the fact that students from the same department have similar interest and they affect each other by sharing knowledge and making learning fun (Cap, 2007).

Table 4.16: The correlation analysis for the informal curricula (Chemical Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities organised by the department	Correlation Coefficient	.274**	.397**
	Sig. (2-tailed)	.000	.000
	N	173	173
Sustainability related activities organised by the faculty	Correlation Coefficient	.178*	.345**
	Sig. (2-tailed)	.019	.000
	N	173	173

Table 4.16: Continued

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities organised by the university	Correlation Coefficient	.390**	.422**
	Sig. (2-tailed)	.000	.000
	N	169	169
Environmentally related activities organised by the department	Correlation Coefficient	.249**	.366**
	Sig. (2-tailed)	.001	.000
	N	171	171
Environmentally related activities organised by the university	Correlation Coefficient	.252**	.426**
	Sig. (2-tailed)	.001	.000
	N	173	173
Environmentally related activities organised by the department	Correlation Coefficient	.337**	.434**
	Sig. (2-tailed)	.000	.000
	N	172	172
The department makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.055	.194**
	Sig. (2-tailed)	.476	.011
	N	173	173
The university makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.029	.197**
	Sig. (2-tailed)	.702	.009
	N	172	172

**. Correlation is significant at the 0.05 level (2-tailed).

4.6.2 Civil Engineering

Based on Table 4.17 for Category A (the correlation between different tactics of the informal curricula with the students' knowledge on sustainability), it was found that all tactics had a positive correlation with the students' knowledge on sustainability. Generally, there were very weak to moderate correlations, with the r_s values ranging from .166 to .409 for all the tactics. All the correlations were considered significant with $p<.05$. Amongst all, 'sustainability activities organized by the university' had the strongest correlation with the students' knowledge on sustainability compared to the other tactics with $r_s = .409$; $p< .05$.

For Category B (correlation between different tactics of the informal curricul with the students' interest towards sustainability), it was found that all the tactics had a positive correlation with the students' interest towards sustainability. Generally, there were weak to moderate correlations, with the r_s values ranging from .248 to .447. All the correlations were considered significant with $p<.05$. Amongst all, 'sustainability activities organized by the university' had the strongest correlation with the students' interest towards sustainability compared to the others with $r_s = .447$; $p< .05$.

The results showed that sustainability activities, which have a more holistic coverage of sustainability knowledge had an influence on both the students' knowledge and interest in sustainability. The results showed that the activities should be organized by the University in order to encourage sustainability learning. As discussed earlier, participation of a larger community can be an impetus to learning (Price, 2005). Therefore, activities organized by the university, which usually encourage across-campus participation may yield greater success in sustainability education through knowledge sharing and support within a community network (Cap, 2007).

Table 4.17: The correlation analysis for the informal curricula (Civil Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities organised by the department	Correlation Coefficient	.295**	.371**
	Sig. (2-tailed)	.000	.000
	N	270	270
Sustainability related activities organised by the faculty	Correlation Coefficient	.365**	.409**
	Sig. (2-tailed)	.000	.000
	N	269	269
Sustainability related activities organised by the university	Correlation Coefficient	.409**	.447**
	Sig. (2-tailed)	.000	.000
	N	270	270
Environmentally related activities organised by the department	Correlation Coefficient	.347**	.397**
	Sig. (2-tailed)	.000	.000
	N	270	270
Environmentally related activities organised by the university	Correlation Coefficient	.293**	.435**
	Sig. (2-tailed)	.000	.000
	N	271	271
Environmentally related activities organised by the department	Correlation Coefficient	.396**	.427**
	Sig. (2-tailed)	.000	.000
	N	268	268

Table 4.17: Continued

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
The department makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.166**	.248**
	Sig. (2-tailed)	.006	.000
	N	268	268
The university makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.146**	.257**
	Sig. (2-tailed)	.016	.000
	N	269	269

**. Correlation is significant at the 0.05 level (2-tailed).

4.6.3 Mechanical Engineering

Based on Table 4.18, for Category A (the correlation between different tactics of the informal education with the students' knowledge on sustainability), it was found that all tactics had a positive correlation with the students' knowledge on sustainability. Generally, there were weak to moderate correlations with the r_s values ranging from .233 to .477 for all the tactics. All the correlations were considered significant with p<.05. Amongst all, 'sustainability activities organized by the university' had the strongest correlation with the students' knowledge on sustainability compared to the other tactics with r_s = .477; p< .05.

For Category B (the correlation between different tactics of the informal education with the students' interest towards sustainability), it was found that all the listed tactics had a positive correlation with the students' interest towards sustainability. Generally, there were weak correlations with the r_s values ranging from .301 to .459. All the correlations were considered significant with p<.05. Amongst all, 'environmentally related activities organized by the department' had the strongest correlation with the students' interest in sustainability compared to the others with r_s = .459; p< .05.

The finding is similar to that of Chemical Engineering. It revealed that sustainability activities that have a more holistic coverage of sustainability knowledge had a higher influence on the students' knowledge and such activities should be organized by the University in order to encourage sustainability learning. This may be due to the peer effects from a large community (Price, 2005).

At the same time, environmental themed activities were also found to be more appealing to the Mechanical Engineering students (Thomas, 2004) and thus were more effective for cultivating students' interest towards sustainability as the students found the activities acceptable and enjoyable.

Table 4.18: The correlation analysis for the informal curricula (Mechanical Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities organised by the department	Correlation Coefficient	.338**	.310**
	Sig. (2-tailed)	.000	.000
	N	205	205
Sustainability related activities organised by the faculty	Correlation Coefficient	.404**	.408**
	Sig. (2-tailed)	.000	.000
	N	204	204
Sustainability related activities organised by the university	Correlation Coefficient	.477**	.442**
	Sig. (2-tailed)	.000	.000
	N	204	204
Environmentally related activities organised by the department	Correlation Coefficient	.365**	.334**
	Sig. (2-tailed)	.000	.000
	N	203	204
Environmentally related activities organised by the university	Correlation Coefficient	.376**	.374**
	Sig. (2-tailed)	.000	.000
	N	202	202
Environmentally related activities organised by the department	Correlation Coefficient	.409**	.459**
	Sig. (2-tailed)	.000	.000
	N	204	204
The department makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.301**	.313**
	Sig. (2-tailed)	.000	.000
	N	204	204
The university makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.233**	.301**
	Sig. (2-tailed)	.000	.000
	N	205	205

**. Correlation is significant at the 0.05 level (2-tailed).

4.6.4 Electrical Engineering

Based on Table 4.19, for Category A (the correlation between different tactics of the informal education with the students' knowledge on sustainability), it was found that all tactics had a positive correlation with the students' knowledge on sustainability.

Generally, there were very weak to weak correlations, with the r_s values ranging from .061 to .328 for all the tactics. Half the correlations were considered significant ($p<.05$) except for 'sustainability activities organized by the department' with $r_s = .121$; $p=.070$, 'environmental related activities organized by the department' with $r_s = .130$; $p=.051$, 'environmental related activities organized by the university' with $r_s = .125$; $p=.062$ and 'the department makes participation in sustainability/ environmental activities compulsory' with $r_s = .061$; $p=.363$. A p-value larger than .05 indicates that there is no strong evidence for the correlation. Amongst all, 'sustainability activities organized by the university' had the strongest correlation with the students' knowledge on sustainability compared to the other tactics with $r_s = .328$; $p< .05$.

For Category B (the correlation between different tactics of the informal education with the students' interest towards sustainability), it was found that all the tactics had very weak to weak correlations with the students' interest towards sustainability with the r_s values ranging from .141 to .383. All the correlations were significant with $p<.05$. Amongst all, 'Sustainability related activities organised by the university' had the strongest correlation with the students' interest towards sustainability compared to the others with $r_s = .383$; $p< .05$.

This finding is similar to that of Civil Engineering. 'Sustainability activities organized by the university' had the highest influence on the students' knowledge and interest in sustainability possibly due to there is a holistic coverage of sustainability knowledge and a collective participation of the campus community, both of which are motivators for sustainability education.

Table 4.19: The correlation analysis for the informal curricula (Electrical Engineering)

		(A) Knowledge on sustainability/ SD	(B) Interests towards sustainability
Sustainability related activities organised by the department	Correlation Coefficient	.121	.224**
	Sig. (2-tailed)	.070	.001
	N	224	224
Sustainability related activities organised by the faculty	Correlation Coefficient	.190**	.241**
	Sig. (2-tailed)	.004	.000
	N	225	225
Sustainability related activities organised by the university	Correlation Coefficient	.328**	.383**
	Sig. (2-tailed)	.000	.000
	N	224	224
Environmentally related activities organised by the department	Correlation Coefficient	.130	.167*
	Sig. (2-tailed)	.051	.012
	N	225	225
Environmentally related activities organised by the university	Correlation Coefficient	.125	.246**
	Sig. (2-tailed)	.062	.000
	N	224	224
Environmentally related activities organised by the department	Correlation Coefficient	.295**	.331**
	Sig. (2-tailed)	.000	.000
	N	224	224
The department makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.061	.141*
	Sig. (2-tailed)	.363	.035
	N	223	223
The university makes participation in sustainability/ environmental activities compulsory	Correlation Coefficient	.183**	.219**
	Sig. (2-tailed)	.006	.001
	N	222	222

**. Correlation is significant at the 0.05 level (2-tailed).

4.6.5 Summary (Informal Curricula)

For Category A (student's knowledge level in sustainability), it was found that only one approach out of the eight, which was 'sustainability related activities organized by the university' had the strongest correlation with student's knowledge level in sustainability for all the studied engineering disciplines, as shown in Table 4.20.

For Category B (student's interest level in sustainability), two tactics were found to have the strongest correlation with the student's interest level in sustainability. 'Environmentally related activities organized by the department' had the strongest correlation with the Chemical and Mechanical Engineering students' interest level in sustainability while 'sustainability related activities organized by the university' had the strongest correlation with the civil and Electrical Engineering students' interest level in sustainability.

The holistic coverage of sustainability elements by 'sustainability related activities organized by the university' may explain why this tactic had the highest influence on the students' knowledge and interest level in sustainability. These activities enable students to have a complex understanding of sustainability and have opportunities to be exposed to different aspects of sustainability. Besides, activities organized by universities usually involve campus-level participation, which creates a critical mass of participants to act as a pull factor to encourage participation from all parties (Hughes & Kroehler, 2008) and provides a platform for those sharing the same interest to learn and harness their interest on sustainability (Price, 2005).

Table 4.20: Tactics (informal curricula) with the highest correlation coefficient with the students' knowledge and interest level in sustainability

Category A – Students' Knowledge Level in Sustainability				
Tactics	Chemical Engineering	Civil Engineering	Mechanical Engineering	Electrical Engineering
Sustainability related activities organized by the university	✓	✓	✓	✓
Sustainability related activities organized by the department				
Category B – Students' Interest Level in Sustainability				
Sustainability related activities organized by the university		✓		✓
Sustainability related activities organized by the department	✓		✓	

4.7 Factors that Reduce Students' Interest in Sustainability Related Activities

Based on the literature review, there are several factors contributing to low interest level in sustainability related activities. The main factors that caused low interest level in sustainability related activities among the targeted engineering students were identified in this study. These factors had been identified earlier based on literature review and listed in the questionnaire distributed to the respondents. The respondents were allowed to choose more than one factor. The predetermined factors are as follows:

i) Lack of information and knowledge

ii) Lack of participation among peers

iii) Lack of support from the lecturers/ management

iv) Dilemma with careers and curricula

v) Bureaucracy in IHE

vi) Lack of relevant interdisciplinary research and indicators

vii) Lack of financial support

viii) Lack of time

ix) others

The analysis was performed using the Multiple Response function in the SPSS.

4.7.1 Chemical Engineering

Fifty six respondents or thirty two percent out of one hundred and seventy three Chemical Engineering respondents who answered 'Disagree' or 'Strongly Disagree' to Question 11 of Section E1 of the questionnaire were prompted to identify the factors which reduced their interests towards sustainability. It was observed that 'Others' was the most chosen response by the respondents at twenty four percent followed by 'lack of participation among peers' at seventeen percent. However, the respondents did not specify what other factors that caused them to have lower interest level in sustainability related activities although a space was provided for them to add their suggestion. Therefore, it was not possible to further articulate what the other factors were. Accordingly, the next on the list was lack of information and knowledge at twelve percent. The result is illustrated in Figure 4.19 and the detailed results are tabulated in Appendix P.

The finding showed that social trust, which is associated with peers influence was the main motivating factor for the Chemical Engineering students to participate in sustainability activities, without which, the students generally felt reluctant to participate in the activities. This finding was in agreement with the report by Nicolaides (2006) that social trust or network played a critical role in promoting sustainability through circulating information. Lack of information and knowledge was another factor that hindered students' participation in sustainability activities. It was believed that the lack-of-sustainability-knowledge among the instructors was among the main causes that made students feel 'confused' about sustainability (Rydhagen & Dackman, 2011).

A re-look at Figure 4.1 (pg. 96) and Appendix C revealed that the horizontal approach was the main approach used by this engineering discipline. Alhough this approach encourages interdisciplinary learning (Crofton, 2000), it may fail to address the complexity of sustainability (Haigh, 2005), which can possibly cause the students to have insufficient information and knowledge of sustainability. This may also explain why the Chemical Engineering students' knowledge and interest level did not fall in the zone of 'very high level', as shown in Figure 4.8 (pg. 108).

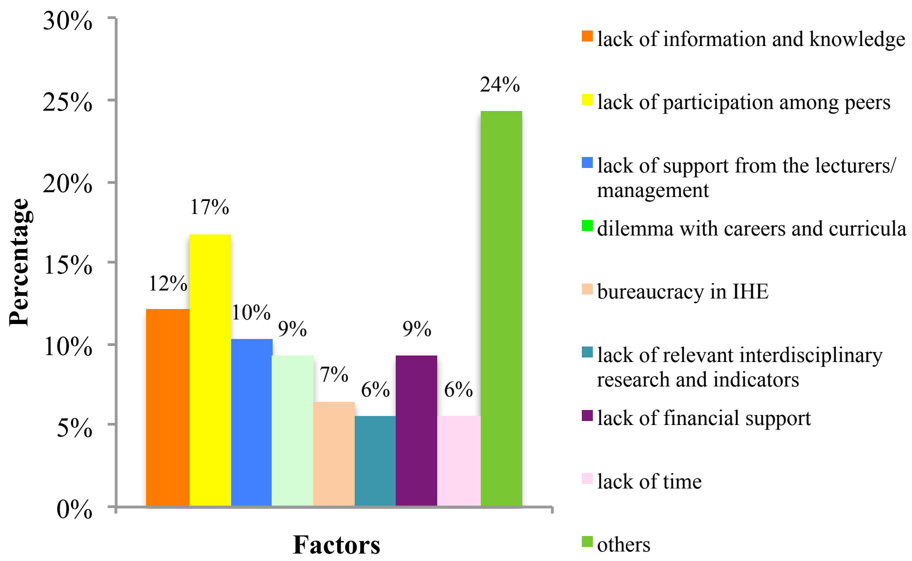


Figure 4.19: Factors that reduced the students' interest in sustainability related activities (Chemical Engineering)

4.7.2 Civil Engineering

Eighty four respondents or thirty one percent out of two hundred and seventy one Civil Engineering respondents who answered 'Disagree' or 'Strongly Disagree' to Question 11 of Section E1 of the questionnaire were prompted to identify the reasons which reduced their interests towards sustainability. It was observed that 'Others' was the most chosen response by the respondents at twenty one percent followed by 'lack of time' at fifteen percent. The respondents did not specify what other factors that caused them to have lower interest level towards sustainability related activities. The next most selected factors were 'lack of information and knowledge' and 'lack of participation among peers' at twelve percent. The findings are illustrated in Figure 4.20 and the detailed results are tabulated in Appendix P.

This finding may be supported by the comment pointed out by Lozano (2006) and Thompson & Green (2005) that students are always loaded with their own work and reluctant to support sustainability activities if these activities are not compulsory for their study. This finding is in agreement with the findings by Jones et al. (2008) that time was a limiting factor for sustainability education. In this case, a re-look at Table 4.2 revealed that a typical Civil Engineering programme generally contained more subjects compared to the other engineering programmes, which proportionally increased the students' workloads. This explains why most Civil Engineering student found 'time' as a factor that discouraged them to participate in sustainability related activities.

Besides, although the horizontal approach was the main approach used in the Civil Engineering curricula, the sustainability information delivered through this approach may not be sufficient to create the intrinsic interest among the students in sustainability (Haigh, 2005). Table 4.7 (pg.121) also shows that rather than the horizontal approach, the vertical approach had a strong correlation with the students' interest level in sustainability. Therefore, there is a possibility that intensive use of the horizontal approach for Civil Engineering may not be suitable for cultivating the students' interest in sustainability. There is also a need to combine the formal curricula with the non-formal and informal learning to further enhance the Civil Engineering students' interest in sustainability.

Lack of support from the management and lecturers was also high on the list. Necessary supports from the IHEs, i.e. funding, policies and initiatives of lecturers (Kumar et al.,2005; Lozano, 2006) may influence the students' perceptions and interest towards sustainability. This is also associated with the 'time factor' whereas the instructors need to spend more time on traditional teaching than guiding the students through sustainability activities. It eventually causes the instructors to distance from giving the necessary support to the students, leaving the students feeling confused. It should be emphasized again that policies and funding, as already discussed by many researchers, play critical roles in making sustainability education successful (Jucker, 2002). The students will not get enough push factor to involve themselves in sustainability related activities without them.

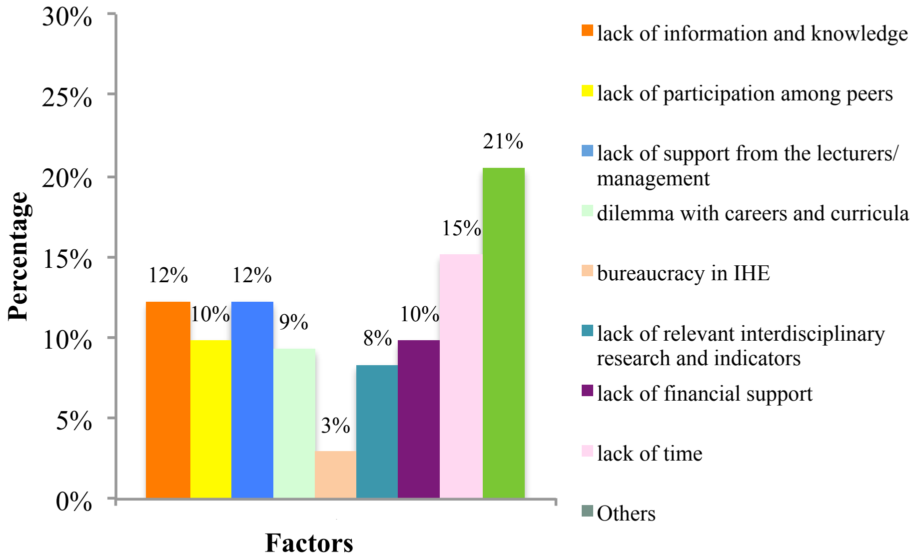


Figure 4.20: Factors that reduced the students' interest towards sustainability related activities (Civil Engineering)

4.7.3 Mechanical Engineering

Fifty respondents or twenty four percent out of two hundred and five Mechanical Engineering respondents who answered 'Disagree' or 'Strongly Disagree' to Question 11 of Section E1 of the questionnaire were prompted to identify the reasons, which reduced their interests towards sustainability. It was observed that 'lack of information and knowledge' was the most chosen response by the respondents at nineteen percent followed by 'Lack of participation among peers' at seventeen point one percent. The result is illustrated in Figure 4.21 and the detailed results are tabulated in Appendix P.

Again, the suggestion by Nicolaides (2006) on peers influence as a motivating factor for participation in sustainability related activities can be used to explain this case.

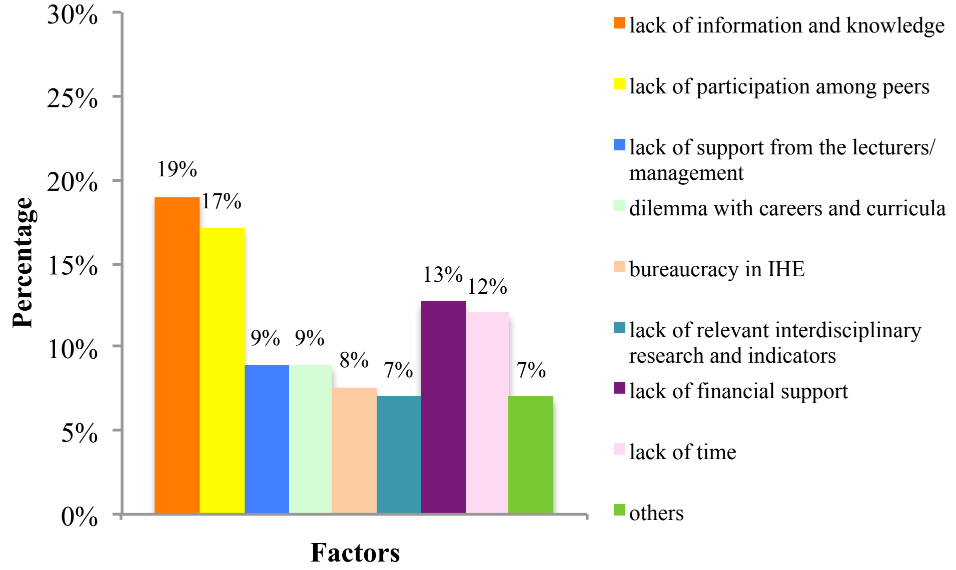


Figure 4.21: Factors that reduced the students' interest towards sustainability related activities (Mechanical Engineering)

4.7.4 Electrical Engineering

Seventy three respondents or thirty two percent out of two hundred and twenty five Electrical Engineering respondents who answered 'Disagree' or 'Strongly Disagree' to Question 11 of Section E1 of the questionnaire were prompted to identify the reasons which reduced their interests towards sustainability. It was observed that 'Others' was the most chosen response by the respondents at twenty five point three percent followed by 'lack of participation among peers' at fourteen point nine percent and 'lack of information and knowledge' at thirteen percent. Similar to the previous engineering disciplines, the respondents did not specify what other factors that reduced their interest towards sustainability. The result is illustrated in Figure 4.22 and the detailed results are tabulated in Appendix P.

It was obvious that the Electrical Engineering students, too, found that support from peers was an important motivator for them to participate in sustainability related activities. To them, 'knowledge and information' was equally important. This finding highlighted the roles played by the instructors and institutions to trigger the 'intention to learn and participate' in sustainability activities.

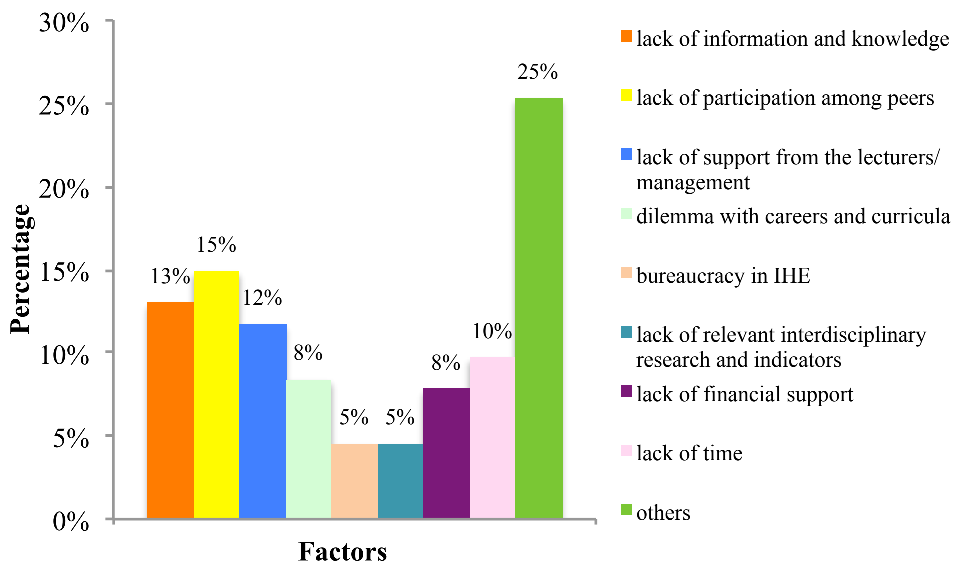


Figure 4.22: Factors that reduced the students' interest towards sustainability related activities (Electrical Engineering)

4.7.5 Summary on the Main Factors Contributing to Reduced Interest In Sustainability Related Activities

The two main contributing factors, apart from 'others' that caused reduced interest in sustainability related activities among the respondents are shown in Table 4.21. It was observed that 'Lack of information and knowledge' was one of the most chosen factors by the respondents.

This finding could be explained by the report of Rydhagen & Dackman (2011) which stated that engineering students are mostly single-disciplinary trained and the concept of 'sustainability' is too abstract and broad to be understood by them (Filho, 2000). Therefore, the instructors play an important role in making the sustainability concept clear. In order to do so, the instructors should have the knowledge about all the dimensions of sustainable development, apart from the technical knowledge (Mulder et al., 2013). However, unfortunately, the instructors themselves are usually not well-equipped with the knowledge, which makes delivery of sustainability education ineffective and fails to inculcate the interest among the students eventually (Warburton, 2003). However, this is just a possible reason based on previous researchers' experience. In order to identify if this really contributes to low interest level in sustainability related activities among the Malaysian engineering students, further studies on the level of sustainability literacy among the instructors from the Malaysian IHEs selected in this research are needed.

The next most chosen factor was 'Lack of participation among peers'. This finding highlighted the roles played by social networks in encouraging sustainability related activities within the IHEs, which was in agreement with Coleman (1990) who stated that a good social network encouraged collective activity for the common good and individual well-being. The finding was also supported by Eshach (2006)'s findings that the societal factor was a key for learning and personal perceptions towards how others react to a condition created self awareness, which decided the success of sustainability education (Singh, 2009; Glavič et al., 2009; Hall and Howe, 2010; Holmberg, 2008).

In this context, the IHEs may consider applying the 'student-activating approaches' for sustainability to encourage participation of students (Wemmenhove and Groot, 2001). It is essential to make the students feel that they are a part of the system and that they are valued so that they are willing to contribute (Hughes & Kroehler, 2008). The students may also be given some autonomy in learning, through project or problem-based learning, in which they are asked to solve real-life issues (Mulder et al., 2013). Some incentives may be provided to encourage the students to take part in the related activities (Dorweiler & Yakhou, 1998).

Table 4.21: The main factors contributing to reduced interest towards sustainability related activities

Reasons	Responses			
	Chemical	Civil	Mechanical	Electrical
lack of information and knowledge	✓	✓	✓	✓
lack of participation among peers	✓		✓	✓
others	✓	✓		✓
lack of time		✓		
lack of support from the lecturers/ management				
dilemma with careers and curricula				
bureaucracy in IHE				
lack of relevant interdisciplinary research and indicators				
lack of financial support				

4.8 Proposed Strategy for Sustainability Integration into the Engineering Curricula

As discussed earlier in Chapter 2, each engineering discipline is different and there is no one sustainability incorporation strategy that fits all. Based on the analyses presented in Section 4.4-4.7, the tactics that had the highest correlation coefficients in Category A and B for all the three educational types – formal, non-formal and informal were identified and considered the most influential tactics on the students' knowledge and interest level in sustainability. On average, although the correlation strength was moderate for all the identified tactics under each category, they still demonstrated the strongest correlation strength compared to the rest in the same group. Besides, moderate correlation strength was already expected because literature showed that there is no single educational approach that has so strong an influence on the students' knowledge and interest level in sustainability. In other words, very strong and strong correlation strength could only be expected if the tactics under all the educational types were combined and analysed. Therefore, despite the moderate correlation strength, the tactics having the highest correlation coefficient under each educational type were selected as the most influential tactics.

As such, a possible sustainability integration strategy encompassing formal, non-formal and informal learning was proposed in this Section by combining the respective tactics that had the highest correlation coefficients in Category A and Category B for each of the engineering discipline that was studied in this research. The information from Section 4.7 (factors that reduced students' interest in sustainability related activities) was used as supplementary information to complement the proposed strategy.

This Section discussed whether the horizontal approach (incorporation of sustainability into existing subjects) or vertical approach (availability of a stand-alone subject on sustainability) in the formal curricula was preferred in the proposed strategy for a particular engineering discipline.

4.8.1 Chemical Engineering

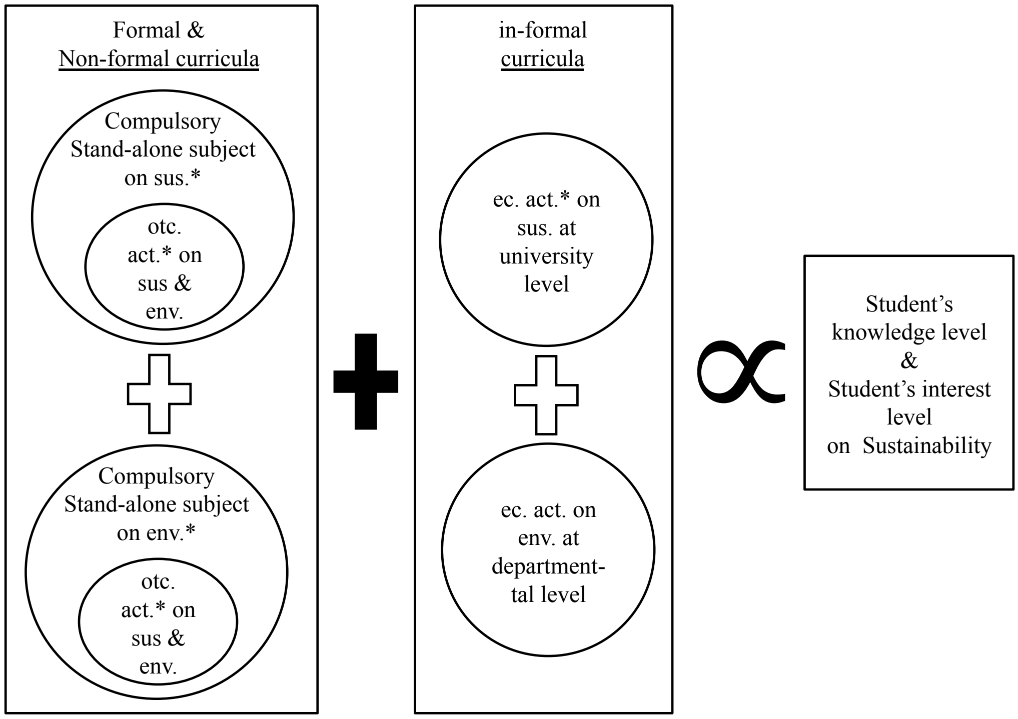
Based on Table 4.22 (pg. 162), it is suggested that the possible strategy to integrate sustainability education into the Chemical Engineering discipline in order to increase the Chemical Engineering students' knowledge and interest level in sustainability is as follows.

Formal curricula	:	1. Compulsory subjects specifically related to sustainability;
		2. Compulsory subjects specifically related to the environment;
Non-formal curricula	:	3. Out-of-classroom activities which are related to sustainability and the environment;
Informal curricula	:	4. Extra-curricular activities related to sustainability at the university level; and
		5. Extra-curricular activities related to environment at the departmental level.

According to the suggested strategy, the vertical approach (availability of a stand-alone subject on sustainability) was found to be potentially useful for sustainability incorporation into the formal curricula of the Chemical Engineering programme. As suggested by Rydhagen & Dackman (2011), a more detailed coverage of sustainability elements was achievable through stand-alone subjects rather than existing subjects which are already rich with traditional engineering knowledge. This approach may prove feasible for the Chemical Engineering students who are heavily involved in industrial processes and who need to have more thorough knowledge on sustainability.

Furthermore, according to Table 4.22 (pg.162), the Chemical Engineering discipline may also want to re-look at the sustainability knowledge and information possessed by the instructors and delivered through institutional policies in order to help elevate the students' interest in sustainability related activities. When it comes to non-formal and informal learning, which mainly involve out-of-classroom projects and activities that require voluntarily participation, it is also suggested that the IHEs or the department should design a strategy that may encourage a critical mass of participation as 'peers effect' was chosen by the Chemical Engineering students as one of the main factors that may affect their interest in sustainability related activities.

In summary, by combining the formal, non-formal and informal curricula, the sustainability integration strategy can be illustrated in the model shown in Figure 4.23. This strategy can be used together with the suggestion mentioned in the previous paragraph to improve the Malaysian Chemical Engineering students' knowledge and interest in sustainability.



**sus: sustainability; Assign.: assignment; otc. act.: out-of-classroom activities; env.: environment;*
ec. act.: extra-curricular activities
The symbol '∝' denotes 'correlate'

Figure 4.23: Suggested strategy for the Chemical Engineering Programme

4.8.2 Civil Engineering

Based on Table 4.22 (pg. 162), it is suggested that the possible strategy to integrate sustainability education into the Civil Engineering curricula in order to improve the students' knowledge and interest level in sustainability is as follows:

Formal curricula :
1. Compulsory subjects specifically related to environment
2. Incorporation of environmental components into the existing subjects

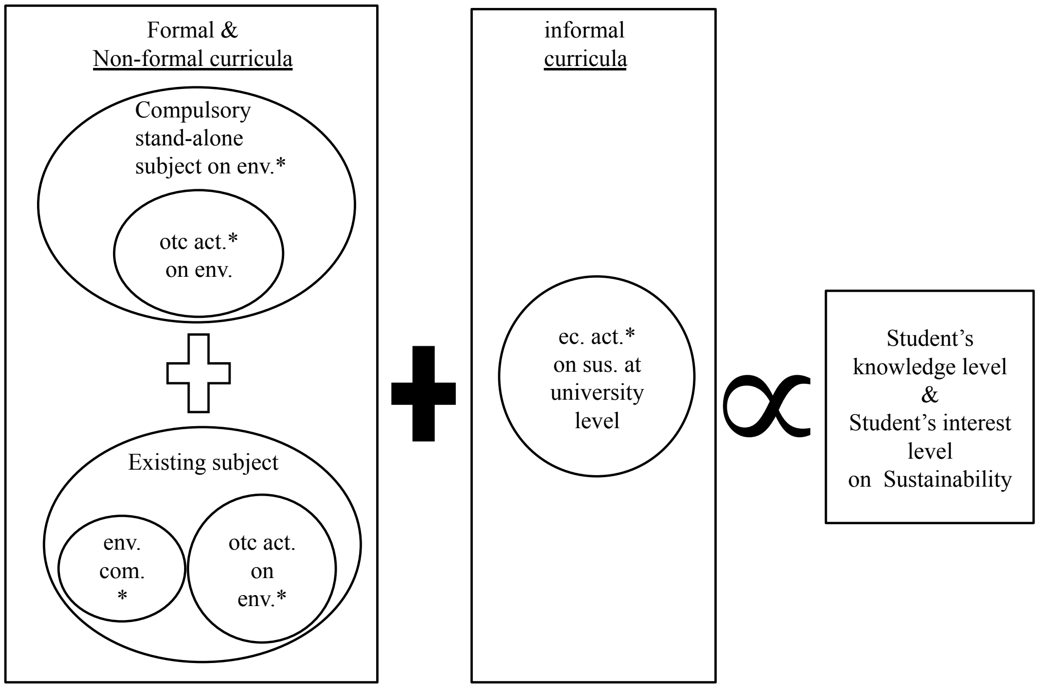
Non-formal curricula :
3. Out-of-classroom activities which are related to environment

Informal curricula : 4. Extra-curricular activities related to sustainability at the university level.

As observed, both the horizontal approach (incorporation of sustainability/ environmental component into existing subjects) and the vertical approach (availability of a stand-alone subject on sustainability) were potentially useful for sustainability incorporation into the Civil Engineering programme. This combination addresses the complex learning needed for sustainability education as suggested by Rydhagen & Dackman (2011) and Warburton (2003) and tackles the shortfalls of each educational type.

Furthermore, according to Table 4.22 (pg.162), the Civil Engineering discipline should access the sustainability knowledge and information possessed by the instructors and delivered through institutional policies in order to help elevate the students' interest in sustainability related activities. When necessary, the instructors should be re-trained. It is also suggested that the students' and instructors' workloads can be reviewed as 'time constraint' was selected by the Civil Engineering students as one of the main factors that reduced their interest in sustainability related activities. As discussed earlier, this programme also contained the highest number of subjects compared to the rest of the engineering disciplines. While a revamp of the curricular structure may be extremely challenging and pose possible complications to programme accreditation, the Civil Engineering programme may try other alternatives such as reviewing the workload, i.e. number of assignments of each subject.

In summary, the proposed sustainability integration strategy for the Civil Engineering discipline is shown in Figure 4.24. This strategy can be used together with the suggestion mentioned in the previous paragraph to improve the Malaysian Civil Engineering students' knowledge and interest in sustainability.



sus.: sustainability; otc. act.: out-of-classroom activities; env.: environment; env. com.: environmental components; ec. act.: extra-curricular activities
The symbol '∝' denotes 'correlate'

Figure 4.24: Suggested Strategy for the Civil Engineering Programme

4.8.3 Mechanical Engineering

Based on Table 4.22 (pg. 162), it is suggested that the possible strategy to integrate sustainability education into the Mechanical Engineering curricula in order to improve the students' knowledge and interest in sustainability is as follows.

Formal curricula : 1. Compulsory academic task or assignment related to sustainability as a part of the curricula

Non-formal curricula : 2. Out-of-classroom activities which are related to sustainability;

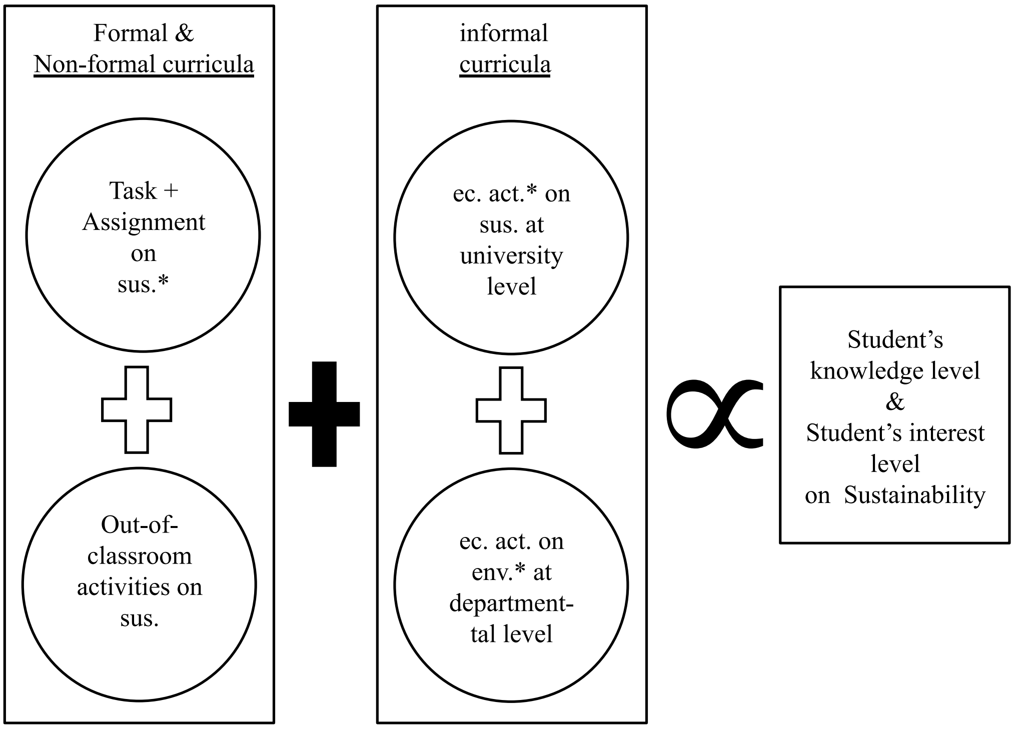
Informal curricula : 3. Extra-curricular activities related to sustainability at the university level; and

4. Extra-curricular activities related to environment at the departmental level.

As observed, it was found that the horizontal approach (incorporation of sustainability/ environmental component into existing subjects) was potentially useful for sustainability incorporation into the Mechanical Engineering programme. This interpretation was built upon the suggested strategy that there should be ‘compulsory academic task or assignment related to sustainability as a part of the curricula’ to stimulate interdisciplinary learning as suggested by Rydhagen & Dackman (2011). The Mechanical Engineering students are mainly involved in hands-on application and since academic task or assignment has long been used as an strategy for efficient engineering education, incorporation of sustainability components can be conveniently incorporated in to the academic task or assignment.

Additionally, according to Table 4.22 (pg.162), the Mechanical Engineering discippline should assess the sustainability knowledge and information possessed by the instructors and delivered through the institutional policies in order to help elevate the students’ interest in sustainability related activities, a similar suggestion that was given to chemical and Civil Engineering.. Similar to the Chemical Engineering programme, this programme also needs to make sure that the activities must be designed in a way that attracts participation from a significant amount of participants since the respondents pointed out that they needed peer support.

In summary, by combining the formal, non-formal and informal educational types, the proposed sustainability integration strategy for the Mechanical Engineering programme is shown in Figure 4.25. This strategy can be used together with the suggestion mentioned in the previous paragraph to improve the Malaysian Mechanical Engineering students' knowledge and interest in sustainability.



** sus: sustainability; env.: environment; ec. act.: extra-curricular activities*
The symbol '∝' denotes 'correlate'

Figure 4.25: Suggested Strategy for the Mechanical Engineering Programme

4.8.4 Electrical Engineering

Based on Table 4.22 (pg. 162), it is suggested that the possible strategy to integrate sustainability education into the Electrical Engineering discipline in order to improve the students' knowledge and interest in sustainability is as follows:

Formal curricula : 1. Compulsory academic task or assignment related to sustainability as a part of the curricula

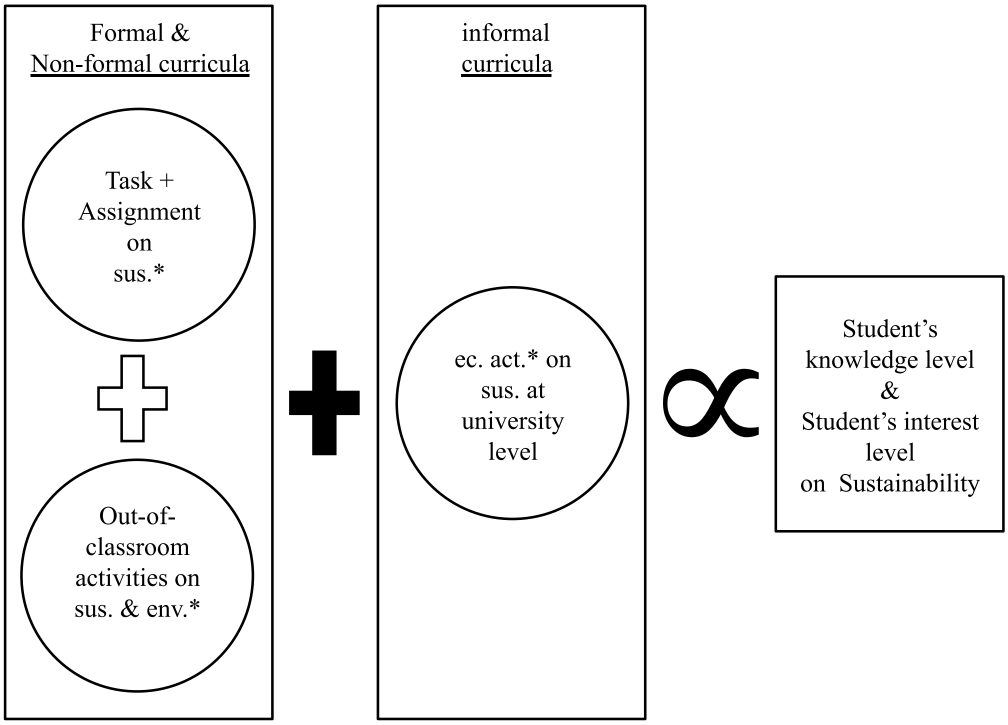
Non-formal curricula : 2. Out-of-classroom activities which are related to sustainability and environment

Informal curricula : 3. Extra-curricular activities related to sustainability at the university level.

As observed, it was found that the horizontal approach was potentially useful for sustainability incorporation into the Electrical Engineering programme. This interpretation was built upon the suggested strategy that there should be 'compulsory academic task or assignment related to sustainability as a part of curricula'. This interpretation was again in line with the suggested strategy by Rydhagen & Dackman (2011) that there should be 'compulsory academic task or assignment related to sustainability as a part of the curricula' to stimulate interdisciplinary learning for sustainability education.

Additionally, according to Table 4.22 (pg.162), similar to the Chemical and Mechanical Engineering programmes, the Electrical Engineering programme needs a re-look into the instructors' competency and institutional roles in delivering sustainability related information. Peer influence and a critical mass of participation are the keys to increase the participation rate of Electrical Engineering students in sustainability related activities.

In summary, by combining the formal, non-formal and informal educational types, the proposed sustainability integration strategy for the Electrical Engineering programme can be illustrated in the model shown in Figure 4.26. This strategy can be used together with the suggestion mentioned in the previous paragraph to improve the Malaysian Electrical Engineering students' knowledge and interest in sustainability.



** sus: sustainability; env.: environment; ec. act.: extra-curricular activities*
The symbol ‘∝’ denotes ‘correlate’

Figure 4.26: Suggested Strategy for the Electrical Engineering Programme

Table 4.22: Tactics with the strongest correlation with the students' knowledge (Category A) and interest level (category B) in sustainability

Types of curricula	Tactics	Chemical		Civil		Mechanical		Electrical	
		Cat.A	Cat. B	Cat. A	Cat. B	Cat. A	Cat. B	Cat. A	Cat. B
Formal Curricula	Compulsory academic task or assignment related to sustainability					✓	✓	✓	✓
	Compulsory subjects specifically related to environment		✓		✓				
	Environmental components incorporated into existing compulsory subjects			✓	✓				
	Compulsory subjects specifically related to sustainability	✓							
	Sustainability incorporated into existing compulsory subjects								
	Internal elective subjects specifically related to sustainability								
	Sustainability incorporated into existing internal elective subjects								
	Academic task or assignment for the elective subjects which are related to sustainability								
	Internal elective subjects specifically related to environment								
	Environmental components incorporated into internal elective subjects								
Non-formal curricula	Sustainability related activities for the subjects	✓				✓	✓	✓	
	Environmentally related activities for the subject		✓	✓	✓				✓
Informal curricula	Sustainability related activities organised by the university	✓		✓	✓	✓		✓	✓
	Environmentally related activities organised by the department		✓				✓		
	Sustainability related activities organised by the department								
	Sustainability related activities organised by the faculty								
	Environmentally related activities organised by the department								
	Environmentally related activities organised by the university								
	The department makes participation in sustainability/ environmental activities compulsory								
	The university makes participation in sustainability/ environmental activities compulsory								

CHAPTER 5: CONCLUSION AND RECOMMENDATION

In this study, four engineering disciplines, namely Chemical, Civil, Mechanical and Electrical Engineering from 5 IHEs in Malaysia were studied. Based on the study, a possible strategy for incorporating sustainability education into each targeted engineering discipline from the formal, non-formal and informal curricula perspectives was proposed together with the identification of the proper approach to be used, i.e. the vertical or horizontal approach. The results of the this study are summarised as follows:

1. The curricular analyses showed that both the vertical and the horizontal approaches were used by Chemical and Civil Engineering while the horizontal approach was the only approach used by Mechanical and Electrical Engineering to incorporate the sustainability aspects into their engineering curricula. Besides, it was found that all the engineering disciplines preferred to deliver sustainability knowledge through compulsory courses, rather than through elective courses. This finding was in agreement with the suggestion by Cortese & Hattan (2010) that knowledge on sustainability should not be only delivered through elective courses.

2. The statistical analyses revealed that the current knowledge and interest levels of the engineering students from the targeted engineering disciplines were generally moderately high to high on a scale of 5 from 'very low' to 'very high'. It indicated that the current strategy has to be improved or revised if the literacy and interest levels on sustainability among the engineering students are to be increased because a successful sustainability education should be able to instill the literacy and interest in sustainability among the learners (Cap, 2007; Morris et al., 2007). This finding also brought this thesis's author to pose a question on whether the horizontal

approach, as suggested by many western researchers and used primarily at the moment in the Malaysian Institutions of Higher Education, can work equally effective for the Malaysian engineering students. The results showed that this approach should be further improved.

3. An integration strategy was proposed for each of the studied engineering disciplines based on the combination of the identified approaches from the perspective of formal, non-formal and informal educational type. The finding suggested that the integration strategy varied with engineering disciplines, which perfectly reflected the comment by Parkin et al. (2004) that sustainability education should be customized according to the engineering disciplines. The integration strategy proposed in this study was the combination of the identified tactics under the formal, non-formal and informal learning, which was the first of its kind for sustainability education, to the best of the researchers' knowledge.

4. The study showed that 'Lack of information and knowledge' and 'Lack of participation from peers' were the main causes for low interest in sustainability related activities among the engineering students. This information complemented the proposed integration strategy by suggesting that Institutions of Higher Education should organize learning activities or lessons that encourage participation of a critical mass of campus residents. This result suggested that the Malaysian instructors and the institutions might not have adequately equipped themselves with knowledge in sustainability despites years of efforts in integrating sustainability into the engineering education. It also posed potential concern that the current knowledge dissemination system in the institutions was either ineffective or insufficient. Besides, the result emphasized again the roles played by peer influence

in making learning activities efficient. On a side note, one of the other interesting findings was that the Malaysian students' interest in sustainability related activities seemed to be influenced by factors other than the ones identified from the existing literature which are mainly based on the European, American and Australian contexts. Although these factors were not identifiable in this research, this result suggested that the scenario in the other countries may not be applicable for this multi-racial country which has complex cultures.

In conclusion, the objectives of this research were fulfilled as the current knowledge and interest level of the Malaysian engineering students from the four identified engineering disciplines were identified, and the sustainability incorporation strategies from the view point of formal, non-formal and informal educational types for the studied engineering disciplines were successfully proposed with an explanation on whether such strategies were horizontal- or vertical-approach based. The main factors, which caused a reduced students' interest in sustainability related activities, were also identified. In short, there are different sustainability incorporation strategies for different engineering disciplines.

5.1 Knowledge Contributions of The Study

This study proposed strategies for integrating sustainability into the engineering education and the findings of this study may contribute in the following ways:

1. **Provided an insight into the current strategy for integrating sustainability into the engineering education in Malaysia**

   Malaysian IHEs are believed to have integrated sustainability education into its engineering education as it is an accreditation requirement by the professional body – Board of Engineers of Malaysia, but there have not been any previous studies aiming at measuring the effectiveness of the integration strategies. A part of this study provided an insight into the effectiveness of the current sustainability integration strategy, which revealed the needs for an improved strategy.

2. **Filled up the research gap on the 'assessment' and 'continual improvement' part of the research on sustainability education**

   The existing literature concerning the Institutions of Higher Education in the developed countries such as Australia, the UK and the US showed that these Institutions of Higher Education had progressively transited their research focus from 'implementation' to 'assessment' and 'continual development' of sustainability education. Malaysia, on the other hand, was lagging behind with very limited publications in this area of research. The literature showed that the research focus of Malaysia in terms of sustainability education was in between 'implementation' and 'assessment'. There was evidently a research gap to fulfill in order to catch up with the progress of the overseas Institutions of Higher Education. Evaluation of the students' literacy and interest in sustainability, corresponding to the current integration strategy, provided necessary information for the 'assessment' section while proposal of the integration strategies can be seen as a continual improvement effort for the current integration strategy.

3. **Proposed an alternative method to measure the effectiveness of an integration strategy**

   Instead of Structure of Observed Learning Outcome (SOLO) and conceptual map, as used commonly by many researchers (Lourdel et al., 2007; Carew & Mitchell, 2002), this study used correlation analysis to correlate students' literacy and interest level in sustainability with the current integration approaches used by the Institutions of Higher Education, through which the tactics that had the highest influence on the students' literacy and interest level in sustainability were identified. This information served as the base on which the integration strategy was developed. Apart from that, it was also the first time correlation analysis had been used for identifying approaches that had the highest influence on students' knowledge and interest in sustainability.

4. **Proposed a strategy which could serve as a reference for other Malaysian Institutions of Higher Education in integration of sustainability into the engineering education**

   There have not yet been any strategies suggested for integrating sustainability into the Malaysian engineering education. The strategies proposed in this study could serve as a reference for other Malaysian Institutions of Higher Education, which offer the same engineering disciplines as studied in this study. This is an essential step to help Malaysian IHEs to strengthen their efforts in improving sustainability education for the engineering disciplines, in particular.

5.2 Recommendation for Future Studies

Based on the research findings and observations during the research, there are a few recommendations for future studies to enrich the pool of knowledge for this subject matter. First of all, pilot studies are recommended for the proposed strategies in this research to evaluate their effectiveness and to further improve them.

A long-term research can be designed to investigate the impact of the proposed sustainability integration strategies on students' career developments or choices after they graduate. This will not only help to assess the effectiveness of the proposed strategies, but help researchers in investigating the possibility of transferring the strategies to other engineering disciplines.

More research can also be conducted in the future on the influence level of the formal, non-formal and informal educational type on successful sustainability incorporation into the engineering curricula in order to determine the type of education that has the highest influence. This information will help the curricula development units' leaders to decide which educational type should be given more emphasis for improving sustainability education.

There should also be further studies to identify the other factors that reduce engineering students' interest in sustainability related activities, which were not stated by the respondents and thus were not identifiable in this study.

Finally, the same research conducted by Azapagic et al. (2005) and Nicolaou & Conlon (2012) may be replicated in Malaysia to identify the knowledge gaps among the engineering students in terms of sustainability knowledge. The information will be valuable to the leaders of the curriculum development units to design more comprehensive sustainability-related subjects to close the knowledge gaps.

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APPENDIX A - KEY TERMS/ PHRASES USED FOR TEXT ANALYSIS

air
application of sustainability
balance
biological
capacity building
climate change
community contribution
culture
ecodesign
ecological well-being
ecology/ ecological
economic risk
economical well-being
efficient use
efficient use of natural resources
efficient energy use
energy
energy efficiency
environment
environmental risk
green
green design
green product
human
mitigation and prevention of pollution
mitigation of climate change
natural resources
pollution
pollution control
pollution minimization
recycling
renewable energy
resources
sanitary system
societal wellbeing
solid waste
sound pollution
sustainability
sustainable development
sustainable manufacturing
sustainable practice
sustainable product
tradition
treatment
water

APPENDIX B - SAMPLE OF QUESTIONNAIRE

SURVEY ON KNOWLEDGE ON SUSTAINABILITY/ SUSTAINABLE DEVELOPMENT (STUDENT)

Date : _______________

Programme :
(Please tick (√) the relevant box)

Chemical Engineering	
Civil Engineering	
Civil and Structural Engineering	
Electrical Engineering	
Electrical and Electronic Engineering	
Mechanical Engineering	

Student Level :
(Please tick (√) the relevant box)

3rd Year Semester 2	
4th Year Semester 1	
4th Year Semester 2	

A) Knowledge on Sustainability / Sustainable Development

Please **tick (√)** the relevant box.

1= Yes, strongly agree 2= Yes, agree 3= Not sure 4= No, disagree 5= No, strongly disagree

Questions	**1**	**2**	**3**	**4**	**5**
1. I have heard about the term 'sustainability' or 'sustainable development'.					
2. I clearly understand the objectives of sustainable development.					
3. I agree that sustainable development is development that fulfills the current needs without jeopardizing the needs of the future generation.					
4. Sustainable development is meant to improve the environment, encourage technology development, improve the economy and protect the cultural elements of a society.					
5. Sustainable development ensures continuous growth of a society.					
6. Sustainable development helps improve the economy while at the same time maintaining or improving the environmental quality.					
7. Sustainable development emphasizes the balance between economic, environmental, cultural and social outcomes.					

B) Integration of Sustainability into Formal Curricula

Please **tick (√)** the relevant box.

1= Yes, strongly agree 2= Yes, agree 3= Not sure 4= No, disagree 5= No, strongly disagree

Note:

i) The term **'Sustainability'** means it **MUST INCLUDE ALL** the components listed below

Environmental issues & management
Societal wellbeing
Economic development
Humane/cultural elements

ii) The term **'Environmental'** means it is inclusive of **ONLY**

Environmental issues & management

B1 This part refers to *Compulsory Subjects ONLY*

Questions	**1**	**2**	**3**	**4**	**5**
1. For the programme I am taking, there are **subjects** that are **specifically related** to **sustainability**.					

Questions	1	2	3	4	5
2. For the programme I am taking, **sustainability** is **incorporated** in some of the subjects I have taken.					
3. I have been given academic task or assignment related to **sustainability**.					
4. For the programme I am taking, there are **subjects** that are **specifically related to environment**.					
5. For the programme I am taking, **environmental** components are incorporated in some of the subjects I have taken.					

B2 This part refers to *Internal (Offered by the same department) Elective Subjects ONLY*

Questions	1	2	3	4	5
1. For the programme I am taking, there are **subjects** that are **specifically related** to **sustainability**.					
2. For the programme I am taking, **sustainability** is **incorporated** in some of the subjects I have taken.					
3. I have been given academic task or assignment related to **sustainability**.					
4. For the programme I am taking, there are **subjects** that are **specifically related to environment**.					
5. For the programme I am taking, **environmental** components are incorporated in some of the subjects I have taken.					

C) Integration of Sustainability into Non-formal Curricula (Out-of-classoom activities required by the programme)

Please **tick (√)** the relevant box.

1= Yes, strongly agree 2= Yes, agree 3= Not sure 4= No, disagree 5= No, strongly disagree

Questions	1	2	3	4	5
1. There are **sustainability** related activities which are compulsory for the programme I am taking.					
2. There are **environmental** related activities which are compulsory for the programme I am taking.					

D) Integration of Sustainability into Informal Curricula (extra-curricula activities organized by the department/ faculty/ university)

Please **tick (√)** the relevant box.

1= Yes, strongly agree 2= Yes, agree 3= Not sure 4= No, disagree 5= No, strongly disagree

Questions	1	2	3	4	5
1. There are **sustainability** related activities organized by my department.					
2. There are **sustainability** related activities organized by my faculty.					
3. There are **sustainability** related activities organized by my university.					
4. There are **environmental** related activities organized by my department.					
5. There are **environmental** related activities organized by my faculty.					
6. There are **environmental** related activities organized by my university.					
7. My **department** has made it compulsory for me to participate in **sustainability/ environmental** related activities (extra-curricula).					
8. My **university** has made it compulsory for me to participate in **sustainability/ environmental** related activities (extra-curricula).					

E) Interests towards Sustainability

Please **tick (√)** the relevant box.
1= Yes, strongly agree 2= Yes, agree 3= Not sure 4= No, disagree 5= No, strongly disagree

Section E1 (Please fill up this section ONLY if you have answered '1' or '2' in one of the questions in Section B, C or D. Otherwise, please proceed to Section E2)

Questions	**1**	**2**	**3**	**4**	**5**
1. Number of subjects that are specifically related to **sustainability** is sufficient.					
2. **Sustainability** related information is sufficiently incorporated into the subjects I have taken.					
3. The department should insert more knowledge on **sustainability** into the programme I am taking.					
4. I am interested in **sustainability** related **subjects**.					
5. I am interested in **sustainability** related **activities**.					
6. Number of subjects that are specifically related to **environment** is sufficient.					
7. **Environmental** components are sufficiently incorporated into the subjects I have taken.					
8. The department should insert more **environmental** knowledge into the programme I am taking.					
9. I am interested in **environment** related **subjects**.					
10. I am interested in **environment** related **activities**.					
11. I am willing to take part in sustainability related activities even if they are not compulsory.					

12. If your answer is '4'or '5' for Question 11, please choose the reasons from the options below (you may choose more than one. Please **tick (√)** the relevant box):

Lack of information and knowledge	
Lack of participation among peers	
Lack of support from the lecturers/ management	
Dilemma with careers and curricula	
Bureaucracy in IHE	
Lack of relevant interdisciplinary research and indicators	
Lack of financial support	
Lack of time	
Others, please state:	

Section E2

Please **tick (√)** the relevant box.
1= Yes, strongly agree 2= Yes, agree 3= Not sure 4= No, disagree 5= No, strongly disagree

Questions	**1**	**2**	**3**	**4**	**5**
1. Sustainability integration into curricula is important. **If you answer '1' or '2', please state why:**					
2. I agree that if sustainability is emphasized, the society will benefit in terms of technological advancement, economic competence, better life quality and healthier environment.					

~ THANK YOU FOR YOUR PARTICIPATION ~

APPENDIX C - LIST OF SUSTAINABILITY RELATED SUBJECTS (CHEMICAL ENGINEERING)

IHE	Subjects related to sustainability
A	Morals and ethics in engineering profession
	Biochemistry
	Environmental management #
	Air and noise pollution*
	Solid waste management*
	Wastewater treatment*
	Advanced process safety and loss prevention*
B	Engineering ethics and technology development
	Chemical engineering laboratory IV
	Pollution control and cleaner production #
	Process plant design project I
	Industrial Safety
	Process plant design and economics
	Process system engineering
	Process plant project design II
	Industrial toxicology*
C	Material Science
	Pollution control engineering
	Waste management and utilization*
	Water and wastewater engineering*
	Air pollution engineering*
	Solid waste engineering*
D	Engineering practice
	Electrical technology
	Engineers in society
	Environmental engineering and management#
	Project design and analysis
	Plant design and economics
	Final year project
	Renewable and alternative energies*#
	Operational research*
	Industrial effluent engineering *
	Petroleum and gas processing engineering*
E	Pollution control
	Pollution control laboratory
	Plant design
	Phytochemical technology*
	Air resources engineering*
	Environmental management*#
	Solid and hazardous waste management*
	Waste incineration*

Note: * *Elective course*
\# *Stand-alone course*
The rest are compulsory courses intertwined with sustainability components

APPENDIX D - LIST OF SUSTAINABILITY RELATED SUBJECTS (CIVIL ENGINEERING)

IHE	Subjects related to sustainability
A	Moral and ethics of engineering profession Water resources Environmental engineering# Integrated design Geo hazards * Surface water hydrology * Environmental risk management* Hazardous waste management* Environmental management system *#
B	Engineering and built environmental professionalism II Environmental engineering studies # Engineering ethics and technology development Sustainable urban training* Environmental geotechnics*#
C	Design I Environmental engineering# Structural design II Water and wastewater engineering Traffic engineering Highway Engineering I Agriculture and man Water system design Highway engineering II Construction method and technology Engineer and society Civil engineering design project Advanced wastewater engineering * Solid waste management engineering*
D	Engineering drawing laboratory Fluid mechanics for civil engineering Engineers in society Water supply and water treatment engineering Soil mechanics Reinforced concrete structure design I Wastewater engineering Geotechnical analysis Construction technology Hydraulic, geotechnical and environmental laboratory Timber and steel structure design Geotechnical engineering design Engineering hydrology Transportation, traffic engineering Reinforced concrete structure design II Construction management Industrial training EIA and solid waste management Advanced concrete technology* Engineering management*

IHE	Subjects related to sustainability
D	River conservation and rehabilitation* Pre-stressed concrete design* Advanced water resources engineering* Advance geotechnical engineering* Environmental studies *#
E	Water treatment Wastewater engineering Hydrology Environmental management# Coastal engineering* Hydrologic analysis and design* Groundwater hydrology* Environmental hydraulic and hydrology* Advanced water and wastewater treatment* Municipal solid waste management* Air pollution and control* Environmental microbiology* Industrial and hazardous waste treatment* Water quality management*

Note: * *Elective course*
\# *Stand-alone course*
The rest are compulsory courses intertwined with sustainability components

APPENDIX E - LIST OF SUSTAINABILITY RELATED SUBJECTS (MECHANICAL ENGINEERING)

IHE	Subjects related to sustainability
A	Moral and ethics of engineering profession
B	Engineering and built environment professionalism II Manufacturing processes Ethics and civilization System design Design project Efficient use and management of energy *#
C	Agriculture and man Engineer and society
D	N/A
E	Professional engineering practice

Note: ** Elective course*
 # Stand-alone course
The rest are compulsory courses intertwined with sustainability components

APPENDIX F - LIST OF SUSTAINABILITY RELATED SUBJECTS (ELECTRICAL ENGINEERING)

IHE	Subjects related to sustainability
A	Moral and ethics in engineering profession
B	Engineering and built environment professionalism II
	Engineering technique and technology development
C	Agriculture and man
	Engineer and society
D	Circuit theory I
	Basic circuit laboratory
	Digital electronics I
	Electronic devices
	Engineering practices
	Signals and systems
	Digital electronics laboratory
	Analogue electronics I
	Power electronics
	Electromagnetic theory
	Electrical laboratory
	Engineers in Society
	Industrial training
E	Professional engineering practice

Note: All are compulsory courses intertwined with sustainability components

APPENDIX G – RESULT OF PILOT STUDY (SECTION A)

Number of respondents for Section A

		N	%
Cases	Valid	70	100.0
	Excluded[a]	0	.0
	Total	70	100.0

Cronbach's alpha value for Section A

Cronbach's Alpha	N of Items
.963	7

Cronbach's alpha reliability analysis for Section A

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
heard about sustainability or SD	10.557	22.453	.794	.963
understand the objectives	10.257	22.542	.870	.957
agree with the statement	10.300	22.068	.872	.956
SD is about the 3 pillars	10.514	22.224	.914	.953
Sustainability. ensures continuous growth of society	10.614	21.603	.904	.954
Sustainability improves economy	10.400	21.954	.903	.954
SD emphasizes the balance among the pillars	10.386	22.849	.823	.960

APPENDIX H – RESULT OF PILOT STUDY (SECTION B)

Number of respondents for Section B

		N	%
Cases	Valid	64	91.4
	Excluded[a]	6	8.6
	Total	70	100.0

Cronbach's alpha value for Section B

Cronbach's Alpha	N of Items
.935	10

Cronbach's alpha Reliability Analysis for Section B

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Availability of specific course on sustainability (compulsory courses)	18.297	38.403	.595	.935
Availability of sustainability incorporation into existing courses (compulsory courses)	18.453	37.680	.753	.929
Given task or assign on sustainability (compulsory courses)	18.313	37.552	.641	.933
Availability of specific course on environment (compulsory courses)	18.563	36.091	.807	.925
Availability of environmental incorporation into existing courses (compulsory courses)	18.438	34.440	.793	.926
Availability of specific course on sustainability (internal elective)	18.156	36.642	.688	.931
Availability of sustainability incorporation into existing courses (internal elective)	18.156	35.816	.838	.924
Given task or assign on sustainability (internal elective)	18.219	36.872	.747	.928
Availability of specific course on environment (internal elective)	18.375	36.079	.801	.926
Availability of environmental incorporation into existing courses (internal elective)	18.266	35.182	.777	.927

APPENDIX I – RESULT OF PILOT STUDY (SECTION C)

Number of Respondents for Section C

		N	%
	70	100.0	70
Cases	0	.0	0
	70	100.0	70

Cronbach’s alpha value for Section C

Cronbach's Alpha	N of Items
.872	2

Cronbach’s alpha reliability analysis for Section C

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
compulsory sustainability related activities	2.500	1.065	.796	.
informal-compulsory environmental related activities	2.486	.659	.796	.

APPENDIX J – RESULT OF PILOT STUDY (SECTION D)

Number of respondents for Section D

		N	%
Cases	Valid	65	92.9
	Excluded[a]	5	7.1
	Total	70	100.0

Cronbach's alpha value for Section D

Cronbach's Alpha	N of Items
.949	8

Cronbach's alpha reliability analysis for Section D

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
sustainability related activities by the department	17.431	34.187	.752	.946
sustainability related activities by faculty	17.785	33.578	.839	.940
sustainability related activities by university	17.708	33.460	.876	.938
environmental related activities by the department	17.415	33.965	.809	.942
environmental related activities by the faculty	17.800	33.850	.850	.940
environmental related activities by the university	17.615	33.803	.874	.939
department makes participation compulsory	17.477	34.785	.687	.951
university makes participation compulsory	17.631	32.580	.832	.941

APPENDIX K – RESULT OF PILOT STUDY (SECTION E)

Number of respondents for Section E

		N	%
Cases	Valid	64	91.4
	Excluded[a]	6	8.6
	Total	70	100.0

Cronbach's alpha value for Section E

Cronbach's Alpha	N of Items
.951	13

Cronbach's alpha reliability analysis for Section E

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
number of sustainability specific course is sufficient	24.656	59.340	.663	.950
Sustainability incorporation is sufficient	24.875	59.254	.838	.945
department should insert more knowledge on sustainability into the programme	25.234	58.722	.843	.945
interested in sustainability related subjects	25.125	59.159	.798	.946
interested in sustainability related activities	25.250	60.095	.725	.948
number of environmentally specific subjects is sufficient	25.063	57.679	.786	.946
environmental component incorporation is sufficient	25.125	58.333	.705	.948
The department should insert more knowledge on env. into the programme	25.281	59.348	.827	.945
interested in environmentally related subjects	25.313	58.631	.793	.946
interested in environmentally related activities	25.438	58.758	.785	.946
willing to take part in sustainability related activities voluntarily	25.109	58.893	.813	.945
Sustainability integration into curricula is important	25.016	58.841	.660	.950
Society will benefit if sustainability is emphasized	25.328	57.653	.675	.950

APPENDIX L - KNOWLEDGE AND INTEREST LEVEL IN SUSTAINABILITY (CHEMICAL ENGINEERING)

Knowledge and Interest Level in Sustainability (Chemical Engineering)

Level	Knowledge Level		Interest Level	
	Frequency	Valid Percentage (%)	Frequency	Valid Percentage (%)
Very High	44	25.4	31	18.0
High	80	46.2	95	55.2
Moderate	27	15.6	39	22.7
Low	19	11.0	6	3.5
Very Low	3	1.7	1	.6
Missing*	0	-	1	-
Total	173	100.0	173	100.0

Mean Score for Knowledge and Interest Level (Chemical Engineering)

	Knowledge level	Interest level
N	173	173
Missing	0	1
Mean Score	3.827	3.8663

APPENDIX M - KNOWLEDGE AND INTEREST LEVEL IN SUSTAINABILITY (CIVIL ENGINEERING)

Knowledge and Interest Level in Sustainability (Civil Engineering)

Level	Knowledge Level		Interest Level	
	Frequency	Valid Percentage (%)	Frequency	Valid Percentage (%)
Very High	88	32.5	79	29.5
High	132	48.7	148	55.2
Moderate	33	12.2	29	10.8
Low	11	4.1	11	4.1
Very Low	7	2.6	1	.4
Missing*	0	-	3	-
Total	271	100.0	268	100.0

Mean Score for Knowledge and Interest Level (Civil Engineering)

	Knowledge level	Interest level
N	271	268
Missing	0	3
Mean Score	4.044	4.0933

APPENDIX N - KNOWLEDGE AND INTEREST LEVEL IN SUSTAINABILITY (MECHANICAL ENGINEERING)

Knowledge and Interest Level in Sustainability (Mechanical Engineering)

Level	Knowledge Level		Interest Level	
	Frequency	Valid Percentage (%)	Frequency	Valid Percentage (%)
Very High	42	20.5	36	17.6
High	90	43.9	103	50.5
Moderate	41	20.0	51	25.0
Low	26	12.7	14	6.9
Very Low	6	2.9		
Missing*	0	-	1	
Total	205	100.0	205	100.0

Mean Score for Knowledge and Interest Level (Mechanical Engineering)

	Knowledge level	Interest level
N	205	204
Missing	0	1
Mean Score	3.663	3.7892

APPENDIX O - KNOWLEDGE AND INTEREST LEVEL IN SUSTAINABILITY (ELECTRICAL ENGINEERING)

Knowledge and Interest Level in Sustainability (Electrical Engineering)

Level	Knowledge Level		Interest Level	
	Frequency	Valid Percentage (%)	Frequency	Valid Percentage (%)
Very High	28	12.4	40	17.9
High	107	47.6	128	57.1
Moderate	60	26.7	53	23.7
Low	28	12.4	3	1.3
Very Low	2	.9	0	0
Missing*	0	-	1	-
Total	225	100.0	225	100.0

Mean Score for Knowledge and Interest Level (Electrical Engineering)

	Knowledge level	Interest level
N	225	224
Missing	0	1
Mean Score	3.582	3.9152

APPENDIX P - FACTORS THAT REDUCED STUDENTS' INTEREST IN SUSTAINABILITY RELATED ACTIVITIES

Factors that reduce interests in sustainability related activities among the Chemical Engineering Students

Reasons	Responses	
	N	Percent
lack of information and knowledge	13	12.1%
lack of participation among peers	18	16.8%
lack of support from the lecturers/ management	11	10.3%
dilemma with careers and curricula	10	9.3%
bureaucracy in IHE	7	6.5%
lack of relevant interdisciplinary research and indicators	6	5.6%
lack of financial support	10	9.3%
lack of time	6	5.6%
others	26	24.3%
Total	107	100.0%

Factors that reduce interests in sustainability related activities among the Civil Engineering Students

Reasons	Responses	
	N	Percent
lack of information and knowledge	25	12.2%
lack of participation among peers	20	9.8%
lack of support from the lecturers/ management	25	12.2%
dilemma with careers and curricula	19	9.3%
bureaucracy in IHE	6	2.9%
lack of relevant interdisciplinary research and indicators	17	8.3%
lack of financial support	20	9.8%
lack of time	31	15.1%
Others	42	20.5%
Total	205	100.0%

Factors that reduce interests in sustainability related activities among the Mechanical Engineering Students

Reasons	Responses	
	N	Percent
lack of information and knowledge	30	19.0%
lack of participation among peers	27	17.1%
lack of support from the lecturers/ management	14	8.9%
dilemma with careers and curricula	14	8.9%
bureaucracy in IHE	12	7.6%
lack of relevant interdisciplinary research and indicators	11	7.0%
lack of financial support	20	12.7%
lack of time	19	12.0%
others	11	7.0%
Total	158	100.0%

Factors that reduce interests in sustainability related activities among the Electrical Engineering Students

Reasons	Responses	
	N	Percent
lack of information and knowledge	20	13.0%
lack of participation among peers	23	14.9%
lack of support from the lecturers/ management	18	11.7%
dilemma with careers and curricula	13	8.4%
bureaucracy in IHE	7	4.5%
lack of relevant interdisciplinary research and indicators	7	4.5%
lack of financial support	12	7.8%
lack of time	15	9.7%
others	39	25.3%
Total	154	100.0%