Integrating Components of Sustainability into Chemical Engineering Curricula*

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Sustainability has been gaining attention worldwide due to rising evidences of environmental problems and societal issues. Tertiary education has responded to the attention by taking a series of initiatives for delivering knowledge of sustainability. Among all, engineering discipline appears to be among the most active in seeking to integrate the components of sustainable development into its curricula. Many researchers have studied the approaches used for integrating sustainability knowledge into engineering education, but most of these studies are only relevant to the European, American and Australian contexts. The relevant information in the Asian context is scant, due to limited published reports or literature on how the Asian universities, including Malaysian’s, are integrating sustainability into their engineering curricula. Therefore, this study aims at studying the current approach used by the Malaysian universities to integrate sustainability into its engineering curricula and identifying which approach is more effective for such integration. This study targeted at the chemical engineering undergraduate programme in five selected universities in Malaysia. A survey was used and a total of 173 responses were collected. Correlation analysis was then conducted. It was found that the undergraduates’ knowledge and interest level of sustainable development was unsatisfactory. The results revealed that specific and compulsory courses related to sustainable development could be more effective for delivering knowledge of sustainability for the undergraduates, a finding that was different from that suggested in the existing literature for the Western Countries such as the United States, United Kingdom, the Netherlands, Sweden and others.

Keywords: sustainability; education; approach; chemical engineering; knowledge; interest

1. Introduction

1.1 Sustainable development

Sustainable development (SD) has attracted much attention among industrial players, governments and public. It is defined as development that meets the present needs without compromising the needs of the future generation [1, 2]. Nevertheless, this term is not to be confused with the term ‘sustainability’, which is defined as design of systems that leads to eventual sustainable use of resources with minimal impact on societal, environmental and economic health [3]. In a nutshell, SD can be seen as a tool to achieve sustainability.

In the last decades, there has been an increasing emphasis on sustainable development and sustainability [4], following which, there rise debates and queries on how SD can be achieved and how to make people understand SD. As technologies advance, more responsibilities are to be borne by the engineering profession with regards to the impact of technologies on the society [5]. Therefore, the society is concerned on how education, especially higher education can help move the globe towards a sustainable future. A notable commitment by the United Nations in 1992 led to the birth of United Nations Decade of Education for Sustainable Development (DESD) 2005–2014, which further highlighted the importance of education for sustainable development (ESD) by outlining the essential characteristics and plans to achieve SD through education [6].

1.2 Education for sustainable development and engineering education

Engineering is among the most active discipline in promoting SD through its education in universities [7]. For example, in the United States (US), the American Society of Engineering Educators (ASEE) has released ‘Statement on Sustainable Development Education’ as an official statement on sustainability education for the engineering disciplines [8]; Both Delft University of Technology (DUT) of the Netherlands and University of Bath of the United Kingdom (UK) have integrated sustainability components into their engineering curricula [8, 9]; while the Swedish government also promotes sustainability integration into engineering education by demanding that the components of sustainable development to be integrated into the

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1.3 Approaches for education for sustainable development

Following DESD, various approaches of integrating sustainability knowledge into education have been discussed and those commonly discussed include (a) some coverage of environmental issues in the existing module [19–20]; (b) a specific or stand-alone course on sustainability [21, 22]; (c) interweaving sustainability with the existing regular courses [23–25]; and (d) a graduate specialization course on SD [20]. [26] suggested that the integration approaches could be categorized into the horizontal and vertical approaches. Based on their explanation, the horizontal approach refers to an approach that integrates sustainability components into the existing courses while the vertical approach refers to delivering sustainability knowledge through a stand-alone course [26]. Therefore, approaches (a) and (c) mentioned above are considered as the horizontal approach while (b) and (d) are the vertical approaches, as summarised in Table 1.

Table 1. Comparison between the horizontal and vertical approaches

<table>
<thead>
<tr>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some coverage of environmental issues in the existing module [19–20]</td>
<td>A specific or stand-alone course on sustainability [21–22]</td>
</tr>
<tr>
<td>Interweaving sustainability with the existing regular courses [23–25]</td>
<td>A graduate specialization course on SD [20]</td>
</tr>
</tbody>
</table>

[10] suggested that the horizontal approach is a more efficient approach as this approach allows students to better relate their profession with SD. This approach is also more interdisciplinary compared to the vertical approach, which appears more relevant for engineering undergraduates [27]. Besides, the higher-order thinking skills required of engineering students, that can be promoted through inquiry-based learning as suggested by [28], could fit well into the horizontal approach. Engineering ethics, which is a component deemed important in chemical engineering education [29, 30] and a component related to the social dimension of sustainable development, could also be embedded into the programme through the horizontal approach. However, there are concerns on whether knowledge of sustainable development can be sufficiently addressed in this approach as the existing engineering courses are usually already compact with the traditional or core engineering knowledge. Besides, some engineering educators are also reluctant to use this approach with a fear that traditional engineering knowledge has to be sacrificed [31].

The vertical approach, on the other hand, is a commonly used approach at the initial stage of incorporating sustainability into engineering curricula [25]. Stand-alone courses on sustainability usually have a more holistic coverage of knowledge on SD as more SD specific examples can be given [10]. However, since such course may be separated from the core engineering curricula, undergraduates may see SD as something irrelevant, which is one of the drawbacks of this approach. Besides, it is
also challenging to introduce new stand-alone courses into the existing curricula as such addition does not only increase the load on instructors but also students [32].

There are countless discussions on these two approaches but there is no consensus on which approach works more effectively for sustainability integration into the engineering discipline. The researchers in the field generally agree that the effectiveness of the approach depends on many factors and as long as an approach is capable of cultivating certain literacy and interest level in SD, the approach is considered appropriate [33].

1.4 National and institutional effort

The literature also shows that there is more published information on efforts to integrate ESD into engineering education in the European, American and Australian universities compared to the Asian countries. To name a few examples, The Observatory and The Alliance for Global Sustainability and The Engineering Education for Sustainable Development (EESD) are in place in the UK to guide integration of SD knowledge into engineering education [7, 34]. ESD for engineering students are also available in some Universities in the Netherlands and Latvia [8, 35]. In Australia, The Institution of Engineers of Australia makes ‘sustainability’ a mandatory component for an engineering baccalaureate [36]. In the Asian context, there are also some countries that have taken institutional and national effort to encourage ESD. For example, Japan has established DESD Implementation Plan to promote sustainability education [37] and University of Tokyo has established Integrated Research System for Sustainability Science (IR3S) to focus on SD relevant work [38]. Taiwan has created Taiwan Sustainable Campus Program (TSCP) [39] and Indian Institutes of Technology have introduced SD into its Environmental Engineering Program [40]. In Africa, University of Cape Town that has been active in ESD, has put a greater emphasis on SD in its new curriculum launched from 2014 [41].

However, unfortunately, there are no national policies for ESD for the engineering disciplines in Malaysia. Most of the relevant efforts are taken by individual organizations or institutions such as the Board of Engineers of Malaysia (BEM) and universities. For example, the BEM has made delivery of SD knowledge a must for all accredited engineering baccalaureate programs [42] while some universities such as Universiti Malaya, Universiti Sains Malaysia and Universiti Teknologi Malaysia have shown institutional effort by establishing policies or SD related centres to promote campus sustainabil-

ity across the campus, though without a special emphasis on engineering education.

1.5 Effectiveness evaluation of integration strategies

There is definitely a wide array of studies on integration of SD knowledge into engineering education, but there is relatively less research that aims at measuring the efficiency of such approaches. As mentioned earlier, a successful ESD should be both interesting and able to cultivate certain degree of literacy in SD. Being interested in and self-devoted to a subject matter ensures a greater learning efficiency. More information on the importance of student engagement and consequent learning is discussed by [43].

Some researchers who have measured effectiveness of ESD for engineering students included [44–47]. [45–47] used a questionnaire to collect information on students’ understanding of SD while [44] used a conceptual map to evaluate the efficiency of a course to deliver ESD. All of their research findings were relevant to the engineering education in the European context. Their findings showed that there may not be a holistic coverage of SD components in their engineering curricula and there was a knowledge on the societal aspect of SD. To the authors’ knowledge, there is no similar research to evaluate the effectiveness of the current strategy used to incorporate SD knowledge into the engineering curricula in the Asian context, including Malaysia.

1.6 The Malaysian scenario

The authors observed a shift of focus in the research relevant to ESD for engineering education in the last 20 years. In the 1990s, the research was mostly on initiation and execution of integration strategies, which then transitioned onto assessment of the integration strategies in the early 2000s. Until recently, most of the research is on continual improvement of the integration strategies. The Asian countries, including Malaysia, seem to be lagging behind in this field of research. The relevant publications published in early 2010s mainly focused on the general aspects of ESD while during the same period, the European universities were focusing on continual improvement strategies, even on specific fields like engineering.

Malaysia is a fast growing country that relies heavily on industrialization, which signifies a high involvement of engineering knowledge. Engineering graduates, especially chemical engineering graduates who are actively involved in manufacturing processes, must therefore be well equipped with knowledge on SD on the country’s journey to achieve sustainability and to fulfil the Prime Minis-
ter’s pledge to reduce the country’s carbon emission intensity by 40% compared to 2005 in 2020. The
BEM has made ESD mandatory for all accredited engineering programmes in Malaysia, it is therefore assumed that all the accredited engineering programmes in Malaysia have integrated SD knowledge into the engineering curricula. However, since there has not been any relevant evaluation, it remains a puzzle on how effective the current integration strategy in Malaysia is, to produce engineers who can practically contribute to sustainable development of Malaysia. This information is important to make sure that our future engineers are equipped with the relevant knowledge to drive the country towards sustainability. In order to clear the puzzle, the authors of this work conducted a survey targeting on the final-year engineering students in 5 universities in Malaysia and did a curricular analysis of the Chemical Engineering Undergraduate Programme. It was then followed by correlation analysis between the curricula and students’ knowledge and interest level of SD to identify the approach that had the highest influence on the effectiveness of ESD. The use of correlation analysis in this study for identifying the best strategy was the first of its kind in this field, to the best of the authors’ knowledge. The approaches identified in this study should help universities in achieving greater success in integrating sustainability knowledge within the chemical engineering curricula, producing engineers who can contribute to sustainable development of the country.

2. Methods

This work targeted only on Chemical Engineering due to its explicit importance and wide involvement in the manufacturing industry. This study was divided into three parts: (i) evaluation of students’ knowledge and interest level in sustainability; (ii) analysis of chemical engineering curricula to determine if the horizontal or vertical approach was used; and (iii) a correlation analysis to identify which approach had the highest influence on students’ knowledge or interest level of sustainability.

The study was conducted at 5 public universities in Malaysia, anonymously known as University A, B, C, D and E. A total of 173 chemical engineering undergraduates, which comprised 41 participants from Institution A, 45 participants from Institution B, 17 participants from Institution C, 40 participants from Institution D and 30 participants from Institution E, participated in this study. These 5 universities were selected as they have an established history in offering chemical engineering undergraduate courses compared to the other universities in Malaysia. Besides, they are among the oldest universities in Malaysia that have a matured administrative and educational system. According to [48, 49], degree of maturity of the administrative and education systems which are among the factors that influence the success of ESD.

2.1 Questionnaire

A questionnaire was designed and used to evaluate students’ level of understanding of SD and interest towards SD. The questionnaire used by [45, 47] was used as a reference but the questionnaire used in this study was designed to adapt to the local context where the community, at large, still have low level of understanding of SD. For example, instead of using questions that evaluate students’ understanding based on individual dimension of SD, the questions were built based on collective definitions of SD. In the questionnaire, both the terms—‘sustainability’ and ‘environment’ were used as some students may not be familiar with the term ‘sustainability’ [45]. It should be noted that the questionnaire used to collect information for this study was also used for other information collection purposes by the authors. It consisted of 5 parts, but only 3 of them were relevant to the theme of this study. Therefore, only the relevant 3 parts were discussed in this paper and they are known as Part 1, 2 and 3 in this paper.

Part 1 of the questionnaire comprised 6 questions, which were oriented around definitions of sustainability to evaluate students’ understanding of SD. Part 2 of the questionnaire consisted of 10 questions relevant to SD knowledge integration into the engineering curricula. The questions were built upon the characteristics of the horizontal and vertical approaches. The questions asked if there were specific courses on SD, or if SD knowledge was integrated within the existing courses. The information collected from this part was used for correlation analysis and to propose the integration strategy that had the highest influence on student’s knowledge and interest in SD later.

Part 3 of the questionnaire comprised 13 questions, aiming at evaluating students’ interest and perception towards SD related courses or activities. The questions asked how interested they were in SD personally and how they perceived the importance of SD for the society.

A 5-point likert-scale was used in the questionnaire, which were “Yes, strongly agree; Yes, agree; Not sure; No, disagree; and No, strongly disagree”. The responses were then interpreted as ‘Very high’ to ‘very low’ correspondingly to reflect the knowledge and interest level, where appropriate, depending on the context of the questions. The responses were then translated into a scoring system on a scale of 1 to 5 for analytical purpose with the highest score (5) assigned to ‘Yes, strongly agree’ and lowest score (1) assigned to ‘Yes, strongly agree’
(1) assigned to ‘No, strongly disagree’, respectively. The collected data were analysed using Statistical Package for Social Sciences (IBM SPSS Statistics V22.0).

The questionnaire was distributed in hardcopy by student helpers and the first author to increase the response rate and ensure that the respondents received the same instructions. Prior to dissemination, a pilot study of the questionnaire was conducted. The Cronbach’s Alpha reliability coefficient of Part 1, 2 and 3 of the questionnaire was more than 0.65, which is above the minimum requirement for reliability analysis [50]. Therefore, the questionnaire was considered reliable and used in this study.

There was a total of 173 responses out of a total population of 249 final-year chemical engineering students from the 5 universities chosen in this study. This sample size was considered sufficient and representative according to [51].

2.2 Curricular analysis

The syllabi outlines of the Chemical Engineering Programme from each of the chosen universities were collected and a text analysis based on key terms to identify courses, which were relevant to SD was carried out. Examples of the key terms used included ‘sustainability’, ‘sustainable’, ‘environment’, ‘societal well-being’ and etc. The context of those key terms was also further analysed to make sure that the course was relevant to SD. For example, the term ‘environment’ which appeared as ‘aquatic environment’ did not reflect sustainability. The identified courses were then further categorized into stand-alone courses (the vertical approach) or courses within which sustainability were intertwined (the horizontal approach). Further, the integration percentage of these courses into the curricula was analysed using Equation (1), a modified formula proposed by [52].

\[
\text{Total number of compulsory subjects related to sustainability} \\
\times 100% = \frac{\text{Total number of compulsory subjects of the programme}}{(1)}
\]

It should be noted that this calculation only considered compulsory courses, which the students must take. Electives courses were not considered as they posed mathematical concern that may affect the accuracy of the statistical analysis, for example, there would be a need for probability analysis on chances students had undertaken SD-related electives and how many allocated slots of electives had been used for SD-related elective courses. However, although not considered in the integration percentage, the number of SD-related electives was identified to describe the overall approach used by the universities to integrate SD into their chemical engineering curricula.

2.3 Correlation analysis

A correlation analysis was conducted between each of the question of Part 2 (Integration approach) with Part 1 (knowledge level) and Part 3 (interest level and perception) of the questionnaire to identify the approach that had the highest influence on students’ knowledge and interest level on SD. Spearman’s rho correlation analysis was used in this study as the data was ordinal and non-parametric. The Spearman’s rho correlation coefficient \(r_s\) within \(-1 \leq r_s \leq +1\). \(r_s\) of +1 indicates positive correlation and vice versa. The strength of the correlation is shown in Table 2. The significance level (p-value, \(p\)) of the correlation was also evaluated alongside the correlation analysis. 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 [53].

The approach that had the highest correlation with students’ knowledge and interest level of sustainability was considered the most effective strategy for integrating SD into the curricula of chemical engineering programmes in Malaysia.

3. Result and discussion

3.1 Knowledge and interest level

Part 1 and 3 of the questionnaire measured the Malaysian final-year chemical engineering undergraduates’ knowledge and interest level of SD. Figs. 1 and 2 show the average score for each of the question of Part 1 and 3 of the questionnaire.

Generally, the analyses revealed that the students’ responses towards SD definitions as stated in Part 1 of the questionnaire were between ‘Not sure’ to ‘Yes, agree’, that could be further translated into an understanding level of between ‘moderate’ and ‘high’, corresponding to an overall mean score of 3.83 a score near the higher end, for Part 1 of the questionnaire.

It was observed that when asked about if they clearly understood the objectives of SD (Item A, Fig. 1), majority of the students’ response were in

### Table 2. Strength of correlation

<table>
<thead>
<tr>
<th>Correlation coefficient ((r_s))</th>
<th>Correlation Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ve or -ve</td>
<td></td>
</tr>
<tr>
<td>0.91–1.00</td>
<td>Very strong</td>
</tr>
<tr>
<td>0.71–0.91</td>
<td>Strong</td>
</tr>
<tr>
<td>0.51–0.70</td>
<td>Average/medium</td>
</tr>
<tr>
<td>0.31–0.50</td>
<td>Weak</td>
</tr>
<tr>
<td>0.01–0.30</td>
<td>Very Weak</td>
</tr>
<tr>
<td>0.00</td>
<td>No correlation</td>
</tr>
</tbody>
</table>

Source: [53].
between ‘Not sure’ and ‘yes, but not fully understood’, corresponding to a mean score of 3.72. They also appeared to link SD more to societal well-being (Item D, Fig. 1) compared to the other SD dimensions, with a mean score 3.86, a slightly higher mean score compared to that of the others. This was a finding that was different from those reported by previous researchers for the European context where there was a knowledge gap in the societal dimension. The overall result suggested that students generally knew about SD but could not be sure of the objectives and various aspects of SD.

With respect to the interest level and perception on SD, the students’ responses towards whether they were interested in SD related issues were in between ‘Not sure’ and ‘Yes, agree’, that could be further translated to an interest level between ‘moderate’ and ‘high’, corresponding to a mean score of 3.87, a score biased towards ‘high interest level’, for Part 3 of the questionnaire.

Students’ interest towards SD was found to be mostly stimulated by SD related activities (Item E, Fig. 2), with a mean score of 4.57, indicating that the students ‘agree’ or ‘strongly agree’ that they were interested in SD related activities.

However, when asked if they were willing to take part in SD related activities voluntarily (Item K, Fig. 2), the responses were in between ‘not sure’ and ‘yes’, corresponding to a mean score of 3.36, a score near the lower end. This scenario could be well explained by the fact that the students were generally loaded with their studies that caused them to be reluctant to allocate time for SD activities if the activities are not necessary, as suggested by [54–55].

It is noteworthy that a typical chemical engineering programme in Malaysia contains 14% more credit hours than the mandatory minimum requirement [56].

The analysis also revealed that the students generally were not sure of the potential benefits SD can bring to the society (item L, Fig. 2), with a mean score of 3.61, falling between ‘not sure’ and ‘yes, agree’. This again, suggested that the undergraduates had an inadequate level of understanding of SD and were not interested in whether SD is beneficial to the society at large.

3.2 Integration of sustainability components into curricula

In terms of sustainability integration into the curricula, it was found that 9.9% of the compulsory courses of chemical engineering curricula contained SD components. On average, there were 8 SD related courses, inclusive of both compulsory and elective courses for the chemical engineering programme, as shown in Table 3. Table 3 also shows that on average, the chemical engineering programme offered 7 courses within which sustainability components were intertwined and 3 of them were elective courses. The analysis also showed that there was 1 stand-alone course on sustainability. It was also interesting to note that all the universities had employed electives to deliver SD knowledge with an average of 3 elective courses on SD. The number of

Authors: Fig. 1. Two "A" columns??

---

**Table 3**

<table>
<thead>
<tr>
<th>Course Type</th>
<th>Year</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory</td>
<td>2022</td>
<td>Environmental Science</td>
</tr>
<tr>
<td>Compulsory</td>
<td>2023</td>
<td>Sustainable Energy Systems</td>
</tr>
<tr>
<td>Elective</td>
<td>2022</td>
<td>Sustainable Manufacturing Processes</td>
</tr>
<tr>
<td>Elective</td>
<td>2023</td>
<td>Sustainable Product Design</td>
</tr>
</tbody>
</table>

Legend:

- **A**: Clearly understand the objectives of SD
- **B**: SD fulfills the current needs without jeopardizing the future needs
- **C**: SD is meant to improve environment, economy and cultural elements while helping technological advancement
- **D**: SD ensures continuous growth of society
- **E**: SD improves economy while improving environmental
- **F**: SD emphasizes the balance among economic, environmental, cultural and societal dimensions

**Fig. 1.** Mean score of knowledge level of sustainability.
SD related courses shown in Table 3 is further illustrated in Fig. 3 to facilitate comparison. Figure 3 clearly shows that 13% of these sustainability courses were stand-alone courses (the vertical approach) while the rest were courses within which SD knowledge was intertwined (the horizontal approach). Use of electives may be explained by the suggestion of previous researchers that SD knowledge can possibly be more efficiently delivered through elective courses, which are normally derived from research [57–58].

The finding suggested that the horizontal approach was the main approach used by the 5 universities to deliver SD knowledge. Besides, the intensive use of the horizontal approach compared to the vertical approach by these universities is also in agreement with the suggestion by some researchers such as [10] that interdisciplinary learning, which is associated with the horizontal approach, may be more effective for ESD. This approach may appear more suitable for the chemical engineering discipline due to its involvement in a wide range of industrial processes that requires interdisciplinary knowledge and capability to relate SD to practice [57].

The information gathered from the curricular analysis served the purpose to explain the current integration approach employed by the universities. The effectiveness of the integration approach was further evaluated and elaborated in the next section.

### 3.3 The approach having the highest influence on students’ knowledge and interest level

Part 2 of the questionnaire provided an answer to whether horizontal approach or vertical approach had the highest influence on Malaysian chemical

![Fig. 2. Mean score of interest level of sustainability.](image)

### Table 3. Integration percentage of SD related courses into the Chemical Engineering Curricula

<table>
<thead>
<tr>
<th>University</th>
<th>Total no. of programme courses</th>
<th>No. of SD related courses</th>
<th>Integration%*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compulsory Elective Horizontal</td>
<td>Vertical Total</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>52 4</td>
<td>6 (4 elec.) 1</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>51 2</td>
<td>8 (1 elec.) 1</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>47 4</td>
<td>6 (4 elec.) 0</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>39 4</td>
<td>9 (3 elec.) 2 (1 elec.)</td>
<td>11</td>
</tr>
<tr>
<td>E</td>
<td>52 4</td>
<td>7 (4 elec.) 1 (1 elec.)</td>
<td>8</td>
</tr>
<tr>
<td>Average</td>
<td>7 (3 elec.)</td>
<td>8 (3 elec.)</td>
<td></td>
</tr>
</tbody>
</table>

* Calculation based on Equation (1).
engineering undergraduates' knowledge and interest level on SD through Spearman's rho correlation analysis.

The result revealed that all the correlations were significant with $p < 0.05$, with the Spearman rho's correlation coefficients ($r_s$) ranging from 0.318 to 0.568 for all the approaches listed under Part 2 of the questionnaire with students' knowledge level of SD. It was found that 'compulsory courses specifically related to sustainability', which is a vertical approach, had the highest correlation to students' knowledge of sustainability. Figure 4 shows the correlation coefficient of each method/question of Part 2 with the students' knowledge level of SD.

Similarly, with respect to the correlations between different approaches with students' interest in SD, all the correlations were significant with $p < 0.05$, with the Spearman rho's correlation coefficients ($r_s$) ranging from 0.293 to 0.492. Amongst all, it was found that 'compulsory subjects specifically related to environment', which is a vertical approach, had the highest correlation to students' knowledge of sustainability. Figure 5 shows the correlation coefficient of each question of Part 2 with the students' interest level of SD. The finding also suggested that compulsory courses had a higher influence on ESD for the Malaysian chemical engineering students.
It is interesting to note that both the approaches that had the highest influence on students' knowledge and interest level of sustainability were the vertical approaches and specific courses on 'environment' seemed to appear more interesting to the students. This finding is in agreement with the report by [22] that the term 'environment' could be more appealing and might gather a higher acceptance among students.

On top of that, the authors also observed that instead of the horizontal approach, which has been suggested by many researchers as a more effective approach for delivering ESD for the engineering students in the European context, may not work equally effective for the Malaysian chemical engineering undergraduates, as suggested by the result. This finding also raises doubts on the effectiveness of the current integration strategy used by the Malaysian universities, which had a higher preference for the horizontal approach over the vertical approach.

The finding that the vertical approach appeared to be more effective is in line with [35]'s suggestion that the vertical approach is normally engaged at the early stage of SD integration. Holistic coverage of SD knowledge, which is achievable using the vertical approach may most likely attract students' interest in SD at the initial stage due to the urge of learning a new knowledge. While the Malaysian universities are generally at the entry level in integrating sustainability into its engineering curricula compared to the developed countries, the vertical approach should prove useful in improving the delivery effectiveness of sustainability knowledge.

4. Limitations of the study

The finding of this study could be the most relevant for research-based universities as data were collected from this type of universities. Since the programme delivery methods between the research and teaching based universities can be substantially different, the finding of this study should be carefully applied if referred by teaching-based universities. Besides, this study only exclusively targeted on the chemical engineering discipline, the proposed integration approach could be more relevant for the undergraduate chemical engineering programme because the degree of emphasis on sustainability and the integration approaches could differ with engineering disciplines.

5. Conclusion

The study revealed that the Chemical Engineering students in Malaysia generally had a moderate to high level of knowledge and interest on SD. The curricular analysis showed that the universities studied in this work used both the horizontal and vertical approaches in integrating SD into their chemical engineering curricula, with a preference for the horizontal approach over the vertical approach. They also used both compulsory and elective courses as means for delivering the SD knowledge. Nevertheless, the analyses of this study showed that the vertical approach had a higher influence on the Chemical Engineering undergraduates' knowledge and interest on SD.
which proved as more effective means for delivery of sustainability knowledge for the chemical engineering students. The present finding is also in contrary to the suggestion by previous researchers based on the Western countries context. The finding of this study posed a doubt on whether the horizontal approach is suitable for the Asian institutions and it also suggested that there is a need for critical analysis of the use of the horizontal approach for sustainability integration into the engineering education. Though this study was based on the Malaysian scenario, this information can serve as a reference for the other universities in the Asian region due to the similarity these countries share in terms of cultures and progresses in education for sustainable development. It also provides a reference for overseas universities for future review of their own integration strategies, especially for universities that plan to establish their universities in the Asian region.

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