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Enhancing sustainability performance of universities: A DMAIC approach

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Abstract

This paper aims to assess and improve the sustainability performance at a higher educational institute (HEI) in UAE using DMAIC methodology, considering five sustainability aspects (knowledge, behaviour, concern, awareness and attitude). One primary and six secondary research questions were defined in the define phase. In the measure phase, a questionnaire was designed to measure the current sustainability level based on the five sustainability aspects. A questionnaire was distributed among campus populations and statistically analysed in the analysis phase. Participation in UI GreenMetric was used in the control phase to monitor the performance from 2018 to 2020. It was found that the communication college has the lowest sustainability level at 25% marginal error compared with other colleges. Also, students have the lowest sustainability level compared with faculty and staff at a 15% marginal error. The proposed framework can help HEI decision-makers assess their sustainability levels and suggest plans to enhance sustainability performance.

KEYWORDS

DMAIC, educational institutions, educational sustainability, sustainability performance

1 | INTRODUCTION

Higher educational institutes (HEIs) play an influential role in sustainable development and are considered important partners in accomplishing sustainability goals, given their primary role as knowledge providers. HEIs try to respond to existing complicated sustainability problems, such as climate change by educating people towards more sustainable ways (Reimers, **2021**). They also help address sustainability awareness and other environmental aspects, including carbon footprint, energy and water consumption (Lopes et al., **2018**). HEIs should pay attention to the sustainability of curricula, the campus and its environment and the behaviour of individuals on campus (Wiek et al., **2011**). Therefore, HEIs should continuously assess and improve their sustainability levels. This requirement creates a need for a holistic approach to assessing and moving the institution towards a more sustainable one, covering all relatable areas.

The sustainability tracking, assessment and rating system (STARS) and the UI GreenMetric are two sustainability rating systems for HEIs (Alshuwaikhat et al., **2016**; Caeiro et al., **2020**). Regardless of the rating

system used, the most challenging aspects are knowledge, behaviour, concern, awareness and attitude of the individuals living and using the HEI. Assessing and understanding these aspects and measuring their levels at any HEI is essential to help achieve better recommendations and excellent sustainability performance results. Based on the conducted literature review results, we inferred that none of the previous works considered measuring all five sustainability aspects (knowledge, behaviour, concern, awareness and attitude) in one study.

Monitoring sustainability performance should be done continuously. The DMAIC approach is a six sigma tool for problem-solving and improvement (Hambleton, **2007**). It is a systematic continuous improvement approach for process improvement and quality (Rifqi et al., **2021**). It was implemented successfully in different sectors, such as banking (Kumar, **2014**), health care (Smith et al., **2011**), manufacturing (Jirasukprasert et al., **2014**), process improvement (Shahada & Alsyouf, **2012**) and baggage flow systems (Alsyouf, Kumar, et al., **2018**). However, according to the authors' knowledge, the DMAIC methodology was not used previously to assess sustainability performance in an HEI. Therefore, this paper aims to assess and improve the sustainability performance of HEIs using the DMAIC methodology, considering all five sustainability aspects (knowledge, behaviour, concern, awareness and attitude). DMAIC methodology is chosen as it is a structured data-driven improvement cycle and helps solve problems by providing a road map for solutions (Baraka & Yadavalli, **2020**). A great advantage of this tool is the control phase, which allows the user to develop plans and monitor the suggested improvements and continuously achieve long-term success (Bass, **2017**). Thus, it can be used efficiently and effectively to achieve the study's aim.

This paper aims to assess the five aspects of sustainability considering different campus populations (students, faculty and staff) and colleges within the same HEI to provide recommendations for improvement that are aligned with the international sustainability rating systems. The DMAIC approach is used to achieve this target and to answer the following research question: 'How can the HEI's sustainability level be improved?'. This paper's novelty is using a structured and systematic approach, that is, the DMAIC methodology that comprehensively assesses sustainability awareness while considering all five sustainability aspects. Furthermore, the study reports the results of 4 years of verifying the suggested approach at one HEI that has achieved excellent results in UI GreenMetric since 2017 by implementing the suggested DMAIC methodology.

The organization of this paper is as follows: Section 2 presents a literature review. Section 3 presents the research objective and question, and Section 4 presents the research methodology. Section 5 provides the results and discussions of the analysis phase. Section 6 provides managerial insights and actions, and Section 7 is the conclusion of the paper.

2 | LITERATURE REVIEW

As the scope of this paper is to assess the sustainability level in an educational institute and provide recommendations based on the requirements of international sustainability standards, in the following subsections, we review previous research on assessing sustainability in HEIs. Then, we summarize the work done using international sustainability standards and the work done on the domains measured in this study (knowledge, behaviour, concern, awareness and attitude). Finally introducing some successful applications of the DMAIC methodology in several domains. The literature review was conducted based on available research papers in databases, such as Scopus, Taylor and Francis and Google Scholar, using the following keywords, sustainability, higher education and education institutions, and using combinations, such as higher education sustainability, educational sustainability and sustainability performance in higher education institutes. The review focused on research papers from 2000 to 2022. Table 1 shows the criteria for inclusion/exclusion of the research papers found.

TABLE 1 Search criterion.

Criteria	Inclusion	Exclusion
Keywords	With keywords—sustainability AND higher education OR sustainability performance OR higher education sustainability OR sustainability in educational institutes. Rating systems, STARS, GreenMetric, DMAIC	Not related to sustainability Not related to DMAIC Not related to sustainability rating systems
Language	English	Other languages
Type of publication	Articles, journals, conference paper, reports and book chapters	News or letters.
Year	2000 to current	Before 2000
Publication status	Final	Draft/in progress

2.1 | Sustainability assessment in HEIs

Scholars and researchers used different techniques and tools to study various sustainability aspects. For instance, Shriberg (2002) analysed cross-institutional assessment tools in terms of advancement and closeness to be ideal for measuring sustainability in HEIs. Critical parameters for sustainability include sustainability in education as part of the curriculum and pursuing change incrementally and systematically, simultaneously. Velazquez et al. (2005) studied the factors causing difficulties in implementing sustainability in HEI. They found that sustainability initiatives on campus are flourishing regardless of these difficulties. Moreover, Velazquez et al. (2006) provided a managerial model for a sustainable university with data from 80 educational institutions that shows how people achieve the beginning force to advance sustainability initiatives to higher steps to become a sustainable institute. Moreover, Lozano (2011) analysed sustainability reports of 12 HEIs and concluded that sustainability reporting is yet in its initial stages. Liu (2021) discussed student mobility and internationalization of higher education.

Nejati and Nejati (2013) investigated the understanding of 379 HEI students towards sustainable university factors. The factors identified are land use, waste, energy, planning, community outreach, commitment and sustainability monitoring. Vicente-Molina et al. (2013) analysed the effect of environmental knowledge and behaviour on students in different countries with different economic levels. Lozano and Watson (2013) proposed a sustainability tool for assessing universities' curricula holistically based on its implementation in two different universities to dictate the current sustainability level of university education and to identify ways to improve it. Kościelniak (2014) analysed the implementation of sustainability in universities in Poland. They presented the challenges to sustainable universities and the level of sustainability implementation in universities. Zdanytė et al. (2014) provided an outline of the advancement in implementing sustainable development in Lithuanian universities to identify ways to expand its implementation.

In addition, Dagiliute and Liobikiene (2015) evaluated the environmental and sustainability opportunities such as sustainability policies, research and curriculum that leads to environmental sustainability at one of the educational institutions in Lithuania. They found that environmental courses provided to students contribute to achieving environmental sustainability by reaching and encouraging students with lower environmental commitment. Also, educational institutions' policies to promote environmental sustainability should be regular and continuous. Abubakar et al. (2016) assessed sustainability awareness in Saudi Arabia by conducting a survey on 152 students from the College of Architecture and Planning at the University of Dammam. Dagiliūtė et al. (2018) compared the students' attitudes towards sustainability between two universities, where one of them is classified as a green university and the other is not. The results based on the depicted survey manifest that there are no notable differences between green and non-green universities in sustainability aspects. As for sustainability attitude, Yapici et al. (2017) assisted the students' environmental attitude and risk perception in Mersin, Turkey, by distributing a questionnaire to 775 students. The results showed a high attitude but low awareness levels. Furthermore, Jung et al. (2019) investigated the behaviour and concern of students that are enrolled in construction-related courses. The results indicated a low environmental concern and behaviour level, resulting in designing a sustainability curriculum to enhance the student's learning experience. Based on the previous research work and to the best of the authors' knowledge, no study compared the sustainability level of colleges within the same university. Hence, we compare sustainability levels between different colleges. Because of its direct interaction with sustainability concepts, we hypothesize that the college of engineering has a higher sustainability level than other colleges (Hypothesis 1). Kivati (2017) analysed the effect of globalizing the educational system and its effect on getting individuals ready for sustainability challenges in Kenya. Katiliūtė et al. (2017) presented how the administrative staff helped in designing a sustainable campus through interviews and provided proposals for universities to implement to achieve sustainability. Lăzăroiu (2017) stated that universities must make convincing undertakings to instruct for sustainability to prevent eventual risk and acquiring rewards. The existing curriculum should be up to date to incorporate sustainability. Furthermore, Hamdan et al. (2020) reported higher behaviour towards sustainability in male students than in female students. However, the work of Hamdan et al. (2020) considered only the behaviour aspect and not the other aspects. Hence, we expand their study to include other sustainability aspects (knowledge, concern, awareness and attitude). We follow the results of Hamdan et al. (2020) and hypothesize that males have a higher sustainability level compared with females in the other aspects (Hypothesis 2). Alsyouf (2020) introduced and implemented a new concept that he named the 'Sustainability Circles' as a tool to enhance sustainability performance by engaging all the university stakeholders. Pocol et al. (2022) applied a two-step cluster analysis to identify groups of francophone socio-economic organizations willing to engage in

co-creating knowledge with universities to adapt the curriculum to the labour market's requirements and ensure sustainable education.

Zwickle et al. (2014) developed an assessment survey to measure sustainability knowledge, and it was analysed using item response theory. Because studying campus sustainability helps in raising awareness in the university's community, Msengi et al. (2019) assessed the student's knowledge and awareness of sustainability initiatives on campus by distributing a seven-category questionnaire based on AASHE Stars campus sustainability survey in the United States. In India, Mir and Khan (2018) studied the perception of students towards different sustainability aspects, including knowledge, attitudes and behaviours. Based on a sample of 437 students at three universities in India, it was found that students' knowledge and behaviour towards sustainability are very low. However, they have a positive attitude. Based on the results of those studies, we hypothesize that students have a lower sustainability knowledge level than the faculty and staff because of the educational difference between the two groups (Hypothesis 3).

2.2 | International sustainability rating systems

Scholars and researchers studied different rating systems in assessing sustainability in HEIs. For instance, Alberta University (2011) contributed to developing a sustainability assessment and monitoring system through annual reporting of the progress to evaluate future sustainability trends. Their concern is on engaging students because their participation will lead to achieving sustainability goals. Fadzil et al. (2012) studied the campus sustainability assessment framework (CSAF) and the STARS to develop a framework for University Kebangsaan Malaysia (UKM). They found that CSAF and STARS do not concentrate on the construction industry or developing buildings physically as a key factor for the campus sustainability assessment and framework because the physical development elements are evaluated by building assessments such as LEED. Urbanski and Filho (2015) analysed STARS data and found that the sustainability definition varies within HEIs and also institutions offering graduate studies have the highest participation in STARS. Also, Salvioni et al. (2017) analysed the information of three universities ranked among the top 500 universities to study the relationship between the sustainability culture and the university ranking and compared it with STARS data for the same universities. Note that sustainability culture refers to maintaining cultural beliefs and practices related to sustainability (Soini & Birkeland, 2014). It was found that universities with high ranking have a management approach based on sustainability. Marans and Callewaert (2017) focused on applying the sustainability cultural indicators programme to assess the enlargement of the waste composting programme only in their university. This was done for 17 undergraduate residence halls in one of the universities.

Moreover, Suwartha and Sari (2013) evaluated the result of UI GreenMetric Ranking for the year 2011 ranking using a descriptive and qualitative approach. As a result, it was inferred that there is an elevating in the number of countries participating in the ranking system and that the UI GreenMetric Ranking gives a chance for each participating university to observe its strength and weakness so that it achieves sustainable development. Presekal et al. (2018) evaluated the annual electricity consumption of participating educational institutes in UI GreenMetric Ranking 2017 using regression analysis based on each country's consumption rate per capita. As a result, it was found that some universities have a higher consumption rate than their country's average rate per capita.

Further, Larrán Jorge et al. (2016) developed a multicomponent quantitative tool to measure university sustainability performance based on a comprehensive literature review. Different items were identified and discussed with the top management of eight different Spanish universities to identify sustainability performance. They comprised 155 indicators grouped into seven categories: environment, corporate governance, society, students, staff, companies and continuous improvement. Bullock and Wilder (2016) developed an evaluation framework consisting of the Global Reporting Initiative and the Association of University Leaders for a Sustainable Future to break down the thoroughness of nine sustainability assessment frameworks for HEIs. It was found that these frameworks are not comprehensive and do not cover the social and economic pillars of sustainability. Berchin et al. (2017) reviewed sustainability in higher education literature to identify the frequent sustainability actions taking a Brazilian federal institute of higher education as a case study, to show how sustainability actions are being implemented. It was found that concerns about sustainability made the federal HEI change its procedure and organizational culture to approach sustainability.

2.3 | Application of DMAIC in different domains

The DMAIC method has been widely used in manufacturing and service industries. For instance,

Gentili et al. (2006) aimed to improve the efficiency and effectiveness of a manufacturing line using lean six sigma and DMAIC methodology. Shahada and Alsyouf (2012) proposed a lean six sigma methodology based on the DMAIC improvement method. They verified it in a case study of make-to-order projects in one of the engineering companies. Besides, Bhat et al. (2014) investigated applying lean six sigma DMAIC to improve the registration process in the Indian healthcare sector. Alsyouf et al. (2014) conducted a study in one of the international airports using the DMAIC method to identify the reasons for mishandled baggage. Abdul and Purwatmini (2016) applied the DMAIC method to improve the quality of call centre service as well as the service blueprint tool to analyse the relationship between quality improvement using DMAIC, customer contact and evidence from customer service. In India, Gupta et al. (2018) used the DMAIC methodology to enhance the tire manufacturing process by reducing the number of defective items. Hakimi et al. (2018) aimed for the production process quality improvement using the DMAIC methodology, focusing on the customer requirement using the design of the experiment tool. Alsyouf, Alsuwaidi, et al. (2018) applied lean six sigma using DMAIC to upgrade the baggage flow performance in a baggage handling system. Shamsuzzaman et al. (2018) implemented the DMAIC methodology in a telecom company to increase customer satisfaction.

2.4 | Research gap analysis and contribution

Table 2 summarizes the reviewed papers based on the scope, country and type. The research in this domain was done either to measure and assess the sustainability level or to improve it, utilizing the international rating systems. However, to the best of the authors' knowledge, no previous work has considered assessing the sustainability level in a continuous improvement framework using the DMAIC methodology in an HEI. Furthermore, some of the previous studies considered multiple HEIs and compared them as the sustainability level differs from one HEI to another based on the location, the available colleges and academic programmes and the individuals. None of the previous works considered all the five sustainability aspects (knowledge, behaviour, concern, awareness and attitude).

Therefore, in this paper, we will assess the sustainability level of knowledge, behaviour, concern, awareness and attitude between different campus populations (students, faculty and staff) and colleges within the same HEI to provide recommendations for improvement that are aligned to the international sustainability rating systems. We will use the DMAIC approach to achieve this target. In addition, we will consider the entire campus population (students, faculty and staff) in the same HEI. Unlike other studies, we will investigate all five sustainability aspects knowledge, behaviour, concern, awareness and attitude. Also, we will calculate the sustainability level for each college and conduct a comparison using statistical analysis.

This work will help decision-makers at HEIs identify sustainability weaknesses and gaps so they can design the right and efficient programmes to boost their sustainability performance. Furthermore, the proposed framework will help them achieve continuous improvement by monitoring the institute's performance.

3 | RESEARCH OBJECTIVE AND QUESTION

The HEI aims to measure its sustainability level among the different campus populations (students, staff and faculty) to achieve sustainability excellence. This paper plans to address the following main research question (RQ), which was defined in consensus after analysing similar cases.

> **RQ.** How can the HEI's sustainability level be improved?

Improving the sustainability level requires understanding the current situation, identifying weaknesses (low-level groups) and preparing action plans to achieve improvement. The following secondary research questions (SRQs) were defined to facilitate answering the main research question.

- **SRQ1**. What is each campus population's knowledge, behaviour, concern, awareness and attitude level, and what is the HEI's sustainability position?
- **SRQ2**. Which campus population(s) (student, staff or faculty) have the lowest sustainability level? Are the sustainability level differences significant?
- **SRQ3**. Which gender has a high sustainability level, and which one needs more attention and focus? Are the sustainability level differences significant?
- **SRQ4**. Which college(s) have the lowest sustainability level? Are the sustainability level differences significant?
- **SRQ5**. What are the main causes of the low sustainability level?
- **SRQ6**. What type of actions need to be taken by decision-makers to enhance the sustainability level?

TABLE 2 Literature review summary.

Paper	Study country	Study type	Study focus
Shriberg (2002)		HEI	Cross-institutional assessment tools
Velazquez et al. (2005)		HEI	Factors behind difficulties in sustainability implementation
Velazquez et al. (2006)		Educational institution	
Lozano (2011)		University reports	
Nejati and Nejati (2013)		HEI	Land use, waste, energy, planning, community outreach, commitment and sustainability monitoring
Vicente-Molina et al. (2013)	Different countries	HEI	Environmental knowledge and behaviour
Lozano and Watson (2013)		HEI	University curricula
Kościelniak (2014)	Poland		
Zdanytė et al. (2014)	Lithuania	HEI	Sustainable development implementation
Dagiliute and Liobikiene (2015)	Lithuania	Education institute	Environmental sustainability
Abubakar et al. (2016)	Saudi Arabia	HEI	Sustainability awareness
Kivati (2017)	Kenya		Effect of globalizing the educational system
Katiliūtė et al. (2017)		HEI	Role of administrative staff in designing sustainable campus
Dagiliūtė et al. (2018)		HEI	Sustainability attitude
Mir and Khan (2018)	India	HEI	Sustainability knowledge, attitude, behaviour
Hamdan et al. (2020)	UAE	HEI	Sustainability behaviour
Alsyouf (2020)	UAE	HEI	Sustainability performance
Alberta University (2011)	Canada	HEI	Sustainability assessment and monitoring
Fadzil et al. (2012)	Malaysia	HEI	Sustainability rating systems (CSAF) and (STARS)
Urbanski and Filho (2015)		HEI	Sustainability rating systems (STARS)
Salvioni et al. (2017)		HEI	Sustainability rating systems (STARS)
Marans and Callewaert (2017)		HEI	Environment (waste composting programme)
Suwartha and Sari (2013)		HEI	Sustainability rating systems (UI GreenMetric)
Presekal et al. (2018)		HEI	Sustainability rating systems (UI GreenMetric)
Larrán Jorge et al. (2016)	Spain	HEI	Sustainability performance in universities
Bullock and Wilder (2016)		HEI	Sustainability evaluation framework
Berchin et al. (2017)	Brazil		Sustainability actions
Zwickle et al. (2014)			Sustainability knowledge
Msengi et al. (2019)	United States	HEI	Sustainability knowledge and awareness
Onder (2006)	Turkey	HEI	Sustainability awareness and behaviour
Yapici et al. (2017)	Turkey	HEI	Sustainability attitude
Jung et al. (2019)		HEI	Sustainability behaviour and concern
Gentili et al. (2006)		Manufacturing	DMAIC and lean six sigma
Shahada and Alsyouf (2012)		Engineering company	Lean six sigma
Bhat et al. (2014)	India	Health care sector	Lean six sigma
Alsyouf et al. (2014)		Airport	DMAIC
Abdul and Purwatmini (2016)		Call centre	DMAIC
Gupta et al. (2018)	India	Manufacturing	DMAIC
Hakimi et al. (2018)		Production	DMAIC
Alsyouf, Alsuwaidi, et al. (2018)		Baggage handling	DMAIC
Shamsuzzaman et al. (2018)		Telecom company	DMAIC

The secondary research questions (SRQ1 through SRQ4) are addressed by exploring the sustainability level based on the knowledge, behaviour, concern, awareness and attitude separately, and then an overall level of sustainability combining all the sustainability aspects is considered. The fifth and sixth secondary research questions (SRQ5 and SRQ6) are addressed based on the results of the first four research questions and through brainstorming sessions with decision-makers while utilizing the available international sustainability rating systems.

The proposed hypotheses are derived from the literature:

- Hypothesis 1: 'The Engineering college sustainability level is higher than other colleges as more sustainability courses are offered as well as the renewable and sustainable major taught.'
- Hypothesis 2: 'Males have higher awareness levels than Females due to higher literacy rates 90.0% compared to 82.7%.'
- Hypothesis 3: 'Students have a lower sustainability knowledge level than the faculty and staff because of the educational difference between the two groups.'

4 | RESEARCH METHODOLOGY

In this paper, we adopted the six sigma DMAIC improvement methodology with its five phases (define, measure, analyse, implement and control). In the 'define' phase, the research questions are set (see Section 3). These research questions are answered throughout the other phases. A data collection plan is prepared in the 'measure' phase, and the needed tools are identified. The gathered data are analysed in the next phase (the 'analyse' phase), and the results are discussed. The 'implement' phase delivers recommendations and action plans to enhance sustainability. The performance and sustainability levels are monitored in the 'control' phase, as shown in Figure 1.

This paper aims to assess the level of sustainability based on the HEI's knowledge, behaviour, concern, awareness and attitude. Thus, a research survey is the most suitable tool to collect the needed data. The research survey elements are explained in the 'measure' phase. Moreover, this work uses descriptive statistics and hypothesis testing to analyse and compare the sustainability level among different groups, as explained in the 'analyse' phase. Thirty brainstorming sessions are conducted across different sustainability circles, and several focus group meetings with decision-makers (e.g., the sustainability office director and the leaders of each sustainability circle) are used to prepare recommendations and action plans for the 'implement' phase. Finally, participation in the UI GreenMetric Ranking is used to measure and control the international sustainability performance level and benchmark it with other universities.

4.1 | Data collection (DMAIC's phase 2: Measure)

This phase's purpose is to create a data collection plan that works as a tool to disclose the performance indicators. The data collection plan consists of distributing a research survey design to measure the sustainability level and submitting an application to the UI GreenMetric Ranking (http://greenmetric.ui.ac.id/) to benchmark the sustainability level with other universities. Designing a research survey requires defining the following elements: the questionnaire design, the survey procedure and the sample design (Alsyouf, Alsuwaidi, et al., **2018**; Prickett & Rapley, **2001**). In the following subsections, we detail the three elements of the survey design.

4.1.1 | Questionnaire design

The questionnaire design is constructed to cover all the targeted sustainability aspects (knowledge, behaviour, concern, awareness and attitude) and to collect general information about the respondents (such as role, student's academic level, college and gender). This general information helps in analysing different campus populations. As discussed in Section 2, some research work targeted sustainability aspects, such as the work of Mir and Khan (**2018**), which targeted knowledge, behaviour and attitude; the work of Abubakar et al. (**2016**), which targeted the awareness aspect; and the work of Jung et al. (**2019**), which targeted the behaviour and concern aspects. The developed questionnaire questions were based on a literature review and encouraged by the works of Blok et al. (**2015**) and Gericke et al. (**2019**) and based on the context of HEI country.

A binary scale (0 or 1) was used for each yes/no question, and a 5-point Likert scale was used for each multiple-choice question in the questionnaire. This approach has been used intensively in the literature in different domains, such as quality management (Alsyouf, Alsuwaidi, et al., **2018**), project management (Hamdan et al., **2019**; Ruqaishi & Bashir, **2015**) and psychology (Koh, **1996**).

The knowledge section consisted of five questions; a correct answer to each question is counted as one point (binary scale). In the awareness section, nine (yes or no) questions were used to determine the awareness level. A binary scale is used in this section, where each 'yes' counts as one point resulting in a total score of nine.

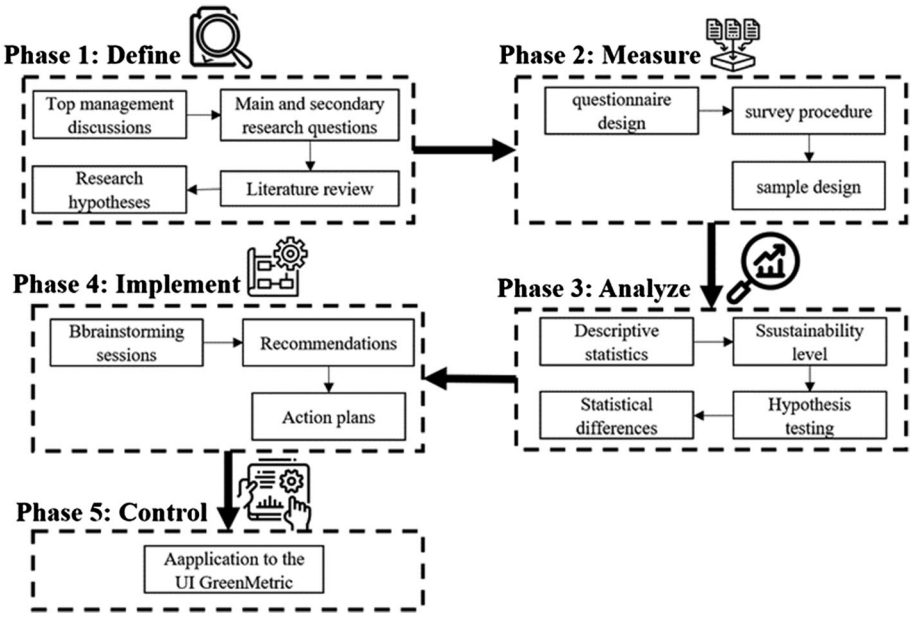

FIGURE 1 Research plan using DMAIC methodology.

Similar to the awareness section, the attitude section contained 12 questions of the type yes/no.

The behaviour section held 23 questions about the participants' daily activities, and the concerns section consisted of eight questions to measure the participants' concerns towards achieving sustainability in the HEI, such as sustainability initiatives on campus, recycling, climate action planning and waste minimization. A 5-point Likert scale from strongly disagree (1) to strongly agree (5) (Joshi et al., **2015**) is used to measure the respondents' agreement level on statements related to both the behaviour and concern sections. As a result, the behaviour section has a maximum of (23×5) 115 points, and the concerns section has a maximum of (8×5) 40 points. Using a Likert scale helps analyse the questionnaire and establish the required data for the hypothesis testing. Figure 2 illustrates the part of the survey.

Furthermore, the following two measures are included:

1. The overall sustainability level is calculated by measuring the total score in all the sustainability aspects.
2. The normalized overall level is calculated as the total normalized score for each aspect (i.e., by dividing the score of each aspect by its total score and then adding all the normalized scores) to eliminate the effect of scale and number of questions.

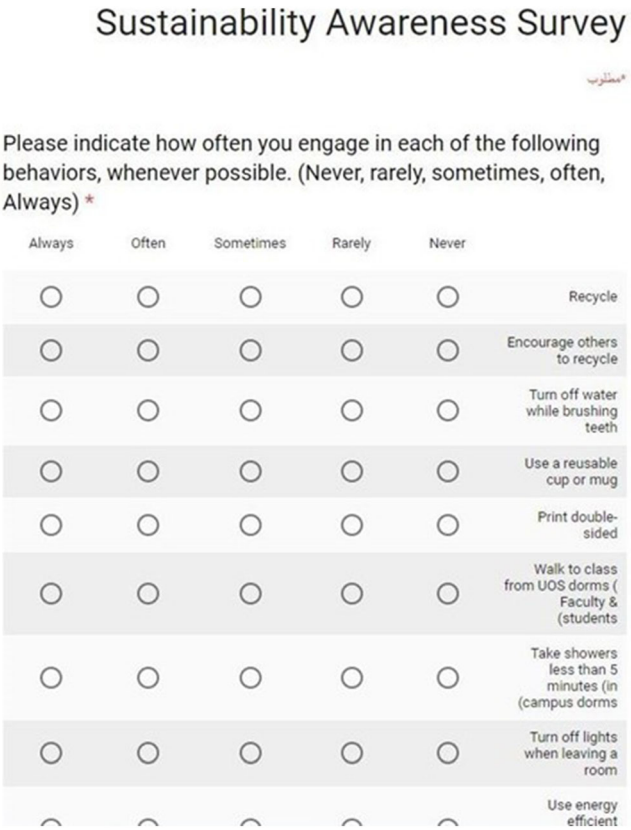

FIGURE 2 Part of the survey questions. [Colour figure can be viewed at wileyonlinelibrary.com]

4.1.2 | Survey procedure

The questionnaire was prepared in an online format. A pilot study was conducted enable to test the reliability, clarity and validity of the questionnaire, by distributing the questionnaire to randomly selected individuals on the campus to get their feedback on the questionnaire design and questions. Feedback and comments were taken into consideration to improve the questionnaire. The questionnaire

was distributed to all students, staff and faculty members in the HEI via email. Participation in the questionnaire was optional and anonymous. It was available for the period 12th of March 2018 to the 5th of April 2018. A weekly reminder email from the chancellor's office was sent to encourage the community to participate.

4.1.3 | Sample design

The targeted population is the campus students, staff members and faculty members. The total number of students, staff and faculty was 16 587 in 2018. The minimum required sample size (using Equation 1) is estimated to be 391 respondents assuming a 5% marginal error. Equation (1) presents Yamane's (**1967**) modified sample size equation that is developed based on the formula of Cochran (**1963**). Equation (1) uses the population size (N) and the marginal error (e) to calculate the minimum required sample size (n). The number of respondents at the end of the survey duration was 646, which corresponds to a response rate of 3.89%. Note that the minimum representative sample rate is 2.36% for a marginal error of 5%. This sample size can be seen as a representative sample size as it is greater than the minimum required sample size (391) for this population.

$$n = \frac{N}{1 + N(e^2)} \quad (1)$$

Moreover, the minimum sample size for each group (gender-based, population-based, college-based, etc.) at different marginal error is given in Table 3. Note here that because the sampling technique was simply random, that is, the questionnaire was sent to the entire HEI population and not targeting each group individually, it was difficult to force population in a specific group to respond. This resulted in a small sample size for some groups such as the group of art and humanity, medicine and communication. Therefore, during the analysis, the marginal error will be stated. In the case of the comparison between the two groups, the highest marginal error among the group will be mentioned. By doing so, we present a conclusion with its potential marginal error.

4.2 | Questionnaire analysis method

Descriptive statistics and hypothesis testing are used to answer the SRQs. Mean, median and interquartile range as descriptive statistics measures are used to answer SRQ1. Equation (2) is used to determine if the sustainability level is statistically low or high, where Ω_i is the

TABLE 3 Minimum required sample size for each group.

Marginal error	5%	10%	15%	20%	25%
Gender					
Males	373	**98**	44	25	16
Female	**384**	99	44	25	16
Population					
Faculty	247	87	**42**	24	16
Staff	306	93	**43**	25	16
Faculty and staff	332	**95**	43	25	16
Students	**388**	99	44	25	16
College					
Engineering	360	**97**	44	25	16
Health sciences	304	93	**43**	25	16
Business administrations	289	91	**43**	24	16
Arts and humanities	316	94	43	**25**	16
Communication	287	91	43	24	**16**
Dental medicine	251	87	42	24	**16**
Fine arts and design	217	83	41	24	**15**
Medicine	274	90	42	**24**	16
Pharmacy	248	87	42	24	**16**
Sciences	268	89	**42**	24	16

Note: Bold values represent the case where the collected sample size from the questionnaire is greater than or equal to the minimum sample size.

mid-score of the i^{th} sustainability aspect. The first set (S_1^i in Equation 2) tests the sustainability level for the i^{th} aspect, where i represents the knowledge level, the behavior level, the concern level, the awareness level, the attitude level, the overall level and the normalized overall level.

The mid-score value for each aspect is given in Table 4. H_0^i in S_1^i represents the null hypothesis for the i^{th} sustainability aspect, and it indicates that the median score is below or equal to the mid score. H_1^i represents the alternative hypothesis, where selecting H_1^i means that a group achieves a higher score than the mid score.

$$S_1^i = \begin{cases} H_0^i : \tilde{\mu}^i = \Omega_i \\ H_1^i : \tilde{\mu}^i > \Omega_i \end{cases} \qquad \forall i = 1...6 \tag{2}$$

Equation (3) is used to compare the sustainability level among different groups (SRQ2–SRQ4). For instance, if one wants to check if sustainability behaviour is higher or lower among males compared with females. The process of determining the sustainability level and comparing the sustainability level between any two groups are illustrated in Figures 3 and 4, respectively.

$$S_{2.1}^i = \begin{cases} H_0 : \tilde{\mu}_A^i = \tilde{\mu}_B^i \\ H_1 : \tilde{\mu}_A^i \neq \tilde{\mu}_B^i \end{cases} \rightarrow S_{2.2}^i = \begin{cases} H_0 : \tilde{\mu}_A^i = \tilde{\mu}_B^i \\ H_1 : \tilde{\mu}_A^i > \tilde{\mu}_B^i \end{cases} \qquad \forall i = 1...6 \tag{3}$$

The second set containing $S_{2.1}^i$ and $S_{2.2}^i$ compares the i^{th} sustainability aspect between group A and group B. As shown in Figure 4, the hypothesis $S_{2.1}^i$ tests if the two groups differ from each other or not, where if a difference exists, the hypothesis $S_{2.2}^i$ is used to identify which group has a higher score than the other. The null hypothesis (H_0^i) in $S_{2.1}^i$ indicates that the two groups have similar sustainability levels, whereas the alternative hypothesis (H_1^i) in $S_{2.1}^i$ indicates that their sustainability levels are different. The null hypothesis (H_0^i) in $S_{2.2}^i$ means that group B has a statistically higher sustainability level than group A (after rejecting H_0^i in $S_{2.1}^i$), whereas the alternative hypothesis (H_1^i) in $S_{2.2}^i$ shows that group A has a statistically higher median than group B.

TABLE 4 Mid-score values used in the hypothesis testing of S_1^i.

i	Sustainability aspect	Mid-score value (Ω_i)
1	Knowledge	2.5
2	Behaviour	57.5
3	Concern	20
4	Awareness	4.5
5	Attitude	6
6	Overall	90.5
7	Normalized overall	2.5

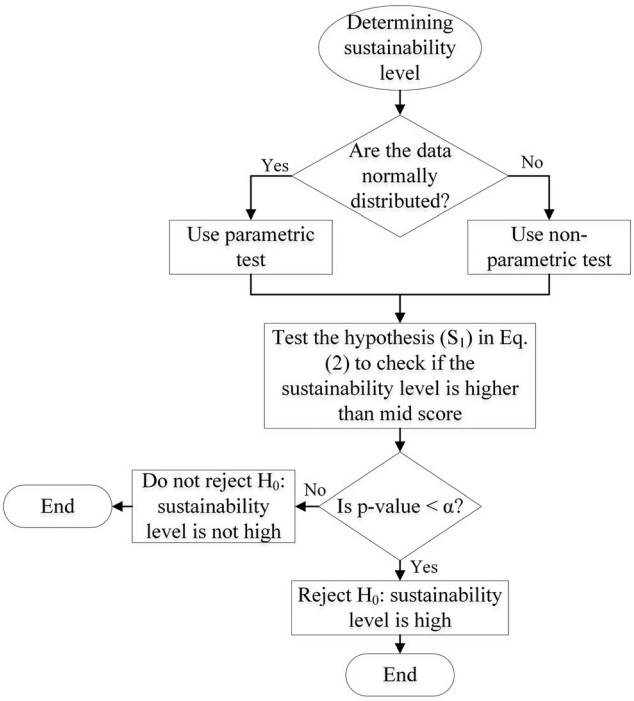

FIGURE 3 Process of determining the sustainability level.

5 | RESULTS AND DISCUSSIONS (DMAIC'S PHASE 3: ANALYSE)

In this phase, the obtained data from the questionnaire and the results of the UI GreenMetric Ranking are analysed to facilitate answering the research questions.

5.1 | Summary of the participants

The total number of questionnaire participants was 646, with 408 female participants (63.16%). We find it reasonable to have such a percentage of female participants because the total female percentage in the HEI is 63.77%. The female sample is considered representative at 5% marginal error, as shown in Table 3. Students were the most active category who participated in this questionnaire (75.70%), followed by the staff category (13.78%) and then the faculty category (10.53%). These percentages are close to the population distribution (students, 87.3%;

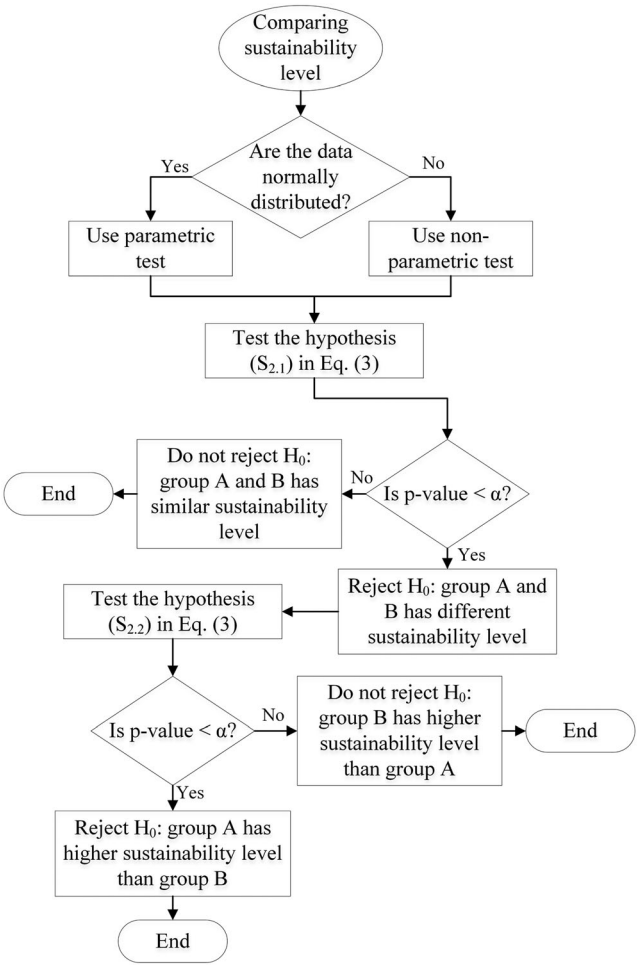

FIGURE 4 Process of comparing sustainability level between any two groups.

staff, 8.5%; and faculty, 4.2%). Students' participation in the survey is considered representative with a marginal error of 5%, and the faculty group and staff group are acceptable with a marginal error of 15%, as in Table 3. The majority of the participants were living outside the campus (71.36%). Figure 5 illustrates the gender distribution of participants based on their role (student, faculty and staff) and shows the students' distribution based on their study level (graduate or undergraduate). The undergraduate level is divided into freshman (1st-year student), sophomore (2nd-year student), junior (3rd-year student) and senior (4th-year student or more). The graduate level represents students pursuing their master's and doctoral studies. Female participants were higher than male participants in all categories except for the faculty members, and senior students were the most active campus population (Figure 5). Engineering participants were the highest among other colleges, followed by the participants from the health sciences (Figure 6). Most of the participants were staying off campus (Figure 7). The high level of off-campus participants comes from the staff (92.13%) and students (75.05%), as several students choose to commute to the university, and the university provides accommodation to faculty members, students and senior staff members.

5.2 | Sustainability levels

Figure 8 shows the median and the interquartile range of the normalized sustainability level based on gender, role and college. Males, faculty and the college of medicine have the highest sustainability levels in their categories. Table 5 gives the median sustainability score under each aspect for the different categories. Table 5 shows that the slightly higher males' normalized overall level comes from the behaviour aspect. Faculty members have higher sustainability knowledge, awareness and attitude than staff. Fine arts and design college has the lowest knowledge and awareness levels. Communication has the lowest behavioural level and concern level (Table 5). Variability in the results is found to be low (between 0.1 and 0.3). It is worth considering the impact of the sample size and variability in judging the significance of these results. Thus, we apply statistical tests in the following section.

5.3 | Impact of variability and sample size on the sustainability results

Variability and sample size play critical roles in affecting the significance of the results. We conduct hypothesis tests to judge whether results vary significantly—two hypotheses we tested. The first hypothesis set is to check whether sustainability levels are more significant than the mid-score. The second hypothesis set is to judge the statistical difference between different categories. The questionnaire results were found to be not normally distributed using a Shapiro–Wilk test with a significance level of 5%. Thus, non-parametric tests based on the median values instead of mean values are used. The first hypothesis test for S_1^i (Equation 2) is carried out using the one-sample non-parametric sign test, and the hypothesis testing for $S_{2.1}^i$ and $S_{2.2}^i$ (Equation 3) are carried out using the independent non-parametric Wilcoxon–Mann–Whitney test. Table 6 shows the *p*-value results of the statistical analysis using Equation (2). A *p*-value smaller than 0.05 means that the null hypothesis is rejected. That is, the median value is greater than the mid-score indicating a higher sustainability aspect level. Values less than the significance level (0.05) are replaced with an asterisk (*) for better readability.

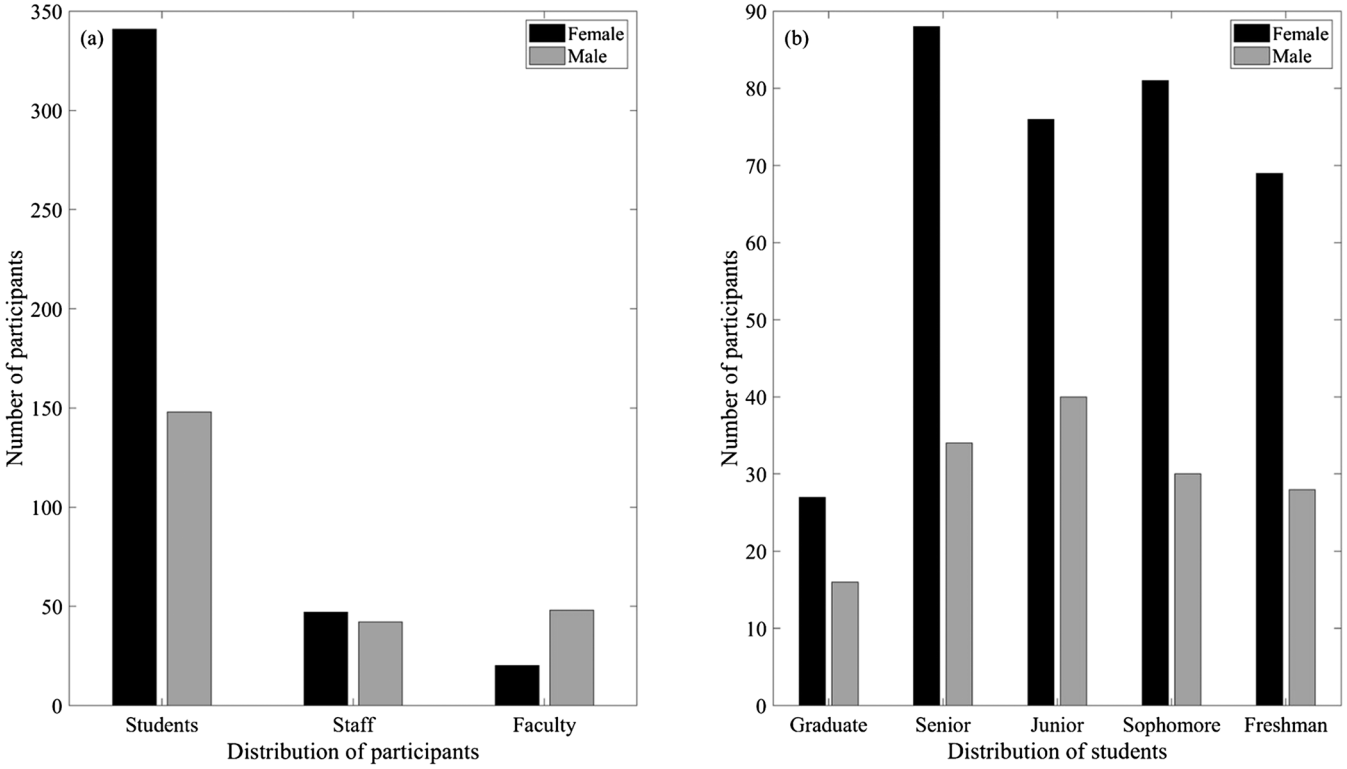

FIGURE 5 Females and males distribution.

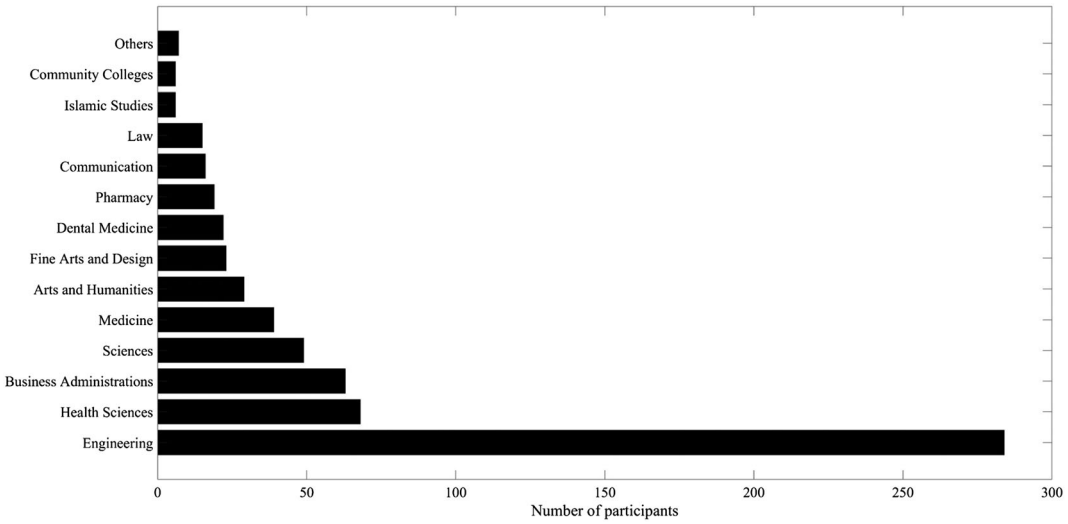

FIGURE 6 Participants based on their college.

The knowledge aspect is significantly low in all categories (gender, campus populations and colleges), whereas the other sustainability aspects are high based on gender and campus population. Low knowledge levels could be due to the low number of sustainability-related events and courses. However, the arts and humanities college showed significantly low sustainability behaviour with a marginal error of 20% because of the sample size, and the communication college showed low behaviour and concern with a marginal error of 25% because of the sample size, as shown in Table 5. The low sustainability level indicates low exposure to these concepts and the best practices in the two colleges, which could be due to the nature of the programmes taught in the two colleges and the type of activities planned. Thus, involving more students, faculty and staff from these two colleges in sustainability-related activities can enhance their concerns and inspire better behaviour. According to

Figure 8, males have a higher overall sustainability level than females, with a 10% marginal error. This is in line with the results of the work by Hamdan et al. (**2020**), which showed that males have higher sustainability behaviour level compared with females. In addition, faculty members showed a higher sustainability level than other campus populations, with a 15% marginal error. The high sustainability level among faculty members can be attributed to the fact that they were exposed previously to sustainability concepts because of their career requirements.

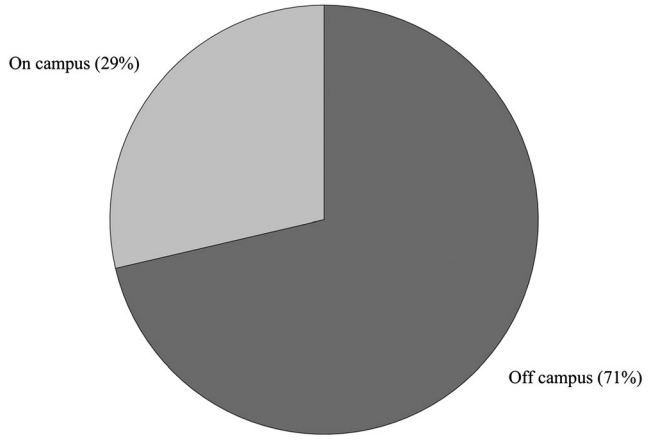

FIGURE 7 Participants based on their living place.

The hypothesis testing in Equation (3) was used to investigate whether the differences are statistically significant. For the gender comparison in all sustainability aspects, the hypothesis testing showed that males have higher knowledge and awareness levels than females. In contrast, the other aspects were found to be statistically the same, as shown in Table 7. This resulted in having the same overall level (due to the high number of points allocated to behaviour, concern and attitude) while normalizing for the number of questions, and scores revealed that males have a higher overall sustainability level.

Faculty and staff showed the same sustainability levels in all aspects except for the knowledge, where faculty showed a higher knowledge level than the staff resulting in a higher normalized overall level for the faculty over the staff. The difference in the knowledge measure could be due to the education level and the involvement of faculty members in research activities, as most of the staff members have bachelor's degrees, whereas the majority of faculty members have PhD degrees. Both faculty and staff members showed higher sustainability levels in all aspects compared with the students' levels. This is similar to the results of the research work by Mir and Khan (**2018**), where they found that students' knowledge and behaviour are very low.

Figure 8 and Table 5 indicate that the lowest sustainability level comes from the communication college,

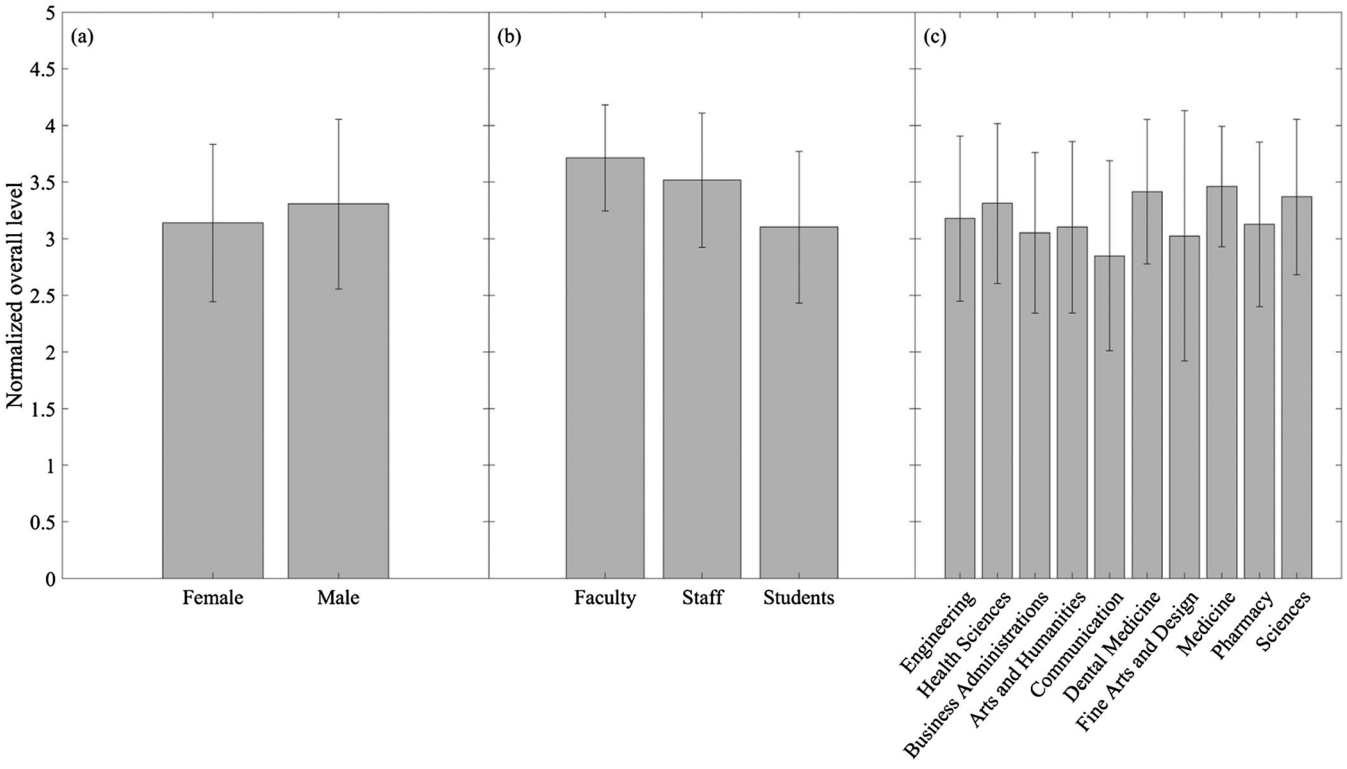

FIGURE 8 Median and the interquartile range of the normalized overall sustainability level.

TABLE 5 Median score under each sustainability aspect

Category		Knowledge (out of 5)	Behaviour (out of 115)	Concern (out of 40)	Awareness (out of 9)	Attitude (out of 12)
Gender	Male	1	69	32	8	9
	Female	1	69	33	8	9
Role	Faculty	2	77	35	9	10
	Staff	1	75	36	9	9
	Students	1	67	32	7	8
College	Engineering	1	69	32	8	9
	Health sciences	1	71.5	35	8	9
	Business administrations	1	69	32	8	9
	Arts and humanities	1	66	32	7	9
	Communication	1	66	24	6.5	9
	Dental medicine	1	71	35	8	9
	Fine arts and design	0	63	32	7	8
	Medicine	1	68	34	9	9
	Pharmacy	1	66	32	9	8
	Sciences	1	75	32	8	9

TABLE 6 *P*-value results of the statistical analysis test (Equation 2) for the significance of each sustainability aspect based on gender, campus population and college.

	Knowledge	Behaviour	Concern	Awareness	Attitude	Overall	Normalized overall
Gender							
Females	1.000	*	*	*	*	*	*
Males	1.000	*	*	*	*	*	*
Campus population							
Faculty	1.000	*	*	*	*	*	*
Staff	1.000	*	*	*	*	*	*
Faculty and staff	1.000	*	*	*	*	*	*
Students	1.000	*	*	*	*	*	*
College							
Engineering	1.000	*	*	*	*	*	*
Health sciences	1.000	*	*	*	*	*	*
Business administrations	1.000	*	*	*	*	*	*
Arts and humanities	1.000	0.068	*	*	*	*	*
Communication	1.000	0.402	0.227	*	*	0.227	*
Dental medicine	1.000	*	*	*	*	*	*
Fine arts and design	1.000	*	*	*	*	*	*
Medicine	1.000	*	*	*	*	*	*
Pharmacy	1.000	*	*	*	*	*	*
Sciences	1.000	*	*	*	*	*	*

Note: The asterisk (*) denotes a *p*-value of <0.05 indicating that the aspect is significantly greater than the mid-score (i.e., high level).

TABLE 7 *P*-value results of the statistical analysis test (Equation 3) for the significant difference of each group under each sustainability aspect

Level of sustainability aspect								
		Knowledge	**Behaviour**	**Concern**	**Awareness**	**Attitude**	**Overall**	**Normalized overall**
Females vs. males	$S^i_{2,1}$	*	0.088	0.718	*	0.945	0.116	*
	$S^i_{2,2}$	1.000	NA	NA	1.00	NA	NA	0.999
Faculty vs. staff	$S^i_{2,1}$	*	0.113	0.529	0.240	0.505	0.081	*
	$S^i_{2,2}$	*	NA	NA	NA	NA	NA	*
Faculty and staff vs. students	$S^i_{2,1}$	*	*	*	*	*	*	*
	$S^i_{2,2}$	*	*	*	*	*	*	*

Note: The asterisk (*) denotes a *p*-value of <0.05 indicating that the two groups are statistically different under $S^i_{2,1}$ and that the first group has a higher level under $S^i_{2,2}$. NA: not applicable $S^i_{2,2}$ test because the two groups are statistically similar under $S^i_{2,1}$.

followed by the college of fine arts and design and the college of business administration. Thus, the action plan should provide a focus for this college.

6 | MANAGERIAL INSIGHTS AND ACTIONS

In summary, the analysis of the mid-score value (Equation 2) revealed that the knowledge level about sustainability is low in the HEI. The communication college has the least sustainability level, with a marginal error of 25%, followed by the college of fine arts and design, with a marginal error of 25%, and business administration, with a marginal error of 15%. In addition, students have the lowest sustainability level when compared with other campus populations. Thus, these categories should be the focal point for decision-makers to achieve improvements.

Zareie and Navimipour (**2016**) found that environmental knowledge has a direct impact on environmental impact. This means that focusing on spreading knowledge can enhance other aspects (behaviour, awareness, concerns and attitude). Although behaviour is found to be statistically higher than the mid-score, it is considered insufficient to achieve sustainability excellence (Table 5). Therefore, a set of recommendations to promote building better knowledge on sustainability is developed. In addition, the high sustainability awareness level would indicate a high acceptance rate of the proposed action plans in the targeted population. In the following subsection, we present the actions taken to improve and control the process.

6.1 | Phase 4: Improve

Based on the brainstorming sessions with decision-makers and in alignment with the UI GreenMetric Ranking guidelines and the STARS guidelines, the following recommendations were developed and communicated to the HEI Sustainability Office:

1- To increase the knowledge level about sustainability among students by introducing more seminars and workshops about relevant sustainability topics.
2- To integrate sustainability in a broader range of courses in various colleges, especially those with low sustainability levels (communication, fine arts and design and business administration).
3- To involve students in sustainability activities by establishing sustainability student clubs, which will increase student's knowledge, awareness, concerns and attitudes about sustainability.
4- To announce more sustainability-related events focusing on students, staff and faculty in the communication collage to increase the sustainability concern and promote more sustainable behaviours and best practices.
5- To provide training sessions and orientation days focusing on sustainability to all campus population and focusing on the new members to improve the sustainability knowledge, awareness and concern among the campus population.
6- To provide awards and incentives to the campus population for their efforts in creating and obtaining sustainable campuses to increase sustainability behaviours and attitudes.

7- To perform students to students (peers to peers) and students to other campus population sustainable activities and events to increase the knowledge and concern of students.
8- To encourage students to carry out sustainable projects with other campus populations to benefit from their knowledge and experiences in different fields to enhance the sustainability level of students.
9- To hold competitions to reduce energy and water consumption and minimize waste generation among all campus populations to promote sustainability behaviours and attitudes among campus populations.

Based on the analysis result and the recommendation provided to the sustainability office, HEI decision-makers initiated the following actions:

- The sustainability office announced 2020 as the year of sustainability.
- The HEI implemented the sustainability circles concept to increase stakeholders' engagement level.
- The sustainability office established two student's sustainability clubs in the HEI and a sustainability hub in the communication college which had the lowest sustainability level based on the results of this study.
- The sustainability curriculum and the sustainability studies circles introduced new courses and established a sustainability research group.
- The sustainability office and the agriculture circle launched the sustainable garden project inside the campus.
- The HEI organized more than 30 different sustainability seminars, workshops, forums and competitions in the year 2019.

6.2 | Phase 5: Control

The top management decision-makers chose the UI GreenMetric Ranking as an indicator to control the HEI performance. They formed a committee of experts in collaboration with the Sustainability Office at the HEI to prepare the application to the UI GreenMetric Ranking. This application is used to measure the level of sustainability and benchmark it with other international universities. The application requires quantitative and qualitative data about the campus infrastructure and setting, water management, waste management, energy and climate, transportation and education. Thus, it can be used to provide an indicator of the overall behaviour of the campus population. The committee prepared and submitted the application in October 2017. The participation results were announced in December 2017, and the HEI achieved a score of 3626 and was ranked 452.

Based on the results of UI GreenMetric in 2017, the decision-makers in the HEI implemented several action plans based on the recommendations provided by the sustainability office and other teams. After that, the HEI applied to the UI GreenMetric Ranking in the following 3 years, 2018, 2019 and 2020, to keep track of the sustainability performance improvements. The results showed higher overall ranking scores for the HEI compared with the year 2017. Its global ranking also increased from 452 in 2017 to 398 in 2018, 294 in 2019 and, finally, to achieve 194 in 2020.

Implementing the proposed recommendations has significantly helped enhance sustainability performance in various aspects. For example, compared with the results of the year 2017, the number of sustainability courses offered increased by 15%, the number of student-run sustainability organizations became 13 and the number of sustainability-related events increased by 69%.

7 | CONCLUSION

The study presented a framework to improve the institute's sustainability level using DMAIC methodology. It aimed to assess and improve the sustainability level at an academic institute by measuring different sustainability aspects (knowledge, behaviour, concern, awareness and attitude), for different campus populations (students, faculty and staff) that share common characteristics and among colleges using statistical analysis techniques, in this case, the DMAIC methodology. The results of the study revealed that the college of communication has the lowest sustainability level. Students have the lowest sustainability level compared with faculty and staff.

The results benefit the decision-makers in the HEI by identifying the weaknesses, knowing the gaps and enhancing the strengths. For instance, the study highlighted that the sustainability knowledge level was low, which led decision-makers to set up action plans to improve knowledge and consequently other aspects, such as behaviour. The presented framework could also inspire decision-makers on how to utilize strengthened areas to develop acceptable action plans. For instance, high awareness level can facilitate implementing various actions as the population acceptance would be high and less change resistance could be anticipated. However, if the awareness level is low, action plans need to start by spreading awareness as individual would tend to resist change. Moreover, the increased awareness and concern

among the HEI community could also enhance the whole society's awareness and concern.

The study scope was limited to colleges that teach in English and that only an English version of the questionnaire was prepared and distributed, which resulted in eliminating colleges that teach in Arabic from the analysis; these colleges are the college of law, Sharia and Islamic studies and community college. Nevertheless, the results of this research were still credible because the number of students studying in the excluded colleges represents only 16% of the total number of students in the whole HEI, which is considered relatively low in comparison with the students studying in the other 10 colleges. In addition, the questionnaire was distributed to faculty, staff and students via their university emails. Thus, technicians and contractors were excluded from this study as they are outsourced and do not have university emails.

Several challenges were associated with this study. The first challenge was the tendency to ignore questionnaires. Low response rate was reported in the first week. Thus, in the following weeks, the HEI's chancellor office sent reminders and explained to the community the importance of this questionnaire. This step improved the response rate significantly as the HEI community realized the importance of this data collection step. The second challenge was the different backgrounds of the targeted population, which required simple and easy to understand questions. Several pilot runs were conducted to improve the readability and the format of the questionnaire. Randomly selected staff, faculty and students were asked to view the questionnaire and provide their feedback.

In a future research direction, a customized questionnaire could be distributed to colleges to measure sustainability aspects. It could lead to deeper understanding of the impact of study field on sustainability knowledge, attitude, awareness and concern. A customized questionnaire will also allow considering the different education levels among the community based on the nature of the topics taught in each college, and different languages can be used for the questionnaire to include other colleges. In addition, a coordination between different HEIs in the country could be established to compare the sustainability levels. This could help connect the study findings to several characteristics, such as the geographical location of the universities, available colleges, national context and diversity. Furthermore, future studies could focus on barriers to sustainability, such as behaviour differences and differences between actions and attitudes.

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