Sustainability assessment framework for engineering and sciences educational institutions in developing countries

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Abstract

There are different factors that may impact the technological, organizational, social, and pedagogical innovation necessary for improving the existing Governmental Egyptian Engineering and Sciences educational institutions to enable offering a more sustainable learning environment for Egyptian students and faculty members. This paper proposes a sustainability assessment framework that can help these educational institutions in achieving the required transformation towards a more sustainable education. First, a literature review is conducted to identify the sustainability factors that need to be considered in achieving a more sustainable education environment in Egypt. Those factors are then tailored to satisfy the Egyptian educational environment through experts' interviews and gap analysis. The factors are then ranked through a survey questionnaire and experts' judgment using a 5-point Likert scale to identify the most significant factors, based on the Pareto principal. A case study of a learning institution in Egypt is adapted to identify the gaps in light of the highly prioritized factors in order to develop guidelines and provide recommendations for improvement.
Keywords: sustainable education, engineering and sciences, pedagogical innovation, gap analysis.

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1 Introduction

In general, sustainability education is considered one of the most critical aspects of education that may hinder the future of a nation. Today's graduates will take the positions of future management, and leadership in any given society, and they will be in need to acquire knowledge and decisions to make correct choices. They should be coupled with information about their society, economy, and environmental issue that change dramatically year over year. Plank [1] stated that education for sustainability development aims at enabling everyone to gain the values, skills, and knowledge, which contribute to building more sustainable society. This implies revising teaching content to respond to global and local challenges. It should also promote teaching methods that enable students to grasp skills, such as interdisciplinary thinking, integrated planning, understanding complexities, cooperating with others in decision-making process, and participating in local, national, and global processes towards sustainable development. Also, Simpson [2] suggested that higher education has a tremendous contribution to enhance sustainability development. For example, University researchers were the first to alert the global warming issue, and researchers are now seeking to find technological and social solutions to assist nations to face this environmental challenge. Therefore, higher education institutions should play their part as centres of teaching and research in their local communities.

2 Literature review

According to the World Commission on Environment and Development [3], sustainable development was defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." Different researchers have tackled the issue of sustainability education. Cole [4] assessed sustainability on a Canadian University Campus. He proposed a framework for the development of Victoria Campus sustainability assessment. West *et al*. [5] recommended international perspectives to flourish the quality in higher education for educational research. Martin *et al*. [6] studied sustainability development in higher education. He proposed some recommendations for future development, such as universities should function as places of research and learning for sustainable development. Also, he proposed that new sustainable development strategy means securing the future, which emphasis the role that education can play in both raising awareness among youth about sustainability development as well as giving them the skills apply sustainability development into practice. Wigmore and Ruiz [7] developed a sustainability assessment framework in higher education institutions. Kaviola and Rochmeder [8] studied sustainability development in higher education in Finland. Koehn and Demment [9] overviewed higher education and sustainability development in Africa. Zilaly [10] investigated the role of higher education and recommended a clean technologies, and environmental policy toward enhancing the higher educational institutions. In addition, some authors have studied the factors affecting

Sustainability development. Evans *et al*. [11] assessed the sustainability indicators that affect the renewable energy technologies. Ghose [12] technological challenges for boosting coal production with environmental Sustainability. Urban *et al*. [13] designed self-reliant networks of technological ecological systems. Smith [14] studied the organizational elements affecting Sustainability. Pluye *et al*. [15] designed a program for sustainability, which focuses on organizational routines. Smith [16] highlighted the importance of organizational learning for Sustainability. Gonzalès and Parrott [17] developed a network theory for the assessment of Sustainability of Socio-Ecological Systems. Assefa and Frostell [18] studied social sustainability and social acceptance in technology assessment. Daniel *et al*. [19] discussed social Sustainability in urban renewal communities. Yuen *et al*. [20] developed a comparative case study for the pedagogical orientation in Hong Kong. Finally, Johansson [21] discussed Pedagogical approaches and their implications for sustainability. All the above researchers did not develop a framework that deals with the sustainability development of the Engineering and Science Institutions in Egypt. Therefore, the Sustainability assessment framework was developed in this paper to overcome this limitation and provide recommendations not only applicable to Egypt, but also to any other developing country.

3 Objectives

The main objective of this paper is to prioritize critical factors affecting sustainability development in Egypt. This is achieved through the development of the sustainability development framework. The consent of framework development can be generalized and applied to other countries by changing related sustainability development factors and expert opinions. The framework solves a major problem that faces educators who want to prioritize critical factors affecting the sustainability development process in order to produce a list of prioritized sustainability factors.

4 Methodology and model development

The proposed framework is composed of six stages: Identifying critical Sustainability Factors, Creating Linguistic Scale to Rate Different Critical Factors and Collecting Experts' Opinions, Performing Statistical Analysis, Assessing the Relative Importance Index (RII) for Prioritization, Conducting a Case Study in Egypt, and Suggesting Recommendations as per in Figure 1.

4.1 Identifying Critical Sustainability Development Factors

Critical Sustainability Development Factors were determined using literature review and interviews with ten experts each of them had twenty years of experience in Sustainability Development Education. Experts agreed that Sustainability Development Factors can be divided into four groups: Technological Factors, Organizational Factors, Social Factors, and Pedagogical Innovation Factors (Table 1).

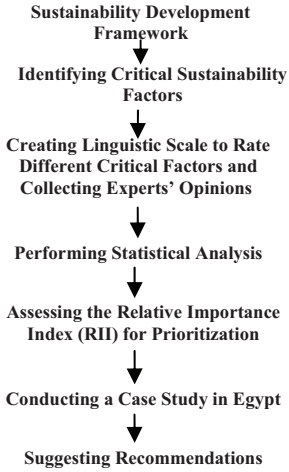

Figure 1: Methodology and model development.

Table 1: Critical sustainability development factors and their groups.

Group (1) Technological factors		**Group (3) Social factors**	
1	Need for acquiring skills for developed industries	21	Ensure participation of different groups (students, women) in social activities
2	Enhance university's curriculum with main changes in energy resource	22	Being aware of environmental injustice and its direct and indirect effects on higher education
3	Enhance students' creativity	23	Understand internationalization of core curriculum
4	Promote the higher education requirements for radical improvement in human technology interfaces	24	Promote lifelong learning
5	Aware the staff about changing in technological skills to enhance these skills in students.	25	Prepare students to post graduation life
6	Establish vocational courses	26	Monitor and evaluate team performance
7	Teach students giving positive respond to global and local challenges	27	Need to avoid in equality within nations and develop internationally recognized curriculum
8	Prepare students to the technological effects on employment	28	Promote community engagement
9	Understand technology and its negative and positive effect on our daily life	29	Implement the university policies
10	Enhance industry intervention in higher education	30	Need to have the ability to work well with others
Group (2) Organizational factors		**Group (4) Pedagogical innovation factors**	
11	Need to face the deficit in real demands in goods and services existed in industrial organizations.	31	Need for distance learning
12	Enhance students' loyalty to working organizations.	32	Need for industries involvement in research
13	Need to know about employment terms and conditions	33	Need for graduating innovative students
14	Need to be aware about number of job vacancies	34	Being aware with changing nature of market needs
15	Promote skills understanding between students and staff	35	Need for providing training to deans and chairs to their work
16	Learn students how to solve problems	36	Need for gaining worldwide accreditation
17	Develop and run international offices	37	Promote experiences in labor market research
18	Need to cope with international division of labour market and its effects in industrial organizations.	38	Being aware of economic challenges for 21st century
19	Being aware of financing development and growth	39	Giving rise to international equity
20	Support learning for life and work	40	Develop staff to cope with international education standards

4.2 Creating Linguistic Scale to Rate Different Critical Factors and collecting experts' opinions

In this step, a survey-based questionnaire was designed to assist experts in ranking Critical Sustainability Development Factors based on the impact of these Sustainability Development factors on the sustainable education enhancement of engineering and science educational institutions, using a five-point Likert scale (Saaty [22]). The scale ranged between (1) *Very Low* and (5) *Very High*, while the term (3) *Medium* was placed as a midterm value on the scale. Moreover, the questionnaire included a section that contained experts' demographic information that defined five qualification criteria of experts: Q1: Years of experience, Q2: Years of experience in Science or education Fields, Q3: Position, Q4: Academic record, and Q5: Public vs. Private Institutions. Table 2 lists experts' qualifications and their attributes.

4.3 Performing statistical analysis

The statistical analysis of the experts' ratings determined the Mean, Median, Mode, Standard Deviation, Standard Error, and 95% Confidence Range to advise on whether the opinions are converging or not. The 95% Confidence Range is a type of interval estimate of a population parameter and is used to indicate the reliability of an estimate, where the 95% Confidence Range reflects a significance level of 0.05 in the current study. The Standard Error was computed to measure the extent to which the means from different samples is expected to vary from the population mean, owing to the chance error in the sampling process, which was computed by dividing the Standard Deviation by the square root of N, where N is the sample size. According to Montgomery [23], computing the Standard Error implies an acceptable agreement among experts. Abdelgawad [24] demonstrated that the calculated Standard Error is to be compared to 0.2, as this value indicates a relatively precise point estimate of agreement among experts on the results (Shen *et al*. [25]).

4.4 Assessing the Relative Importance Index (RII) for prioritization

In this step, the Relative Importance Index (RII) was utilized to prioritize Critical Sustainability Development Factors, based on the ranking of the experts (collected from step 2). This approach was applied because of its simplicity and ability to provide subjective and objective assessments of multiple factors (Elbarkouky *et al*. [26]).

The average rating of the fifty experts (Table 2) who participated in the process of prioritizing Critical Sustainability Development Factors was computed. 'Equation (1)' illustrates the RII computation.

$$RIIj = \sum_{i=1}^{n} \frac{yj}{z} \tag{1}$$

where, *yj* is the rating score assigned to each risk event (*j*) by each expert (*i*) on the Likert scale from 1 to 5, and *z* is the highest possible rating value of the

Likert scale [22], which is 5 in this case. The *RII* value has a range between 0 to 1 (0 not inclusive), such that the higher its value, the more important the risk event is.

Table 2: Experts' qualifications (attributes).

Expert No.	**Q1** Years of Experience	**Q2** Years in Education or Science Fields	**Q3** Position	**Q4** Academic record	**Q5** Public vs. Private
1	11–15	6–10	Professor	PhD	Public
2	11–15	6–10	Professor	PhD	Public
3	11–15	6–10	Assco Prof	PhD	Public
4	11–15	11–15	Assco Prof	PhD	Public
5	11–15	6–10	Assco Prof	PhD	Public
6	11–15	6–10	Assco Prof	PhD	Public
7	6–10	6–10	Assco Prof	PhD	Public
8	1–5	< 1	Ass Prof	PhD	Public
9	1–5	1–5	Ass Prof	PhD	Public
10	< 1	< 1	Ass Prof	PhD	Public
11	1–5	< 1	Ass Prof	PhD	Public
12	1–5	1–5	Ass Prof	PhD	Public
13	16–20	16–20	Professor	PhD	Public
14	16–20	16–20	Professor	PhD	Public
15	11–15	11–15	Professor	PhD	Public
16	16–20	16–20	Professor	PhD	Public
17	16–20	11–15	Professor	PhD	Public
18	11–15	6–10	Assco Prof	PhD	Public
19	< 1	< 1	Ass Prof	PhD	Public
20	16–20	11–15	Professor	PhD	Public
21	11–15	6–10	Assco Prof	PhD	Public
22	1–5	1–5	Ass Prof	PhD	Public
23	1–5	< 1	Ass Prof	PhD	Public
24	1–5	< 1	Ass Prof	PhD	Public
25	1–5	1–5	Ass Prof	PhD	Public
26	16–20	16–20	Professor	PhD	Public
27	16–20	16–20	Professor	PhD	Public
28	6–10	6–10	Assco Prof	PhD	Public
29	16–20	16–20	Professor	PhD	Public
30	6–10	6–10	Assco Prof	PhD	Public
31	16–20	16–20	Professor	PhD	Private
32	6–10	6–10	Ass Prof	PhD	Private
33	1–5	1–5	TA	Master	Private
34	16–20	16–20	Professor	PhD	Private
35	1–5	< 1	TA	Master	Private
36	16–20	11–15	PM	Master	Private
37	1–5	< 1	SPE	Bachelor	Private
38	16–20	16–20	PM	Master	Private
39	16–20	16–20	PM	Master	Private
40	1–5	1–5	SPE	Master	Private
41	11–15	6–10	SPE	Bachelor	Private
42	16–20	11–15	PM	Bachelor	Private
43	16–20	16–20	PM	Master	Private
44	11–15	6–10	PM	Bachelor	Private
45	11–15	6–10	PM	Master	Private
46	6–10	1–5	SPE	Bachelor	Private
47	11–15	11–15	PM	Bachelor	Private
48	11–15	11–15	PM	Bachelor	Private
49	11–15	11–15	SPE	Master	Private
50	16–20	6–10	PM	Master	Private

As illustrated in Table 2, the PM stands for Project Manager, SPE stands for Senior Project Engineer, Ass Prof stands for Assistant Professor, Assco Prof stands for Associate Professor and TA stands for Teaching Assistant.

5 Conducting a case study in Egypt (Ain Shams University)

Sustainability development plays a vital role in enhancing the understanding of youth and developing there needed skills in order to be able to cope with the changes in the technological, economical, and social requirement. The Sustainability assessment framework was applied in this case study to be able to identify and qualify the factors affecting the development of the sustainability objectives. Case study is conducted on Ain Shams University, which is public university, and is considered as one the biggest universities in the field of Engineering and Science, and 6 October University, which is a private university and considered one of the most growing private universities in Egypt.

The forty sustainability factors that have been previously identified in step 1 of the framework were introduced to fifty Egyptian experts to solicit their opinions regarding the linguistic criticality of factors that would affect the development of sustainability objectives. The survey was conducted using the linguistic rating scales and questionnaire-based survey (step 2). The experts were carefully selected to possess different levels of experience, represent different sizes and maintain different experience levels in sustainability. The statistical Analysis was performed in (Step 3) in order to ensure the correctness of the data collected from experts, and to ensure that their final assessment is a result of common agreement. The Relative Importance Index (RII) was computed using equation (1) Step 5 to rank different factors affecting the sustainability development based on their consequence on sustainability assessment. Table 3 illustrates the computations of the Mean, Median, Mode, Standard Deviation, 95% Confidence Range, Average Rating, Relative Importance Index (RII), and rank of different factors.

6 Recommendations

A set of recommendations were developed to enhance the sustainability development using literature review and interviews with experts with fifty experts.

1. Graduates' skills should be developed in order to meet the needs of the modernized industries.
2. Both university curricula and methods of teaching should be examined in order to improve the mentality of the students, and cope with the radical technological changes.
3. Higher education institutions have to include local and global challenges in their curriculum, and motivate students to learn how to respond to these challenges positively.
4. Higher education institutions have to aware students about the changing demands of employment, and labor markets.
5. Higher education institutions have to contain international offices for
6. Famous universities in order to acquire a variety of knowledge.
7. Team work skills should be strengthened within the university
8. Curriculum in order to develop students' skills in this field.

Table 3: List of prioritized sustainability development factors.

Factors ID	Mean	Median	Mode	Standard Deviation	Standard Error	95% Confidence Range	RII	Rank
19	4.88	5	5	0.385	0.088	[5.035, 4.725]	0.976	1
15	4.76	5	5	0.591	0.109	[4.952, 4.568]	0.952	2
2	4.7	5	5	0.505	0.1	[4.876, 4.524]	0.94	3
26	4.68	5	5	0.471	0.097	[4.851, 4.509]	0.936	4
1	4.56	5	5	0.501	0.1	[4.736, 4.384]	0.912	5
7	4.5	5	5	0.814	0.128	[4.725, 4.275]	0.9	6
39	4.48	4.5	5	0.544	0.104	[4.663, 4.297]	0.896	7
18	4.46	5	5	0.788	0.126	[4.682, 4.238]	0.892	8
29	4.46	5	5	0.734	0.121	[4.673, 4.247]	0.892	8
34	4.46	5	5	0.762	0.123	[4.677, 4.243]	0.892	8
33	4.44	5	5	0.705	0.119	[4.65, 4.23]	0.888	9
11	4.42	5	5	0.758	0.123	[4.637, 4.203]	0.884	10
24	4.42	5	5	0.731	0.121	[4.633, 4.207]	0.884	10
40	4.42	5	5	0.859	0.131	[4.651, 4.189]	0.884	10
4	4.38	4.5	5	0.697	0.118	[4.588, 4.172]	0.876	11
10	4.36	4	5	0.693	0.118	[4.568, 4.152]	0.872	12
5	4.3	5	5	0.814	0.128	[4.525, 4.075]	0.86	13
8	4.3	4	4	0.463	0.096	[4.469, 4.131]	0.86	13
30	4.26	4	4	0.723	0.12	[4.471, 4.049]	0.852	14
3	4.24	4	4	0.687	0.117	[4.446, 4.034]	0.848	15
9	4.14	4	5	0.783	0.125	[4.36, 3.92]	0.828	16
24	4.12	4	4	0.659	0.115	[4.323, 3.917]	0.824	17
27	4.1	4.5	5	1.111	0.149	[4.362, 3.838]	0.82	18
6	4.08	4	4	0.778	0.125	[4.3, 3.86]	0.816	19
32	4.06	4	4	0.512	0.101	[4.238, 3.882]	0.812	20
35	4.06	4	5	0.818	0.128	[4.285, 3.835]	0.812	20
37	4.06	4	5	0.89	0.133	[4.294, 3.826]	0.812	20
16	4.04	4	4	0.832	0.129	[4.267, 3.813]	0.808	21
20	4.02	4	4	0.795	0.126	[4.242, 3.798]	0.804	22
13	3.98	4	5	0.958	0.138	[4.223, 3.737]	0.796	23
38	3.98	4	4	0.82	0.128	[4.205, 3.755]	0.796	23
31	3.96	4	3	0.925	0.136	[4.199, 3.721]	0.792	24
28	3.92	4	4	1.085	0.147	[4.179, 3.661]	0.784	25
12	3.92	4	4	1.027	0.143	[4.172, 3.668]	0.784	25
14	3.86	4	4	0.729	0.121	[4.073, 3.647]	0.772	26
17	3.78	4	4	0.815	0.128	[4.005, 3.555]	0.756	27
22	3.78	4	5	1.148	0.152	[4.048, 3.512]	0.756	27
36	3.68	4	3	0.683	0.117	[3.886, 3.474]	0.736	28
21	3.52	4	5	1.474	0.172	[3.823, 3.217]	0.704	29
23	3.18	4	4	0.919	0.136	[3.419, 2.941]	0.636	30

9. Administration in Universities should aware the staff and faculty members about financing development and the rate of growth in order to provide this experience to students.
10. Universities have to provide social services, and social activities, and advice students to participate in this field.
11. Higher education institutions have to promote lifelong learning.
12. Higher education institutions have to aware students about post graduation life, and how to develop their skills.
13. Universalities have to develop internationally recognized curriculum.
14. Higher education institutions have to develop students' skills in order to obtain finally an innovative graduate.

15. Universities should have a linkage with international organizations, such as UNESCO, International Bank, and International Monetary Fund in order to achieve worldwide accreditation.
16. Universities have to promote research activities in the field of international education.
17. Universities have to develop their staff to cope with international education standards.

7 Conclusion

A Sustainability Assessment Framework was developed in this paper to prioritize different factors affecting the development of Sustainability objective. The proposed framework was composed of six stages: Identifying critical Sustainability Factors, Creating Linguistic Scale to Rate Different Critical Factors ,and Collecting Experts' Opinions, Performing Statistical Analysis, Assessing the Relative Importance Index (RII) for Prioritization, Conducting a Case Study in Egypt, and Suggesting Recommendations. Factors affecting the sustainability development were identified using literature review and interviews with experts. A case study was conducted to demonstrate the validity of the Sustainability assessment framework in identifying, and qualifying different factors affecting the sustainability development. The framework provided an improvement over previous sustainability models by incorporating the use of the Relative Importance Index (RII) to prioritize different factors affecting the sustainability development. The framework improves over the previous models, which rely on the subjective assessment. In the future, the highly prioritized sustainability factors will be introduced to another quantitative sustainability assessment model that quantify these factors that is currently under preparation.

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