



# Investigating the Higher Education Curriculum for Sustainable Software Development

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**Abstract:** Awareness and understanding of sustainability among students is commonly related to the environment aspect especially pollutions. However, the students are confused how to link the sustainability aspect with software development levels, such as software design and coding. Thus, this paper aims to investigate the sustainability dimensions' awareness among the higher education students. It investigates the sustainability dimensions in the course curriculum of computer sciences (CS), information technology (IT) and software engineering (SE). The survey among CS, IT and SE students at the Saudi university in the western and southern regions of the kingdom is conducted in order to investigate their awareness regarding sustainable development. A total of 318 related students from various public sector universities in the western and southern regions of the Kingdom of Saudi Arabia (KSA) contributed by surveys of their awareness towards sustainable development. The results indicates that 71% of them are unaware of the term of sustainable development, only 17% of them know the basic definition of sustainable development, and 12% of them have an idea of how sustainable development is related to the software development. Furthermore, it indicates that the current curriculum does not sufficiently cover specific subjects about sustainable development. As a results, the educational institutes and universities have to provide sustainability awareness and understanding among the students and thus they have to develop their vision, policy, teaching strategies, research objectives, and curriculum.

**Keywords:** Sustainability, Curriculum, Sustainable Development, Software Development, Saudi University, Higher Education

## 1. INTRODUCTION

Sustainability concept has been discussed in several fields such as engineering [1], manufacturing [2], and environmental sciences [3]. It is commonly referred to the fundamental dimensions including economic, social, technological and environmental aspects [3]. Currently, sustainability concept has started expanding in the fields of computer science (CS), Software engineering (SE) [4] and Information Technology (IT) [5].

Sustainable software refers to the software capacity that can be long-lasting and environment-friendly [6]. It is related to the software development characteristics that the final work product must including longevity and environmental friendliness [7-8].

Sustainable development focuses on the operational activities practices in order to achieve the sustainable software goal [9]. Thus, eliciting requirement, modelling, designing and development of the software over sustainable development practices are critical procedures [10-11].

Providing awareness and understanding of sustainability among students is fundamentally required.

The industry, researchers and academia have to change agents to realise the benefits of sustainability in the industry and among students in order to achieve sustainable development goals. Furthermore, to meet the sustainability goals, the students have been educated to prepare them for industry. Thus, investigating the higher education policy is highly required topic. Therefore, in this paper, we will try to answer the following two questions:

- To what extent the sustainability awareness and understanding among students?
- To what level sustainability dimensions are filled in the course curriculum of SE, CS, Information System (IS) and IT major.

In this research, we have taken the Kingdom of Saudi Arabia (KSA) as the case study to discover whether essential knowledge of sustainability is merged in the higher education curriculum. We will comprehensively investigate the course curriculum in order to ensure whether these majors degree programs have adequate content of sustainability.

In this research, a survey throughout the questionnaire is conducted among the KSA universities students to



investigate their awareness and understanding about sustainable development.

The rest of the paper is organized into four sections. Section 2 presents the literature review. Section 3 presents the research methods. Section 4 shows the results and explains the detail discussion of the results. Finally, the conclusion and future work directions are outlined in section 5.

## 2. LITERATURE REVIEW

Sustainability identifies as the capacity to survive over the longer period in the aspect of social, environment technological in order to save the future resources [12-13]. The sustainable development is the acts and procedures of the development of the sustainable product [14]. The literature shows that academicians and practitioners are interested in software development sustainability [7]. For example, the green software that has been proposed in [15] which is friendly environmental software. It has categorized into four aspects: (1) like energy efficient, (2) green policies, (3) produces smartness in the system, and (4) environmentally friendly products.

Literature shows that the concept of sustainable software is linked with the coding style and thus the coding style has to be sustainable by realizing the sustainability goals over the sustainable development practices [16]. Moreover, literature shows that it cannot be easily to consider the software development sustainability in the software engineering discipline [6][17].

Educating sustainability and enhancing its awareness and understanding among students is a critical concern. Therefore, understanding and educating the sustainable software development should be encouraged from the educational institutes and universities. Furthermore, the universities all over the world have to consider the sustainability and achieving sustainability in terms of their curriculum, operations and research [2][18]. Educating sustainability among students can cover several aspects, such as risk reduction, sustainable designs, green computing [19], and sustainable resources consumption [1].

Literature shows that the awareness and understanding of sustainability among students is commonly related to the environment aspect especially pollutions [18][20]. However, the students are confuse how to link the sustainability aspect with software development levels, such as software design [21-22], and coding [18]. As a results, the educational institutes and universities have to provide sustainability awareness and understanding among the students and thus they have to develop their vision, policy, teaching strategies, research objectives, and curriculum [23-25]. Thus, this paper aims to examine the level of sustainability diffusion in the CS, IT, IS and SE course curriculum along with the level of sustainability awareness and understanding among the students.

## 3. RESEARCH METHODOLOGY

Firstly, As the questionnaire methodology is valuable to discover findings from different perspectives [26], we have used it in this paper to investigate whether the sustainability related courses are united in the existing CS, IT, IS and SE programs at the KSA universities, and to what extent sustainability concepts are understandable among their students. The survey throughout the questionnaire is conducted among the CS, IT, IS and SE students at KSA universities for investigating their sustainable development awareness and understanding.

Secondly, the interview as the qualitative research method is conducted in the study to validate the questionnaires results. The interview has followed several steps, (1) interview plans; (2) interview instrument generated and validated; and (3) collecting that data by running the interview. The first step is the interview plans. The stakeholders are identified, who are the CS, IT, IS and SE students at KSA universities from different levels, in this step. There are 8 individuals selected to participate in this study. However, only 5 of them had accepted to share their views regarding their sustainable development awareness and understanding in their program curriculums. Thus, the response rate was 62.5% in this study.

### A. Conduction of Survey

A survey is conducted to investigate the level of sustainability awareness among university students in KSA. The prime objective behind this is to investigate their level of understanding about sustainable development. Moreover, the core is to examine students' proficiency in sustainability concepts and how they can use sustainability knowledge for sustainable software development. In this regard, questions are adapted from the existing literature [27-28]. After modifying and aligning the contents of the questions with the aim of this survey, the developed questionnaire is validated for its content and constructs [29-30]. In this regard, five experts from academia were contacted. However, three academicians responded to participate. The predefined criteria of experts include; having more than ten years of experience, must be involved in software development and have sound knowledge about sustainability. Their valuable suggestions are incorporated consequently. The five-point Likert scale has been used where it includes extremely aware, moderately aware, somewhat aware, slightly aware, and not at all aware.

Distribution of the questionnaire among the target audiences, who are the students at Saudi universities at the western and southern regions of the kingdom, is done through online survey via Google survey tool. As this research intends to focus more on a number of students, an online survey is much more useful because of its capability to collect data from diversified people with the objective of efficiency and cost-effective, as compared to the conventional survey.

**B. Data Sources**

A diversified target population was approached by sending an invitation to all major universities of western and southern regions of KSA. The list of selected universities from two regions is shown in Table I.

TABLE I. LIST OF SELECTED UNIVERSITIES

#	Name of Selected Universities	Region
1	Umm Al-Qura University	Western
2	King Abdulaziz University	Western
3	Taif University	Western
4	University of Jeddah	Western
5	Taibah University	Western
5	King Khalid University	Southern
6	Jazan University	Southern
7	Al Baha University	Southern
8	Najran University	Southern
9	Bisha University	Southern

A total of 9 universities had shown their willingness to respond to the invitations. The link of web questionnaire (Google Survey Form) has been sent to the student's email addresses. Thus, a total of 318 responses from students (filled questionnaire) were collected in four-month duration (August 2019 to November 2019). Upon validating the received responses based on predefined quality criteria, 30 of the responses were discarded because of the partial fulfilment of the questionnaire. Finally, a total of 288 responses were considered for further analysis.

Table II shows the socio-demographic details of the participants including their age, gender, degree, and levels.

TABLE II. DEMOGRAPHIC STATISTICS OF PARTICIPANTS STUDENTS

Demographic Detail	No	%
Age	18-23 y	55.6%
	23-30 y	20.8%
	> 30 y	23.6%
Gender	Male	61.8%
	Female	38.2%
Degree	CS	46.2%
	IT	29.5%
	IS	17.4%
	SE	6.9%
Level	Undergraduate	62.5%
	Postgraduate	37.5%

**C. Data Analysis**

Data encoding is done by using a statistical tool for data analysis. The frequency and weighted means are

computed. The aim of performing these statistics is to investigate the students' response rate against their level of awareness regarding sustainable development.

**4. RESULTS AND DISCUSSION**

This study examined the curriculum followed by universities in KSA, whether sustainability is incorporated in programs and course contents. Besides, the extent of awareness about sustainability among students is also investigated. The detail results reporting is given in the following subsection.

**A. The Result from Conducted Survey**

The survey is conducted in order to investigate the students' level of awareness for sustainable development. The detailed results of 288 respondents of the survey have been shown in Table III. The table comprises columns named as 'questions', 'optimistic', 'pessimistic' and 'impartial'.

**B. Results Analysis and Discussion**

The results indicated that mostly all universities have a lack of focus on offering any program for sustainable development. However, a few of these universities have taken the initiative of offering such courses for undergraduate and postgraduate students.

For undergraduate students, the courses such as 'software project management', 'professional practice', 'software house practices' and 'Software engineering economics' are offered by some of these universities. When we analyse these courses contents, we found that few courses have been incorporated related to the sustainable development and how it's important to improve quality of life. Figure 1 shows the details of these courses' contents and their mapped with the sustainability dimensions.

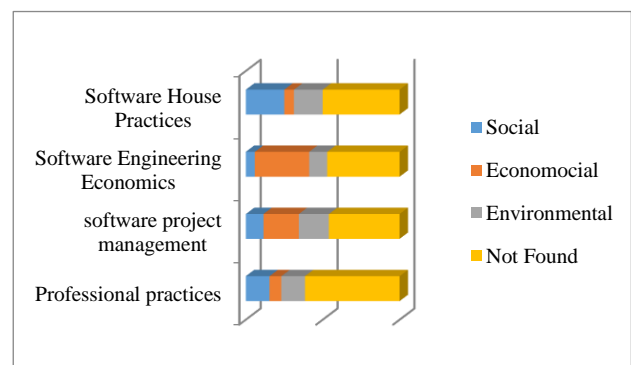


Figure 1. Mapping of undergraduate courses contents with sustainability dimensions



TABLE III. QUESTIONNAIRE RESPONSES RESULT

#	Questions	Sample size of survey questionnaire: 288							
		Optimistic			Pessimistic			Impartial	
		EA	MA	%	SA	NAA	%	SWA	%
1	Are you familiar with the environmental sustainability concept?	48	54	35.42	76	52	44.44	56	20.16
2	The environment-friendly software can contribute to a healthy environment.	36	72	38.19	82	38	43.06	52	18.75
3	Energy efficient software is the contributors towards sustainable environment.	30	48	27.08	76	56	45.83	78	27.08
4	Software can emit heat in environment.	28	46	25.69	84	82	57.64	48	16.67
5	Software can be the main driver that can have social influence.	38	42	27.78	66	74	48.61	68	23.61
6	Software can provides automation to various business sectors to contribute to society.	70	76	50.69	64	40	36.11	38	13.19
7	Software can aid to live a better and healthy life.	36	56	31.94	56	68	43.06	72	25.00
8	Software contributes to society by providing information and learning.	52	76	44.44	74	34	37.50	52	18.06
9	Software can produces economical solutions in industry.	42	64	36.81	74	46	41.67	62	21.53
10	Software can help to increase productivity of organizations.	52	76	44.44	66	38	36.11	56	19.44
11	Software can contribute for economical sustainability.	42	62	36.11	70	58	44.44	56	19.44
12	Software to be sustained over a long period of time is the success of the software.	62	76	47.92	62	34	33.33	54	18.75
13	Software can be sustained by integrating sustainability aspects in software engineering?	36	48	29.17	72	70	49.31	62	21.53
14	Sustainable software engineering addresses sustainability practices including code optimization, resources utilization and energy efficient coding.	44	46	31.25	76	58	46.53	64	2.22

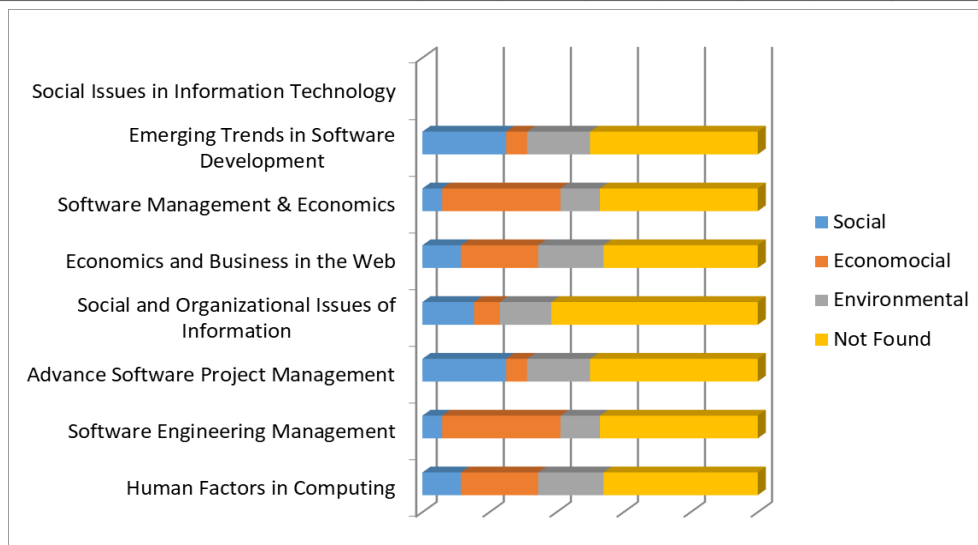


Figure 2. Mapping of postgraduate courses contents with sustainability dimensions



Firstly, we found that the course of ‘software project management’ generally covers the project management concepts and inly covers few topics related to sustainable development concepts. However, it ignores the understanding of economic and environmental sustainable development concepts.

Secondly, the ‘professional practices’ course covers the general ethics contents for software development. However, only a few lessons cover the economic, social and environmental sustainable development concepts.

Thirdly, the ‘software house practices’ course is incorporate the management and technical parts of how to run software houses. It only covers the social sustainable development concept.

Lastly, the ‘software engineering economics’ course covers the economic sustainable development concept.

For the postgraduate students, the courses such as ‘Software engineering management’, ‘Advanced software project management’, ‘Social and Organizational Issues of Information, Economics and Business in the Web’, ‘Human factors in computing’, ‘Software Management & Economics’, ‘Social Issues in Information Technology’ and ‘Emerging Trends in Software Development’ are offered.

It is surprisingly found that a few courses are offered directly for sustainable development. However, they have less targeted topics regarding the sustainability dimensions, such as the economic, environmental, social and technological. In addition, the results indicate that these offered courses have a lack of attention regarding ‘energy driven coding standards’, ‘Energy efficient programming’ and ‘policy development for heat conducting environment’. Figure 2 shows the details of the postgraduate courses' contents and their mapped with the sustainability dimensions. Thus, the results indicate that the universities have to propose and offer more courses about the sustainable development.

When we analysis the postgraduate courses contents, we firstly found that the ‘Social Issues in Information Technology’, ‘Economics and Business in the Web’ and ‘Social and Organizational Issues of Information’ courses are considered the social concept of sustainability. Secondly, the and ‘Software Management and Economics’ and ‘Emerging Trends in Software Development’ courses are considered the economic concept of sustainability. However, the environmental concept of sustainability is not considered in these courses.

As shown in Table II, the first four questions related to the environmental dimension of the sustainability. The results indicate that about 31% of the undergraduate and postgraduate students understand the environmental sustainable development concept as they have an optimistic response. Moreover, about 48% of them aware

about the environmental sustainable development concept as they have a pessimistic response while about 13% of them are impartial about the environmental sustainable development concept.

The questions from 5 to 8 related to social dimension of sustainability. The results indicate that about 39% of the undergraduate and postgraduate students understand the social sustainable development concept as they have an optimistic response. Moreover, about 41% of them aware about the social sustainable development concept as they have a pessimistic response while about 5% of them are impartial about the social sustainable development concept.

The questions from 9 to 11 related to economic dimension of sustainability. The results indicate that about 39% of the undergraduate and postgraduate students understand the economic sustainable development concept as they have an optimistic response. Moreover, about 41% of them aware about the economic sustainable development concept as they have a pessimistic response while about 7% of them are impartial about the economic sustainable development concept.

The questions from 12 to 14 related to sustainable software development. The results indicate that about 36% of the undergraduate and postgraduate students understand the sustainable software development as they have an optimistic response. Moreover, about 43% of them aware about the sustainable software development as they have a pessimistic response while about 4% of them are impartial about the sustainable software development. Figure 3 shows the summary of survey findings.

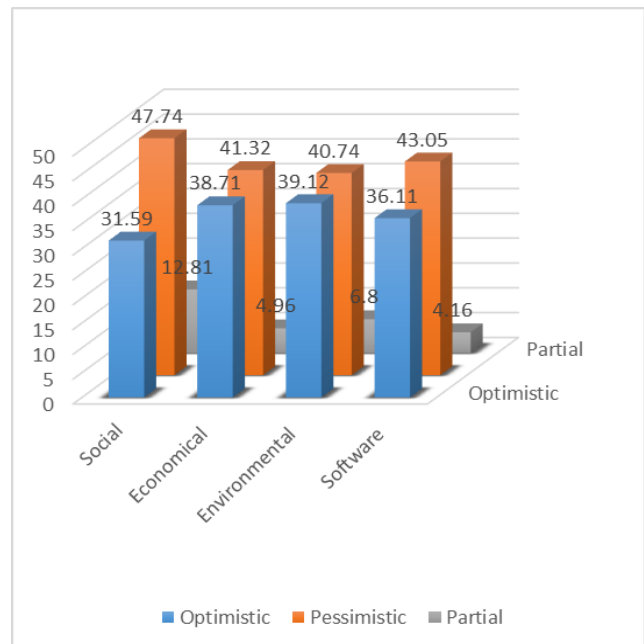


Figure 3. The Summary of Survey Findings





In summary, the results indicate that about 43% of the undergraduate and postgraduate students are either not at aware or slightly aware about the sustainable development. However, about 36% of them are aware about the sustainable development. Furthermore, about 7% of them are slightly aware about the sustainable development. Lastly, the students have lack of understanding about the sustainability concept awareness in the software development.

Sustainable development practices in the CS, SE and IT fields are essential concept for addressing the industry needs. However, there is a concern of how much does sustainable development provided to the students in their education. The CS, SE and IT curriculums are unable to incorporate the sustainable development concept in order to create environment-friendly systems. Thus, these curriculums have to include units that can help students for improving their coding schemes background and improving their understanding of socially accepted systems for enhancing their life quality.

## 5. CONCLUSION

To respond to the challenging nature of sustainable development into CS, SE and IT disciplines, the students have to be educated and well aware of the diffusion of sustainable development dimensions. This paper aims to investigate that whether our education is building the right capacity among the CS, SE and IT students to outperform later in industry, and is curriculum followed in KSA equipped with sufficient substance of sustainability to provide learning platforms for students to react such emerging sustainability challenge? Thus, the survey methodology is used to investigate the awareness level of sustainable development among the CS, SE and IT students at the Saudi universities in the western and southern regions of the kingdom.

It indicates that the curriculum is yet to incorporate the critical aspects of sustainable development into CS, SE and IT programs and courses. Furthermore, the survey analysis indicates that the students are not well aware of sustainable development concerns in CS, SE and IT majors. If the awareness and education for sustainable development among students is unattended and ignored, it can impact directly the students' abilities to incorporate the sustainable development aspects in IT and software projects that can eventually increase the possibility of software failures.

Hence, the industries have to play an essential role over training and workshops to guide students and the offered curriculum of CS, SE and IT majors. The survey was conducted comprehensively. However, the sample size is one of the limitations of these survey. In addition, another limitation is that this survey only deals with CS,

SE and IT majors. Thus, dealing with sustainable development in other fields can be considered as future work. Moreover, creating education curriculum that can consider the sustainable development is another future work direction.

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