DEVELOPMENT OF STUDENT SUSTAINABILITY AWARENESS, ATTITUDES AND ACTIONS

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ABSTRACT

Research on sustainability in Higher Education lacks the focus on measuring the differences in knowledge, attitudes and actions of students before and after being exposed to the 17 Sustainable Development Goals (SDGs), especially within a West-Asian context. The 17 SDGs and their learning objectives, developed by the UNESCO (2017), represent the framework of this study. For each of the SDGs, a relevant learning objective has been selected for measuring the awareness, attitude and action of students working on an engineering design/build project in teams. The learning objective of each SDG has been selected based on relevance for the given context. Students participated in a questionnaire survey to evaluate their awareness, attitude and action related to the SDGs on a 4-point response scale. This has been done twice, before and after being exposed to a design/build project using a Conceive-Design-Implement-Operate (CDIO) framework. Descriptive statistics as well as inferential statistics have been carried out in order to analyze the impact of the project on students' perspectives and illustrate the extent of the influence. Some SDGs were more affected by the project scenario than others. Scaffolding engineering students' learning of the SDGs by personal reflection ensured that no goal is excluded from the learning process. The results show that students' learning needs to be supported by reflection on these goals in order to avoid confining the learning process to SDGs that are developed more intensively by the project scenario. It is recommended to do future studies using an experimental/control group design in order to differentiate learning supported by reflection versus project scenario. The findings confirm the approach of including real life sustainability issues in the project scenario. This study is part of an ongoing research effort related to sustainability and engineering education in the region of the Gulf Cooperation Council (GCC).

KEYWORDS

Sustainability, Sustainable Development Goals, Knowledge, Awareness, Action, Standards: 4, 5, 8

INTRODUCTION AND BACKGROUND

Education has always been a longstanding solution for spreading peace and solving social challenges on a local and global scale. Educating for peace known as "peace education" aims to foster the necessary knowledge, skills and attitudes that cultivate a culture of peace and a prosperous society (United Nations Educational, Scientific and Cultural Organization, 2008). Peace education should be integrated and mainstreamed throughout any educational

experience provided in the educational institution (Fountain, 1999). Engineering is a profession that is central to the resource consumption and continuous development (Huntzinger *et al.*, 2007). Future engineers should gain the sense of responsibility and carefulness towards solving issues and creating a better world. Therefore, it is the duty of higher education institutions to enable students to participate in the solutions necessary for the encountered challenges (Svanström *et al.*, 2008). The United Nations developed the Sustainable Development Goals (SDGs) with the aim of protecting the planet and creating a peaceful, prosperous and sustainable environment for people to enjoy. Incorporating these goals in engineering curricula widens the horizon of future engineers through letting them think about the local and global challenges and the possible solutions that can be used (Gereluk, 2012).

The United Nations Sustainable Development Goals (SDGs)

Never before has humanity faced an enormous amount of challenges as we encounter today (Svanström et al., 2008). In 2015, 17 SDGs were formally adopted at the United Nations (UN) Sustainable Development Summit. One of the main aims of the UN is to achieve these SDGs by 2030 and thus secure a more sustainable future for all. SDGs seek to strengthen universal peace and provide a common vision for peaceful and prosperous societies. Sustainable development acts as a blueprint to secure the needs of the present without compromising the ability to meet the needs of the future (Boluk et al., 2019). Integrating sustainability in education is a recent trend amongst higher education institutions (Shephard & Furnari, 2013). Promoting quality education is essential for improving people's lives and taking sustainable development one step forward (Unesco, 2017).
The SDGs can serve the purpose of an overarching framework to systematically integrate the necessary knowledge, skills and values of peace education in addition to introducing future engineers to the concept of sustainable development. The 17 SDGs developed by the UNESCO (2017) are summarized below:

1. *No Poverty* (SDG 1) focuses on annihilating extreme poverty for all people everywhere (currently measured as people living on less than $1.25/day and access to affordable housing for all people).
2. *Zero Hunger* (SDG 2) focuses on problems related to limiting hunger and increasing sustainable agriculture and proper nutrition.
3. *Good Health and Well-being* (SDG 3) focuses on creating a healthy indoor and outdoor environment in addition to the utilization of sustainable and environment friendly building materials.
4. *Quality Education* (SDG 4) focuses on assuring life-long learning opportunities for all people and facilitating high-quality education for a sustainable built environment.
5. *Gender Equality* (SDG 5) focuses on fighting all forms of gender discrimination and violence in addition to eliminating the causes of gender inequality.
6. *Clean Water and Sanitation* (SDG 6) focuses on promoting waste water treatment and recycling in addition to increasing efficiency of water consumption in building construction and building material manufacturing.
7. *Affordable and Clean Energy* (SDG 7) focuses on increasing the investments in renewable energy and enhancing energy efficiency in buildings.
8. *Decent Work and Economic Growth* (SDG 8) focuses on increasing job creation through the building sector, cultivating innovation and providing a safe working environment.
9. *Industries, Innovation and Infrastructure* (SDG 9) focuses on developing reliable, sustainable and resilient infrastructure. It also covers increasing the usage of clean technologies in buildings and infrastructure.

10. *Reduce Inequalities* (SDG 10) generally focuses on inequality and discrimination within the society and especially against minority groups within a nation.
11. *Sustainable Cities and Communities* (SDG 11) focuses on providing a safe, affordable and accessible transport within cities and districts in addition to facilitating access to green spaces in cities.
12. *Responsible Consumption and Production* (SDG 12) promotes recycling in new building construction and renovation. It also endorses sustainability-oriented procurement practices for new construction and renovation.
13. *Climate Action* (SDG 13) focuses on climate change mitigation and adaptation in the built environment in addition to enhancing the resilience of the built environment towards natural disasters.
14. *Life Below Water* (SDG 14) focuses on ecology, ecosystems, how the current climate change is influencing these aspects and potentially minimizing these effects.
15. *Life on Land* (SDG 15) focuses on reducing the degradation of natural habitats and loss of biodiversity.
16. *Peace, Justice and Strong Institutions* (SDG 16) focuses on the social justice, inclusion and peace in nations and the law enforcement of these aspects.
17. *Partnerships for the Goals* (SDG 17) focuses on building long-term partnership between organizations and governments that would nurture financing for sustainable development, trade policies and the interconnectedness of different countries and populations.

Annan-Diab & Molinari (2017) followed the six principles of PRME (Purpose, Values, Method, Research, Partnerships and Dialogue) as a framework to integrate the sustainable development into a higher education curriculum. They recognized how this integration positively influenced the knowledge and awareness of students towards sustainable development. Similarly, Jain *et al*. (2013) previewed how the sustainable development concepts were embedded in higher education through various educational methods that also foster interdisciplinarity teamwork and role playing. Willats *et al.* (2018) emphasized the importance of integrating SDGs in the higher education institution curriculum through focusing on the different facets of sustainable development and moving away from the idea that sustainability is exclusively an environmental issue. They described how the integration was done in a holistic manner throughout a range of courses in the curriculum, rather than focusing on one course only, in order to cover the knowledge requirements and complexity of sustainable development. Looking into the literature, there is a general focus on the knowledge related to SDGs rather than the attitudes to be embedded in the students' behavior and actions to be taken towards the matter of sustainability.

PURPOSE

The purpose of this study is to identify the development of knowledge, attitude and action related to the 17 SDGs among engineering students of a private college in the GCC (Gulf Cooperation Council) region, during a design build project carried out within a CDIO framework. Although, only a few SDGs (3, 4, and 7) are directly related to this design build project, all 17 SDGs have been discussed with all students during the project. The results allow a comparison between students' perception before project commencement and after project completion. Furthermore, the difference between knowledge, attitude and action are analyzed.

METHODOLOGY

The framework for this study is reflected by the 17 SDGs developed by the UNESCO (2017). Following the approach of Sunthonkanokpong and Murphy (2019), one learning objective has been selected based on the five learning objectives per SDG provided by the UNESCO (2017) for each: knowledge, attitude and action. Discussions with students were conducted to ensure that the questionnaire's length is not overwhelming, and a total of 51 (3 × 17) items were included accordingly. During a focus group meeting of four faculty members, it was ensured that the selected learning objectives were relevant for the given context. In order to evaluate students' perception of knowledge, attitude and action related to the 17 SDGs, one questionnaire-based survey has been carried out before commencing the design build project (in the following called pre-test), and a second survey has been carried out after completing the project (in the following called post-test). Following the recommendation of Garland (1991, p.70), a 4-point response scale was chosen in order to avoid a midpoint of the instrument scale (i.e. uncertain or unsure), which could cause a social desirability bias among respondents. All 17 questionnaire statements related to knowledge begin with "My knowledge of…", the statements related to attitude begin with "I feel…" and the statements related to action begin with "I will…". The latter set of statements was introduced with "If I run my own engineering company,…". An example of statements for the *knowledge*, *attitude* and *action* section is shown for SDG 1 in Table 1.

Table 1. Example of Questionnaire Statements Related to SDG 1

Questionnaire section	Question [answer scale]
Knowledge	My knowledge of the consequences of poverty for poor individuals and society is… [very low, low, high, very high]
Attitude	I feel empathy for the people in poor situations. [strongly disagree, disagree, agree, strongly agree]
Action	I will provide some practical relief to people in a poor country and encourage my staff to be involved too. [No, unlikely, likely, yes]

The project brief of the design build project included the following information, and students had six weeks to work on the project. Furthermore, students were required to reflect each week on two to three SDGs, i.e. they were asked to answer the "What? So what? and What now? questions". This approach ensured that students interacted also with SDGs that were not directly related to the design build project.

Introduction

In factories and workshops of many parts of the world only standard exhaust fans are used for ventilation of the workplace. With increasing work activities and operation of equipment, the ventilation is insufficient and poses a risk for the health of the employees working in such an environment. Many business owners are not willing to increase wall openings and to procure and install larger exhaust fans, but they might consider exchanging existing blades with more efficient blades.

Project Scope

The International Health Organization (client, represented by your professor) has approached your interdisciplinary engineering design team to investigate if existing

standard designs of exhaust fan blades (also called ventilation fan blades) can be optimized regarding weight (i.e. material consumption) and efficiency (i.e. ventilation capacity). The International Health Organization is interested in innovative design solutions and a physical model that reflects the shape of the exhaust fan blades and spinner.

The following requirements have to be met:

1) Research existing blade designs and efficiencies.
2) Research existing building codes and regulations regarding ventilation of workplaces.
3) Identify improvement potential of blades and spinner (e.g. shape, number of blades, etc.)
4) Design improved blades / spinner for a circular body (housing) and 200mm diameter sweep area.
5) Calculate the possible ventilation capacity based on realistic assumptions and compare with existing standards for exhaust fans.
6) Estimate the manufacturing cost of blades and spinner.
7) Estimate the financial consequences for business owners (e.g. electricity consumption, impact on work productivity, etc.)
8) Each team needs to 3-D-print a physical model of their blades and spinner using a scale of 1:2.
9) Each team member needs to show relevant sketches, sources and calculations in their Workbook. Excel is to be used for repetitive calculations.
10) Each team has to apply professional project management techniques.

For the descriptive statistics, Mean, Median and Standard Deviation have been computed, and for the significance testing a *t*-test for two samples has been applied since the number of students of the pre-test was not identical with the number of students of the post-test. Results of *t*-tests have been shown to be fairly robust against violating the assumption of a normal distribution, but they are strongly influenced by outliers (Pfahl *et al.,* 2004). Therefore, the existence of outliers has been analyzed, and it was found that all scores of the two tests are within +/- 2 standard deviations around the mean score.
Results of the data analysis are presented in the following section, before completing the study with a discussion section and conclusions.

RESULTS

The results of the descriptive statistics are shown for the pre-test and post-test in Table 2. For the pre-test, the highest Mean was found for SDG 4 of the *knowledge* section, SDG 2 of the *attitude* section and SDG 11 of the *action* section; whereas the lowest Mean was identified for SDG 9 of the *knowledge* and the *action* section and for SDG 15 of the *attitude* section. Regarding the post-test, the highest Mean was found for SDG 6 of the *knowledge* section, SDG 17 of the *attitude* section and SDG 14 of the *action* section; whereas the lowest Mean was found for SDG 17 of the *knowledge* section, SDG 15 of the *attitude* section and SDG 9 of the *action* section.
Results of the *t*-test are shown in Table 3. For the *knowledge* section, six SDGs (i.e. SDGs 1, 2, 8, 9, 15, and 16) show a statistically significant higher Mean (at alpha = 0.05) for the post-test; whereas results of two SDGs (i.e. SDG 4 and SDG 13) do not confirm the expected direction of the effect.

Table 2. Descriptive Statistics Results for Pre-test and Post-test (Increased Mean are Bold)

SDG	Pre-test / Post-test	Knowledge			Attitude			Action		
		Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Poverty	Pre-test	2.76	3	0.64	3.52	4	0.65	3.42	3	0.66
	Post-test	**2.97**	3	0.72	3.51	4	0.64	3.31	3	0.71
Hunger	Pre-test	2.75	3	0.75	3.79	4	0.52	3.54	4	0.69
	Post-test	**2.93**	3	0.75	3.59	4	0.53	3.38	3	0.62
Health	Pre-test	3.27	3	0.64	3.65	4	0.54	3.20	3	0.81
	Post-test	**3.29**	3	0.70	3.57	4	0.58	**3.30**	3	0.58
Education	Pre-test	3.38	3	0.60	3.60	4	0.59	3.40	3	0.67
	Post-test	3.34	3	0.60	3.57	4	0.52	3.40	3	0.59
Gender	Pre-test	3.07	3	0.71	3.33	4	0.85	3.58	4	0.69
	Post-test	**3.22**	3	0.74	**3.45**	3	0.63	3.56	4	0.68
Water & Sanitation	Pre-test	3.18	3	0.74	3.40	3	0.65	3.43	4	0.67
	Post-test	**3.35**	3	0.78	**3.49**	4	0.62	3.40	3	0.68
Energy	Pre-test	2.90	3	0.80	3.42	3	0.59	3.30	3	0.75
	Post-test	**3.07**	3	0.94	**3.44**	3	0.70	**3.38**	3	0.71
Economy	Pre-test	2.43	2	0.81	3.51	4	0.66	3.63	4	0.60
	Post-test	**2.89**	3	1.03	**3.52**	3	0.72	3.54	4	0.73
Industry	Pre-test	2.29	2	0.76	3.23	3	0.65	2.94	3	0.83
	Post-test	**2.85**	3	1.08	**3.35**	3	0.79	**3.23**	3	1.01
Inequalities	Pre-test	2.91	3	0.75	3.57	4	0.69	3.27	3	0.70
	Post-test	**3.02**	3	1.08	3.57	4	0.88	**3.41**	3	0.89
Cities & Communities	Pre-test	3.14	3	0.67	3.45	4	0.63	3.73	4	0.51
	Post-test	**3.24**	3	1.12	**3.57**	4	0.96	3.65	4	0.94
Production & Consumption	Pre-test	3.02	3	0.75	3.33	3	0.64	3.52	4	0.61
	Post-test	**3.12**	3	1.21	**3.52**	3	1.04	**3.56**	4	1.07
Climate	Pre-test	3.07	3	0.67	3.41	3	0.62	3.06	3	0.93
	Post-test	**3.18**	3	1.30	**3.51**	3	1.13	**3.36**	3	1.23
Water Life	Pre-test	2.88	3	0.88	3.38	3	0.65	3.57	4	0.66
	Post-test	**3.15**	3	1.39	**3.44**	3	1.27	**3.63**	4	1.26
Land Life	Pre-test	2.45	2	0.84	3.06	3	0.84	3.18	3	0.74
	Post-test	**3.08**	3	1.51	**3.34**	3	1.41	**3.42**	3	1.40
Peace	Pre-test	2.78	3	0.93	3.63	4	0.60	3.30	3	0.72
	Post-test	**3.15**	3	1.57	3.62	3	1.40	**3.57**	3	1.44
Partnership	Pre-test	2.56	3	0.85	3.50	4	0.58	2.97	3	0.82
	Post-test	**2.84**	3	1.75	**3.63**	4	1.52	**3.46**	3	1.61

For the *attitude* section, no SDG shows a statistically significant higher Mean (at alpha = 0.05) for the post-test; whereas results of ten SDGs (i.e. SDGs 2, 3, 4, 7, 8, 10, 13, 14, 16, and 17) do not confirm the expected direction of the effect.
For the action section, two SDGs show a statistically significant higher Mean (at alpha = 0.05) for the post-test (i.e. SDG 9 and SDG 17); whereas results of nine SDGs (i.e. SDGs 1, 2, 4, 5, 6, 8, 11, 12 and 14) do not confirm the expected direction of the effect. Figures 1 to 3 show the difference in means related to the students' knowledge, attitude and action during the pre-test and post-test.

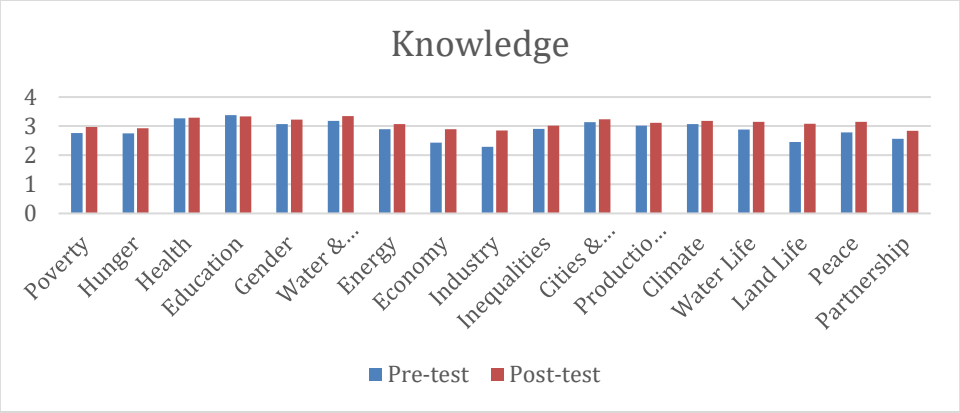

Figure 1. Mean of pre-test and post-test results of students' knowledge

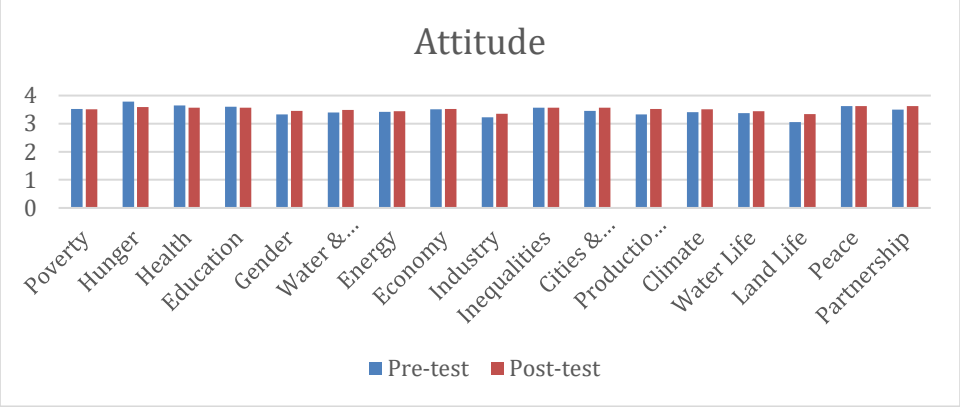

Figure 2. Mean of pre-test and post-test results of students' attitude

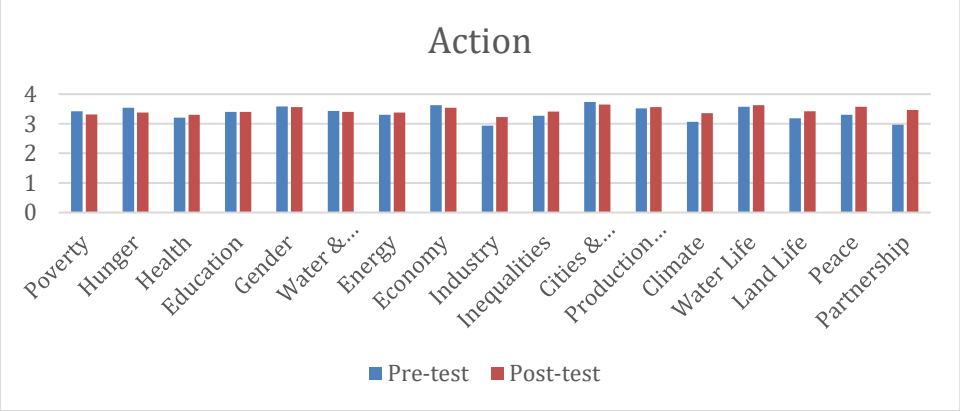

Figure 3. Mean of pre-test and post-test results of students' action

Table 3. Results of the *t*-test (Knowledge, Attitude, Action)

SDG	Knowledge				Attitude				Action			
	Degrees of freedom	*t*-Value	*p*-Value	t $Crit_{0.95}$	Degrees of freedom	*t*-Value	*p*-Value	t $Crit_{0.95}$	Degrees of freedom	*t*-Value	*p*-Value	t $Crit_{0.95}$
Poverty	180	2.320	0.011	1.653	184	0.138	0.445	1.653	183	-0.854	0.197	1.653
Hunger	183	1.757	0.040	1.653	184	-2.381	0.009	1.653	183	-1.475	0.071	1.653
Health	179	0.182	0.428	1.653	181	-0.825	0.205	1.653	173	0.983	0.164	1.654
Education	183	-0.472	0.319	1.653	183	-0.461	0.323	1.653	183	-0.075	0.470	1.653
Gender	183	1.206	0.115	1.653	173	0.918	0.180	1.654	184	-0.389	0.349	1.653
Water & Sanitation	183	1.345	0.090	1.653	183	0.790	0.215	1.653	184	-0.632	0.264	1.653
Energy	181	1.044	0.149	1.653	183	-0.191	0.424	1.653	179	0.424	0.336	1.653
Economy	180	3.236	0.001	1.653	181	-0.492	0.312	1.653	184	-1.589	0.057	1.653
Industry	177	4.029	0.000	1.654	180	0.687	0.246	1.653	184	1.903	0.029	1.653
Inequalities	181	0.335	0.369	1.653	181	-0.789	0.216	1.653	179	0.672	0.251	1.653
Cities & Communities	177	0.188	0.425	1.654	184	0.467	0.320	1.653	181	-2.099	0.019	1.653
Production & Consumption	182	0.012	0.495	1.653	182	1.023	0.154	1.653	184	-0.606	0.273	1.653
Climate	175	-0.058	0.477	1.654	183	-0.073	0.471	1.653	175	1.600	0.056	1.654
Water Life	184	1.281	0.101	1.653	184	-0.568	0.285	1.653	184	-0.648	0.259	1.653
Land Life	183	4.020	<0.001	1.653	181	1.314	0.095	1.653	184	1.066	0.144	1.653
Peace	183	1.809	0.036	1.653	183	-1.781	0.038	1.653	181	1.345	0.090	1.653
Partnership	181	0.882	0.189	1.653	184	-0.264	0.396	1.653	184	2.972	0.002	1.653

DISCUSSION

Descriptive statistical results shown in Table 2 indicate that at pre-test stage three SDGs (8, 9, and 15) in the *knowledge* section have a median value of 2 which is not shown in any other SDGs of *attitude* and *action* sections. Interestingly, as shown in Table 3, the same SDGs improved significantly in the *knowledge* section (the highest improvement in all SDGs of all sections). At the post-test stage the median values for all three sections were more than 2. This indicates that knowledge related to these SDGs prior to the design-build project for majority of the students participated in this study was at a lower level compared to other SDGs. The values reported in Table 2 indicate that the mean values (pre- and post-test stages) in the *knowledge* section is generally lower than those in the other two sections. This may indicate that due to lack of knowledge, a design-build project (or any other type of educational assignment) can be a great tool to improve the students' knowledge related to the SDGs. Generally speaking, the standard deviations of values reported for the *knowledge* section is higher than those reported for *attitude* and *action* sections; while students may have similar views in the *attitude* and *action* sections, the study shows that students have wildly varying degrees of knowledge of the SDGs. It makes sense since attitude and action are strongly connected to the culture of people.

After completing the design-build project, inferential statistical results tabulated in Table 3 indicate that the knowledge of students of all SDGs (except SDG 4 and SDG 13) have been improved, with six SDGs showing significant improvement (SDGs 1, 2, 8, 9, 15, and 16).

On the other hand, participating in the design-build project did not show any significant improvement in the attitude and action of students for majority of the SDGs (except in SDG 9 and SDG 17 in the *action* section). In fact, completing the project showed an adverse effect on

most of the SDGs in these two sections. Since the action of students in SDGs 9 and 17 has been significantly improved, it shows that students not only understood that developing reliable, sustainable and resilience infrastructure and long-term partnership between organizations and governments are important, but also would be willing to act more seriously after finishing the project.

One of the main reasons that most of the SDGs (15 out of 17) have been improved or significantly improved in the *knowledge* section can be related to the fact that the project was done in an educational institution with more emphasis on the knowledge transfer. It also shows the importance of the CDIO approach and how effective it can be in a relatively short period of time.

Several CDIO standards were addressed in this study. The CDIO standard 3 was addressed through enhancing some of the personal, interpersonal knowledge and attitudes of students that were involved in the examined project. The CDIO standards 4 and 8 were also addressed through this research as the students were introduced to new concepts that are vital to sustainable and ethical engineering practice and were engaged to form their own opinions and respond accordingly.

The adverse effect of completing the design-build project on most SDGs (10 out of 17 in the *attitude* section and 9 out of 17 in the *action* section) can be explained in several ways. First of all, attitude is a settled way of thinking or feeling about something and changing it significantly in a relatively short period of time (six weeks for the design-build project in this study) will be quite challenging. Secondly, change (or significant change) in action requires a change in attitude, seeing as attitude and action are interconnected. Thirdly, after gaining more knowledge about the SDGs, students became more realistic in evaluating their attitude and action. This means that pre-test results in the *attitude* and *action* sections may not be as realistic as the post-test results.

It will be interesting to perform a similar study over a longer period of time (e.g. pre-test of freshmen students and post-test of the same students when they graduate) and/or in a different environment (e.g. employees of large size companies) to study the effect of the duration of exposure to the SDGs, as well as being exposed to real-life scenarios in a workplace.

CONCLUSION

The following conclusions can be drawn from this study:

1. The CDIO approach in educational institutions can improve (or significantly improve) the knowledge of students related to the SDGs. This is in line with the findings of other researchers as mentioned in the *introduction and background* section of this paper. Three CDIO standards were covered in this research.
2. Personal reflections on the SDGs by students were effective in improving their knowledge in a relatively short period of time.
3. Attitude and action (especially attitude) cannot be significantly improved in a short period of time as they are related to the culture of students.
4. Gaining more knowledge may help students to evaluate their attitude and action related to the SDGs in a more realistic way, and this may adversely affect the results for these two sections.
5. Long-term study on students group as well as performing similar study on group of practicing engineers will help to understand the matter.

LIMITATIONS

Due to the nature and duration of the study, there was no clear influence on the actions taken by students that would in return satisfy the SDGs. Future researches may be able to address the Longitudinal nature of this requirement through covering an extended period of time and looking further into how education about the SDGs truly influence the actions of students during their studies and beyond graduation.

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