Development and Implementation of Sustainability IoT Based Curriculum

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Abstract

Sustainable development has three main pillars, economic, social, and environmental. In the strive for a sustainable world, environmental and social issues must be addressed as they affect the world economy. With the past industrial revolutions and their negative effects on our world, it is becoming essential to involve students in sustainability as engineering and technology are important elements into fixing the past negative effects on our planet. Consequently, educating engineering students on sustainable development is wide spreading in the past few years and is actually taking place worldwide in many modern faculties and universities. Aside from the United Nations mandates, it is those engineers who are to make the efforts in their respective fields to create ways to improve the sustainable world around us. There are many methods to go about teaching such a subject, some are direct and some uses indirect methods. Building upon the experience of others and the wide spectra of methods, a new curriculum is designed, based on innovations in technologies, to cover sustainability along with environmental and social implications. The curriculum relies on a mixture of learning techniques especially suitable for a developing and growing educational environment where the subject matter experts are not abundantly available. The method used in the design and implementation allows flexible usage and integration of the course by educational institutions and new universities. The results of applying the course content on a sample of 50 student is collected and analysed. The tabulated data and graphs show the strong points of the course materials as well as the areas of improvements.

Keywords: sustainable development, teaching methodology, educational systems, learning outcomes, data analysis, ICT, IoT
JEL classification: I20

Introduction

The design and introduction of a new curriculum into an educational system requires the compliance with many factors including the study program that is being followed by the institution, the need and capabilities of the students and governing laws and regulations. Some of these regulations are inflexible and may require many levels of approval. A good method should allow the gradual introduction with wide availability to all the intended users. As such, we have approached the design of our course using compatible models in teaching engineering students. The course can be introduced gradually into the various departments as per a pre-set plan then get expanded into the school curriculum in subsequent semesters.

Education around the world depends more and more on the use of technology and the integration of the new teaching methods. However, while smart educational environment uses the newest trends of Information Communication Technology (ICT),

it can also have negative impacts on the world resources. As such, there is a need to investigate the effect of using ICT equipment on the environment, society, and the sustainable development (SD). Moving forward, the enabling technologies such as Internet of Things (IoT) can be used in many ways to help sustainability.

The environment and society are very much close to sustainable development, after all, it is the environment that need to be improved for the best conditions of the society. As a result, the concepts of sustainable development can be combined with environment and society into one syllabus. Therefore, it is essential to educate the future professionals who will work in the sustainability field. The teaching must be done in a way that it becomes relevant and possible for the students to relate to and this can be achieved by introducing stimulating exercises.

It is becoming clear that sustainable development requires good attention, in particular, within the fields of engineering. The United Nations (UN) Sustainable Development Goals (SDG) are agreed upon in 2014, "SDG, (2016)". The 17 SDGs cover not only engineering aspects but all other areas that affect the environment and society. It is important to notice the characteristics of sustainability and its relation to the environmental issues; such as climate change, reducing greenhouse gas emissions, and the limited supplies of non-renewable resources.

Background and Motivation

The United Nations (UN) has been inspirational instrument in developing the concepts of Engineering Education for Sustainable Development (EESD). The UN has named the decade 2005-2014 the UN Decade of Education for Sustainable Development led by "UNESCO (2005)". Consequently, there have been substantial achievements on international scale relevant to EESD, "Byrne et al (2010)". Examples of EESD initiatives were documented by academic authors in papers published in either conference proceedings or peer-reviewed scientific journals.

In Sweden; the Royal Institute of Technology has taken a long trip on teaching sustainability to students. Each student enrols in at least one SD course during his/her degree. The teaching method varies from one course to another; some use direct method while other use indirect method. The first method relies on a fixed SD curriculum with pre-determined related topics given in lectures, and the students are then given assignment or projects related to these topics. The later method uses topic from the specific engineering discipline and ask the students to figure out the effect of a particular problem on sustainability, "KTH, (2016)".

Another good example is the master program in sustainable development at Uppsala University. The program is composed of four semesters and 120 credit hours. It introduces sustainable development's worldviews and visions towards natural resources, society and environment; energy, water and food. It also ends with a degree project in sustainable development, "Uppsala (2016)".

In Netherland, at Delft University of Technology, "Moulder, K. (2004)" presented sustainability as a tool to open up the windows of engineering education; followed by "Kamp, L. 2006", who discussed engineering education in sustainable development.

In United Kingdom; Fenner et al (2005) illustrated embedding sustainable development into curricula of engineering departments at Cambridge University. Humphries-Smith, T. (2008) discussed sustainable design and the design curriculum at Bournemouth University.

In Spain; "Ferrer-Balas et al (2008)" discussed education transformation towards sustainable development at the Technical University of Catalonia.

In the United States of America; "Allenby et al (2009)" published a national overview of EESD in the American institutions of higher education. "Epstein et al (2009)" presented EESD case study at the Massachusetts Institute of Technology.

In Japan; "Onuki & Takashi (2009)" elaborated on the graduate program in sustainability science at the University of Tokyo. "Uwasu et al (2009)" discussed mobilizing science and technology towards sustainability at Osaka University.

In China; "Xu, K. (2008)" presented the status of EESD in Chinese universities within a national overview about engineering education and technology in a fast developing China.

In Australia; "Mitchell, C. (2000)" discussed concentricity and its consequences upon integrating sustainability in chemical engineering practice and education at University of Sydney. "Bryce. et al (2004)" implemented a program in sustainability for engineers at Sydney University of Technology. Daniell & Maier (2005) illustrated their embedding sustainability in civil and environmental engineering courses at University of Adelaide.

In Africa; "Olorunfemi & Dahunsi (2004)" presented their experience at Lagos State Polytechnic as a move towards a sustainable engineering education in Nigeria. "Ramjeawon, T. (2008)" at University of Mauritius elaborated on sustainable development as enabling the role of engineers in the engineering professions in Mauritius.

Methodology

The design of a curriculum includes a rich set of features that allows it to be used for wide range of educational purposes. The curriculum covers the sustainability requirements and a rich set of topics on environment and society such as the greenhouse effect, global warming, and climate changes. The curriculum main topics are given in Table 1. The concepts of sustainable development are first introduced along with the UN definitions and future plans. Next, ICT solutions for sustainable development are introduced followed by the concept of smart sustainable cities and their environment.

Table 1
The overall course topics

Introduction to Environment and Sustainability
Humans and the environment
Gases contributing to the greenhouse effect
Global warming and climate changes
Concept of Sustainable Development and UN plans
Introducing ICT-solutions for Sustainable Development
Concept of Smart Sustainable Cities and the environment
Air pollution and the environment air quality index
Water resources and ground water
Water pollution and Wastewater treatment and disposal
Solid pollution and solid waste management
Control and Disposal of Wastes, Mitigation, Reuse/Recycle
Industry growth and Alternative/Green Energies

Source: actual course contents prepared by the authors

Engineering students in particular should be taught how to perform sustainable design, which is a collaborative approach to fulfil sustainable development

strategies and goals. The design strategies include things such as energy conservation and elimination of toxic materials. Sustainable architecture education for engineers should focus on using the knowledge and skills in sustainable design in order to achieve energy efficiency as well as convenience in the built environment, "Educate (2010)". The main objective is to meet the main pillars of sustainability; economic (growth, capital, etc.), social (human resources, health, education, etc.), and environmental (habitat, species, biodiversity, etc.).

While ICT has positive effects on the society, it also has negative effects. The positive effects include increased access to information, increased opportunities for education, and improved telecommunications. The negative impact of ICT on society includes reduced personal social interaction in daily lives and also causing some ethical problems due to the amount of misleading information available on the internet. Now, we know that sustainable development requires a deep societal transformation in many areas and we also know that ICT is already affecting the society. Hence, we need to steer the digital revolution into the direction of sustainability. The current cyber-physical revolution is in a position to give a big boost to sustainability.

Meeting sustainability goals in cities requires sustainable use of resources which requires the evolution of cities into smart cities or a smarter cities with many smart applications. IoT technology is the critical enabler of smart city development and of meeting the sustainability requirements such as energy efficiency, improved security, and other convenient applications. It is known that cities consume about 75% of the globally produced energy, "UN-Habitat (2011)". Technological advances must make cities becoming more intelligently connected in order to save energy and operating costs. IoT enables energy technologies to be more efficient and sustainable by supporting new ideas such as virtual power stations and energy storage technology, "Web (2017)", having the potential for energy savings.

Thus, the implementation of the curriculum utilized various techniques in order to provide the maximum benefits to the students. In addition to the lectures on the topics listed in Table 1, the students are exposed to another weekly session where they present their acquired knowledge. At the beginning of the course, a list of possible topics are given to the students to select the ones that interest them. The students can also select a relevant topic outside the list if they wish to do so.

The course itself is composed of four contact hours per week; two hours for lecturing on the identified topics using two way interactive communication with the students. The other two hours are used for various objectives, the first of which is to involve the students in researching topic related to sustainable development. Teams of two students each are formed and are asked to collect information on one of the pre-selected topics then come and present it in the class with all the other students attending. Second, inviting guest speaker on related topics provides the students with empirical explanations and open discussions. In addition to these activities, site visits to related organizations are arranged for the same concept.

After completing the lectures on sustainable development, the students were asked to participate in a survey in order to assess their understanding of the sustainability issues and the way the information was disseminated to the class. The results of this experiment are presented in the next section.

Results

We used the concepts described in the methodology section to execute the sustainability course under consideration. The experiment was conduct on a sample of 50 student and the results of the course statistics are documented below. The

survey measured the SD topic acceptability, the teaching methods, the acquired knowledge, and the SD applicability as understood and assessed by the student sample.

Teaching methods

90.1% of the students were satisfied with the teaching methods used in this course which included interactive class lectures that are posted on the university web site in order to help the students study the course materials. The students found the sustainable development lecture notes very clear and easy to read and study. In addition, the students were extremely satisfied with the dissemination of instructions through a Facebook group that aided them communicating their ideas about sustainable development outside classroom formalities.

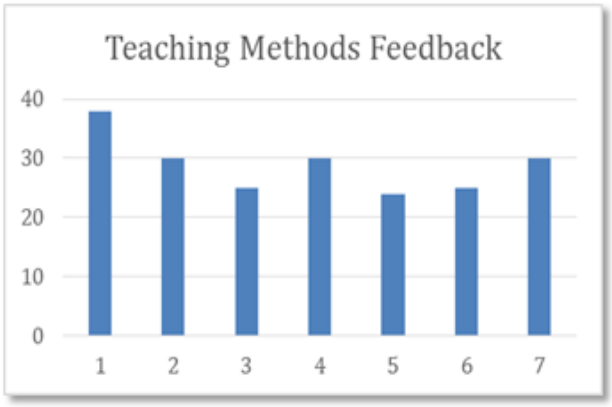
Table 2
Teaching Methods Survey Items

1	Posting the lectures on the web sites helped me study the course materials
2	The sustainable development lecture notes were very clear and easy to read and study
3	The tutorial section was beneficial to getting better knowledge out of this course
4	The external seminars helped me widen my scope of knowledge about sustainable development
5	The student presentation helped in enriching my knowledge about diverse topics of sustainable development
6	While preparing for my presentation, I found lots of literature on the internet related to sustainable development
7	Forming unofficial Facebook group helped students to communicate their ideas about sustainability outside classroom formalities

Source: actual survey items prepared by the authors

A very high percentage, 75.5%, of the students believes that this course can be improved by adding a student mini-project related to sustainable development and the environment for the duration of the academic term. This suggestion will be incorporated in the next offering of the course.

Figure 1
Teaching Methods Feedback



Source: chart of the data collected by the authors

More than half students, 69.4% of the students, strongly believe that this course could be more effective by interacting through video-conference with students studying sustainable development in advanced countries, however, there are some logistics that need to be addressed before implementing this collaboration. Also, 71.4% of the

students strongly believe that this course could be more beneficial by arranging trips to professional environmental organizations and consulting firms. Figure 1 shows the teaching methods feedback in correspondence with Table 2.

Topic acceptability

High percentage, 65.1%, of the students strongly accepts the introduction of the sustainable development topic into the engineering curriculum. These students indicated that studying sustainability help them in understanding the social and environmental issues and broaden their thinking about the overall engineering effects on sustainable development. Basically, taking this course opened their eyes to the importance of sustainable development.

The same results indicated that a course covering the concept of sustainable development should be taught in every engineering department as engineers are mostly responsible for solving the negative environmental effects due to extensive and diverse industrialization and the studying of sustainability help in changing the behaviour towards the environment.

However, only 40.8% of the students believe that sustainability knowledge will help in getting better job opportunities and that the sustainability skills and environmental awareness are still not a high priority in many corporate jobs. This data can be explained in the light of two facts; 1) the awareness about the topic in our country currently is not very high, and 2) while the overall awareness about the topic is higher than in our country but worldwide is still in its infancy, not to mention that the SDGs are only approved in 2014.

Acquired knowledge

On the acquired knowledge area, the overall results revealed that 81.9% of the students became aware of the sustainability issues including natural system functions, ecological diversity, and balancing the use of renewable energy sources. They believe that sustainability protect the natural environment while influencing the way we live and that the economic development is giving people what they want without compromising the quality of life; to the contrary, living in urban areas is becoming more sustainable than living in remote areas.

It was interesting to find out that the students understand that the SDGs should not be assessed individually for their feasibility and suitability, without considering the remaining goals and that these goals are inter-related. For instance, reducing inequality within and among cities is one of the sustainability goals that is touching all aspects of human life. Sustainability draws on politics, economics, philosophy and other social sciences. As such, sustainable development focuses on balancing that fine line in between the ever increasing human needs and the need to protect the environment.

Finally, less than 2% of the students were aware of SD applicability and the new enabling technologies. The majority understand ICT effects and how it makes our lives more productive, and that the future of IoT applications will enhance our smart living and building smart new sustainable cities.

Discussion

The world resources must be sustainable in order to balance the quality of life for generations to come. Teaching young generations about sustainable world is of major importance as these generations will have to perform the recommendations of the research studies in this area. Economic, social, environmental, and even cultural concerns must be well understood by the students. As such, the initiative

taken in this paper was to implement the ideas set forward in the design methodology. The results showed great potential in steering our engineers in the direction of sustainable design.

Adding tutorial sessions to this course proved to be very successful in widening the scope of the students as they diligently performed in presentations about selected sustainable development topics, and also allowed the students to interact within themselves and with the course instructors as well. Inviting external speakers and visiting sites with activities relevant to course topics proved to be very effective in motivating the interest of students in learning sustainable development as a new paradigm then finding its application in their engineering disciplines as well.

Although this experiment is run on a class of diverse engineering students, the plan is to extend it during the upcoming semesters to wider classes of the student community. The fact that more than 90% of the samples indicated satisfaction with the course materials is a very encouraging result to support the way forward.

Conclusion

The innovations in technology and the recent cyber-physical industrial revolution have opened the way for exploring the area of learning, teaching, and curriculum development. The proper teaching of sustainability should be an approach that uses both, dedicated specific courses as well as relevant activities that are integrated into the rest of the teaching curriculum.

The ICT community needs to conduct research on how to educate students on topics of sustainable development. The students need to be taught how to get the required answers on their own in order to apply the sustainability knowledge to their future professions.

Both methodology in teaching and the selected topics for internet researching in sustainable development as embedded into a course on environment and society for engineering students at our university proved to be a successful approach that needs expansion into other engineering curriculums.

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