Environmental Education and Sustainable Development in Engineering Field Implementation and Learning Outcomes

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Abstract

The "zero-waste campus" programs at the Universiti Kebangsaan Malaysia (UKM) and UKM Lestari are two examples of UKM's drive to adopt the concept of sustainability in the management, administration, education, research, development and daily practice of the campus community by the year 2020. In this respect, education is an important component that could influence and shape the practice and culture of caring for the environment. Based on educational needs with regard to environmental and sustainable development (ESD), particularly in the engineering field, efforts are being made to see to what degree the educational mission has been implemented in accordance with the ESD concept. This paper emphasizes the need to review the various components of ESD in teaching and learning at the undergraduate level within the Faculty of Engineering & Built Environment (FKAB), UKM, with the aims of improving ESD education. Each engineering program has one program outcome (PO7) for the ESD component. Based on the courses offered, it is apparent that more ESD components are taught in the Chemical Engineering degree program. However, there is no specific course on sustainable development, and further study is required to assess the importance of this course in all academic programs at FKAB. Environmental elements in the field of engineering education should be formally provided to the students to enable them to understand the overall concept of environmental conservation, protection and enhancement. In this respect, appreciation for the complexities and interconnectivity of various environmental components shall ensure that decisions and actions made in all engineering undertakings will treat the interest of environmental sustainability as paramount.

Keywords: *Environmental and sustainable development (ESD); education; engineering; program outcomes*

I. Introduction

There are different definitions of ESD in the educational field. The general definition of ESD is development that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable development is a concept that emphasizes the conservation and preservation of natural resources. Sustainable development seeks to balance human needs and demands with the environment's capacity to handle human consumption and industry. It is not limited to a mere activity; rather, it is

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comprehensive and is closely related to human life on Earth. Three elements constitute the concept of sustainable development: economic, social and environmental. These three elements are interconnected and provide for the human needs of security, harmony and peace. Ashford [1] describes the concept of sustainable development in terms of three dimensions: the environment, employment and the economy. According to him, these dimensions constitute the three-dimensional concept of sustainable development.

Sustainability is the driver of innovation [2]. Sustainability is environmentally friendly (reduces environmental pollution) and can reduce costs and increase revenue. Companies must aim for sustainability in their operations to compete in global business. Severe environmental degradation in recent years has led engineering educators to incorporate the concepts of green engineering and sustainability into their undergraduate education [3]. The current need for sustainability components in industry and in education show that they are an important part of the education system, particularly in the field of engineering. The emphasis on the environment and sustainability in engineering is very important. In conjunction with the Third Meeting of the Regional Forum on the Environment and the Minister of Health in Kuala Lumpur on September 10, 2013, the Prime Minister also noted the importance of the environment in the development of the country. He outlined six steps to be taken to preserve health and the environment in the development plan: analyzing the relationship between environmental health and development; prioritizing environmental health issues within the larger development objectives; and assessing institutional mandates, capacity, regulation and enforcement in relation to the budget for environmental health [4].

Environmental education in engineering needs to be provided to students to imbue them with the concepts of environmental stewardship and sustainable design. More importantly, it is their responsibility to ensure that their decisions and actions are taken in the interest of environmental preservation. Engineers are responsible for providing the community's needs related to transportation, water supply, sewage, energy production, waste management, pollution control systems, and, over time, other very challenging issues. The demands of various interested parties need to be met, including those of traders concerned with the design of a cost-effective and superior solution; consumers who need an easy, comfortable and safe solution; and the government, which requires economic, social and advanced technologies without a negative impact on the environment. Every day, environmental problems become increasingly complex, with various plans and actions needing to be undertaken. As a result, even political pressure is affecting the engineering profession. Therefore, the engineering challenges, especially with regard to environmental protection and sustainable development, demand the best action to meet the interests of all. Prospective engineers must be prepared to meet these challenges by obtaining adequate knowledge before stepping into the working world

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where they will hold important positions and be capable of truly shaping the development of the country for the benefit of present and future generations.

The environment is closely related to sustainable development. Education is an important channel for delivering relevant knowledge to ensure a harmonious life for many generations to come. Emphasis on the concept of ESD in the field of engineering education is one of the program outcomes, as required by the Engineering Accreditation Council of Malaysia for engineering programs in Civil Engineering, Chemical Engineering, Electrical Engineering and Mechanical Engineering. This requirement demonstrates the importance of ESD in engineering education. What is the definition of ESD? A number of authors make reference to relevant definitions of sustainable development and how ESD components are applied in the field of education (Table 1). How do civil engineering, chemical engineering, electrical engineering and mechanical engineering deliver education in environmental science and sustainable development to students? Is it necessary to have compulsory ESD courses in each of the programs or simply include ESD in specific courses? What are effective teaching methods to impart information to the students? These are valuable questions that must be answered to help the individual become more responsible regarding the environment. With limited natural resources and human needs increase over time, engineers will have to be exposed to the importance of environmental preservation. For example, to prevent environmental damage, engineers are responsible for developing methods to produce energy in a carbon-neutral manner. They are also asked to design buildings that use environmentally friendly materials and provide a transportation system that does not use fossil fuels. These requirements need the engineering education system to introduce the concept of sustainable development in teaching and learning. Unfortunately, some studies show that engineers who are knowledgeable about and skilled in the practice of sustainable development are scarce in some places and that, as a result, they are unable to perform their responsibilities effectively [10].

Table 1: Definition of sustainable development

Definition of Sustainable Development	Reference
Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meets their needs.	[5]
Sustainability is considered to be the indefinite survival of the human species (with a quality of life beyond biological survival) through the maintenance of basic life support systems (air, water, land, biota) and the existence of infrastructure and institutions which distribute and protect the components of these systems.	[6]
Sustainable development concerns thinking in new and more integrated ways about the inter-relationships within and between the natural and cultural environments.	[7]

According to the Brundtland Commission (1987), sustainable development is development that meets the needs of the present without compromising the ability of future generation to meet their own needs.	[8]
The concept of sustainable development means more than mere improvements in eco-efficiency and free global markets, with its emphasis on social development.	[9]

II. Current System of Undergraduate Engineering Programs at universiti kebangsaan malaysia:environment and sustainability

The purpose of undergraduate engineering and architecture programs is the production of engineers and architects who use scientific knowledge to create wealth that enhances the quality of life [11]. Engineers need to be innovative, creative and ethical in the design and manufacture of materials needed by the community. An ESD component is important in the process of teaching and learning in order to produce engineers who can generate wealth and improve living standards by meeting the needs of the community. Are the programs offered meeting the needs for sustainable development? Based on comment "concern" regarding the issue of sustainability in Department of Civil & Structural Engineering (JKAS) programs, the panel recommended that the needs of sustainable development be fully identified and measured in the courses offered [12]. This concern should be addressed by FKAB in all engineering programs.

The Faculty of Engineering & Built Environment at UKM offers 11 engineering programs for undergraduate students, and these programs are recognized by the Engineering Accreditation Council (EAC), Board of Engineers, Malaysia. Based on the engineering program requirements, EAC (2012) [13] has prescribed one program outcome (PO7) related to environment and sustainable development:

"Environment and Sustainability: Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development."

To produce engineers as outlined, the Faculty has established six educational objectives and 12 program outcomes (PO) for academic session 2013-2014, to be achieved in accordance with their respective departments. A PO related to the environment and sustainable development is described in PO7: "Having an understanding of the social, cultural, global and environmental responsibilities and ethics of a professional engineer and the need for sustainable development". All departments use the same PO for ESD components as is described in PO7. JKAS has detailed indicators for measuring PO7, as shown in Table 2. From 9 programs offered, JKAS offers specialization in Civil and Environmental Engineering programs.

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Engineering students must take and pass at least 20 units of university coursework (the same requirement as in all departments) and 31 units of faculty courses, as well as 145 to 161 credits of departmental courses (including compulsory courses). Both the KB and KK programs have the total highest number of credits (181), whereas the KA program has the lowest total number of credits (165). Figure 1 shows a comparison of the credit numbers for undergraduate engineering programs in FKAB. Zain et al. (2012) [14] conducted a survey related to teaching and learning ESD in FKAB among engineering students, and the results show that students in the JKAS department place the highest emphasis on ESD issues in the teaching and learning process. Further studies are necessary to determine the methods used for the teaching and learning of ESD according to EAC requirements based on course outcomes, program outcomes and the required number of credits offered.

Table 2 shows the PO7 assessment in the JKAS departments according to 6 Bloom's Taxonomy indicators. Determination of placement, from the highest level of the taxonomy (7C6: Creation / Synthesis) to the lowest level (7C1: knowledge) was made by matching keywords found in every level of the evaluation criteria. The method of assessment is either through final exams, mid-semester exams, assignments, quizzes and projects. Table 3 shows the evaluation of PO7 for departmental courses for both programs (KKKH for KA & KKKW for KS). The table shows how the assessment is carried out, based on the comments on PO7 made by EAC assessors. An initial survey of the 17 courses offered in the Semester II Session 20122013 shows that only 5 courses (29%) assess PO7: one course for each first, second and third year student and two courses for fourth year students (20% to 33%). There is no evaluation on PO7, however, in the KA program for first year students.

Table 2: PO7 indicators & level of bloom's taxonomy

Indicators & Bloom's Taxonomy Level	**Description of Indicators**
Creation/Synthesis (7C6): Formulates new structures from existing knowledge and skills.	Able to **develop** or **generate** or **propose** or **formulate** or **incorporate** or **plan** new structures from existing knowledge of the impact of professional engineering solutions in societal and environmental contexts and the need for sustainable development.
Evaluation (7C5): Judges the value of material for a given purpose.	Able to **assess** or **evaluate** or **justify** or **review** or **defend** or **investigate** or **appraise** or **argue** or **select** or **support** or **interpret** or **conclude** knowledge on the impact of professional engineering solutions in societal and environmental contexts and the need for sustainable development.

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Analysis (7C4): Understands both the content and structure of material.	Able to **analyze** or **contrast** or **categorize** or **compare** or **differentiate** or **examine** or **relate** knowledge of the impact of professional engineering solutions in societal and environmental contexts and the need for sustainable development.
Application (7C3): Uses learning in new and concrete situations (higher level of understanding).	Able to **demonstrate** or **implement** or **execute** or **solve** or **apply** or use knowledge of the impact of professional engineering solutions in societal and environmental contexts and the need for sustainable development.
Comprehension (7C2): Grasps the meaning of material (lowest level of understanding).	Able to **describe** or **explain** or **discuss** or **give examples** or **paraphrase** or **classify** or **summarize** or **illustrate** knowledge of the impact of professional engineering solutions in societal and environmental contexts and the need for sustainable development.
Knowledge (7C1): Remembers previously learned material.	Able to **identify** or **recall** or **remember** or **define** or **state** or **label** or **list** or **name** or **arrange** or **define** or **memorize** or **reproduce** knowledge of the impact of professional engineering solutions in societal and environmental contexts and the need for sustainable development.

Source: (Badaruzzaman2013) [15]

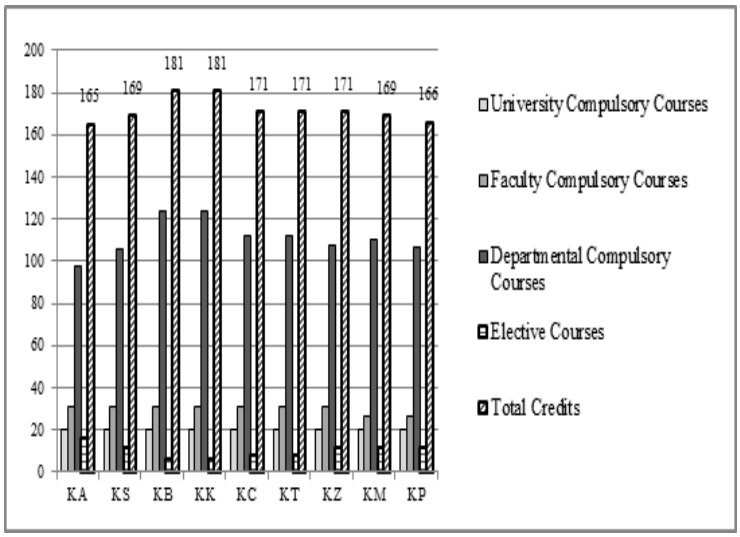

Figure 1: Comparison of the number of credits for the Undergraduate Engineering Program in FKAB

Note: Bachelor of Engineering (Civil & Structural): KA; Bachelor of Engineering (Civil & Environment): KS; Bachelor of Engineering (Biochemical): KB; Bachelor of Engineering (Chemical): KK; Bachelor of Engineering (Microelectronic): KC; Bachelor of Engineering (Communication & Computer): KT; Bachelor of Engineering (Electric & Electronic): KZ; Bachelor of Engineering (Mechanical): KM; Bachelor of Engineering (Manufacturing): KP
Source: (FKAB 2013)[11]

Table 3: Evaluation of PO7 for Departmental Courses in Civil & Structural Engineering (JKAS) Departments for both programs (KKKH FOR KA & KKKW FOR KS)

Academic Session (Sem II Session 20122013)	**Course Code W=Compulsory Course E=Elective Course**	**Course Name**		**Assessment Method**
Year 1	KKKW1104 (W)	Principles of Chemical Process	√	PBL Project
	KKKH1124 (W)	Engineering Survey	x	-
	KKKH1174 (W)	Engineering Graphics	x	-
Year 2	KKKH2184 (W)	Environmental Engineering Studies	√	PBL Project
	KKKH2254 (W)	Geotechnic 1	x	-
	KKKH2284 (W)	Structural Mechanics & Analysis	x	-
Year 3	KKKH3014 (W)	Numerical Analysis	x	-
	KKKW3224 (W)	Water Supply Engineering & Sewerage Systems	√	Mid Examination & Final Examination
	KKKH3254 (W)	Highway Engineering	x	-
	KKKH3314 (W)	Steel Structure and Timber Design	x	-
	KKKH3134 (W)	Open Channel Hydraulics	x	-
Year 4	KKKH4194 (W)	Project Management	x	-
	KKKH4106 (W)	Research Project II	x	-
	KKKW4206 (W)	Environmental Research Project II	x	-
	KKKH4264 (W)	Integrated Design Project II	√	Design Project
	KKKH4934 (E)	Finite Elements	x	-
	KKKH4334 (E)	Groundwater Engineering	x	-
	KKKH4284 (E)	Sustainable Urban Planning	√	PBL Project

Note: √ = Assessment on PO7; x = No Assessment on PO7

Information obtained from the teaching file on PO7 assessment (Sem II Session 20122013) for the other engineering programs is shown in Table 4. An initial study showed that no special courses on the environment and sustainable development are offered in the engineering program at FKAB, but ESD components are included in the various courses as appropriate, and the JKKP Department (KKKR & KKKB) has the highest course evaluation on PO7 in the teaching and learning process.

Table 4: PO7 assessment for Departmental courses (JKMB, JKEES & JKKP)

Department	PO7 Assessment for Departmental Courses
Mechanical Engineering (JKMB)	KKKM3944 System Design (W)
Electrical & Electronic Engineering (JKEES)	KKKT3124 Digital Communication (W) KKKT4945 Project II (W) KKKL1142 Electrical & Electronic Laboratory I KKKL1124 Circuit Theory II (W) KKKL3104 CAD/CAE (W) KKKL4034 Power System Analysis (E) KKKC2124 Microelectronic (W) KKKC3124/KKKC4034/KKKL3014 Integrated Circuit Manufacturing Technology (W) KKKZ3144 Power Engineering (W)
Chemical & Process Engineering (JKKP)	KKKR1244 Chemical Engineering Thermodynamic II (W) KKKR2324 Separation Process I (W) KKKR2412 Chemical Engineering Laboratory II KKKR3664/KKKR3674 Utility Design and Integration Process (W) KKKR3544 Separation Process II (W) KKKR3694 Pollution Control and Cleaner Technology (W) KKKR4865 Research Project II (W) KKKR3644/KKKR3654 Pressure Vessel Design (W) KKKR3612 Chemical Engineering Laboratory IV (W) KKKR3663 Utility Design & Safety Operation Process (W) KKKR4064 Petrochemical Processes (E) KKKR4034 Chemical Analysis & Toxicology (E) KKKR4044 Food Engineering (E) KKKR4014 System Optimization (E) KKKB1234 Microbiology for Engineers (W) KKKB2424 Bioreactor 1 (W) KKKB2422 Biochemical Engineering Laboratory II (W) KKKB3642 Biochemical Engineering Laboratory IV (W) KKKB3663 Computer Aided Design & Plant Safe Operation (W) KKKB4816 Process Plant Design Project II (W) KKKB4865 Research Project II (W)

The survey among students is important to determine the effectiveness of teaching and learning processes carried out on ESD components. Shahrom et al (2015)[16] discussed the student's views (432 students from year one until year four) from all departments in the Faculty of Engineering and Built Environmental (FKAB) on suppression of the ESD components in the teaching and learning process, plus to determine the workability of the components is influencing the students' action on taking care of the environment. Table 5 list the courses given by students that emphasis on ESD and the ones with the highest frequency listed were highlighted for each department, as bold. The third year students from JKEES and JKMB chose the Engineering Ethics and Technology Development as the course that emphasis on ESD. Whilst, JKAS fourth year students chose Integration Project Design I and II. However, students from JKKP naming the basic Principle of Chemical Process as the course that emphasis on ESD aspect for their department. The Engineering Ethics and Technology Development is the potential course that can emphasis more on ESD because it is a compulsory course for all departments and engineering ethics need a deep understanding about an engineer responsibility, not only towards mankind but also the environment.

Table 5: Lists of courses based on departments given by students that emphasis on ESD

Departments	**Year**	**Name of the Course**
JKEES	One	Physics for Engineers
		Personal Development
		Engineering and Built Environment Professionalism
	Two	None
	Three	**Engineering Ethics and Technology Development**
		Measurements and Instrumentation
		System Design
	Four	Electrical Power Generation and Energy Conversion
		Electromagnetic Engineering
JKAS	One	Engineering and Built Environment Professionalism
		Statics and Dynamics
		Vector Calculus
		Principle of Chemical Processes
	Two	Materials and Technology
		Environmental Engineering Studies
		Fluid Mechanics
		Civil Engineering Materials and Technology
	Three	Hydrology
		Civil Engineering Construction & Management
		Reinforced Concrete Design

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	Four	**Integrated Design Project I & II**
		Bioreactor System
		Solid Waste Management
		Research Project
JKMB	One	Engineering Design Graphic
		Material Sciences
	Two	Manufacturing Processes : KM & KP
		Thermodynamics I
	Three	**Engineering Ethics and Technology Development**
		Manufacturing Processes II
		Thermodynamics II
	Four	Manufacturing Ergonomics (Elective)
		Product Design
		Design Project
		Engineering Economy and Entrepreneurships
JKKP	One	**Principles of Chemical Processes**
		Engineering and Built Environment Professionalism
	Two	Biochemistry for Engineers
		Engineering Ethics and Technology Development
		Organic Chemistry for Engineers
		Enzyme and Biomolecular Technology
		Engineering Material
		Reactor I
		Separation Processes I
	Three	Reactor II
		Separation Processes II
	Four	Research Project I and II
		Process Systems Engineering
		Industrial Safety
		Process Plant Design Project

III. Conclusion

The importance of environmental education and sustainable development should be addressed in the field of engineering education at higher education institutions. An initial study showed that no special courses on the environment and sustainable development are offered in the engineering program at FKAB, but ESD components are included in the various courses as appropriate in PO7.

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