

TEACHING GREEN ENGINEERING PRINCIPLES AND APPLICATION THROUGH ACTIVE LEARNING

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Abstract

Active learning refers any approach to instruction in which all students are required to involve in the learning process. The purpose of the manuscript is to evaluate the application of active learning in teaching Green Engineering Principles and Applications as a compulsory course in environmental engineering department curriculum, Curtin University Malaysia. Green engineering can be defined as an approach of the design, process, product and commercialization that follow environmentally conscious attitude, principles and values combined with multi-disciplinary engineering science that to minimize pollutant and promote local and global sustainability. Green engineering encompasses the conceptualization and implementation of reducing environmental impacts, maximize energy efficiency and develop the greener processes and product that bring environmental and economic benefit. A simple approach that combining the classical lecture-presentation and active engagement of the students with the course materials through case studies, problem solving and discussion has been developed. In conclusion, introducing the active learning to the students on solving any problems improve the students' ability in achieving the course outcome and thus the programme outcome of the Department of Environmental Engineering, Curtin University Malaysia.

Keywords: active learning, assessment, course description, green engineering

Introduction

Sustainable engineering is a multi-disciplinary concept to engineering problems by looking at the interaction between technical, social, economic and ecological system in all future technological endeavors. There are some pressing challenge that rapid population growth induces the environmental pollution, depletion of materials and energy and damage to ecosystem. The role of decision making in an engineering aspect was based merely on current situation costs. These costs did not consider any approach of upcoming prices to civilization from destruction of social and environment. The situation allows us to make products at possible low price. We have to study the complete lifespan of the product and also observe communal aspects than only than just cost of resources and energy (Hesketh, 2017). Several engineering and science academic institution in many

countries have implemented green chemistry/engineering as a main topic in their core program of undergraduate or a postgraduate course. Beside that a lot of funding have been invested to green chemistry research and training in many countries (Günter, Akkuzu, & Alpat, 2017; Karpudewan, Hj Ismail, & Mohamed, 2011; Kennedy, 2016; Martin, Rivale, & Diller, 2007). A few years ago, Green Chemistry course is applied into the course schedules of academic degree and graduate education as a compulsory subject for the students majoring in chemistry or materials in The University of Science and Technology of China. At the same time, green chemistry was introduced to doctoral program by Sichuan University, China to improve scientific literacy among the graduate students and to enhance their corresponding skills in chemistry (Wang, Li, & He, 2018).

The present situation of teaching approach of undergraduate subject is very dependent on conventional lecture-explanation of the class material and home assignments, without any participation and contribution of the students during learning process. This article presents a simple description of active learning application in the learning process of green engineering subject to the students of environmental engineering in Curtin University Malaysia.

Literature review

Principles of Green Chemistry

The use of Green Engineering is the tools for engineers to enable them to design and manufacture products. Green engineering can be broadly defined as a framework for sustainable development that transformed from existing engineering disciplines and practices. The twelve Principles of Green Engineering as foundation of sustainability was originally developed by Paul Anastas and Julie Zimmerman as follows (Anastas & Warner, 2000):

1. Inherent Rather Than Circumstantial
2. Prevention Instead of Treatment
3. Design for Separation
4. Maximize Efficiency
5. Output-Pulled Versus Input-Pushed
6. Conserve Complexity
7. Durability Rather Than Immortality
8. Meet Need, Minimize Excess
9. Minimize Material Diversity
10. Integrate Material and Energy Flows
11. Design for Commercial “Afterlife”
12. Renewable Rather Than Depleting

Active learning

The concept of active learning was popularized by previous researcher (Bonwell & Eison, 1991; Cavanagh, 2011; Lumpkin, Achen, & Dodd, 2015). Active learning is defined as the engagement of students in learning activities, inspires students to reflect intensely about their learning progress and achievement (Hyun, Ediger, & Lee, 2017). Active learning is founded on a theory of learning called constructivism which ensures the student to be engaged with the content in order to learn the subject. Active learning focus on how students become the main

creators and focus of information and science (Cattaneo, 2017). On the contrary, the conventional passive learning approach showed that students only sit passively receiving the information from the lecturer who, as the expert of knowledge. Active learning drastically enhances the student critical thinking skills during their involvement in class activity such as class debates, flipped classroom, gaming, the 1-minute paper, think-pair-share activities, case studies, or real-life problem discussion (Adkins, 2018; Aktumen & Bulut, 2013; Della Sciucca & Fochi, 2016; Goodwin, 2003; Li, Wu, & Lin, 2019; Mellecker, Witherspoon, & Watterson, 2013). The students are more interested and eager to learn through challenging material when they are feeling capable and accommodated by the teachers. Active learning also promotes a sense of togetherness among students and teachers (Umbach & Wawrzynski, 2005). Green Engineering Principles and Applications, ENEN3001, has been introduced as a compulsory course at the Department of Environmental Engineering, Curtin University Malaysia since 2017. The objective of the course is to develop a theoretical and practical basis for green engineering, including the fundamental of green chemistry. Upon successful completion of this course, the students are expected to develop knowledge and skills related to theoretical and practical aspects of green engineering. These include applying theoretical principles of green engineering concepts to eco-industrial development to meet specific parameters and communicating the results in written and oral forms.

Course description

Green Engineering Principles and Applications (ENEN3001) is a 25 credit value (Australian University system) that equal to four-credit-hour course (Australian University system) and contains of lectures (4 hours per week) and tutorial (1 hour per week). ENEN3001 is only for the students in the department of environmental engineering and it covers various topic such as principles of green engineering, pollution prevention, cleaner production, environmental impact assessment, eco-industrial development. In the course outline, all topics are orally taught thought power-point presentation, discussed in class and some design of product is assigned as team projects. The new teaching approach was developed through the involvement of students in the discussion of some real-life problem in the class as part of the PBL (Problem Based Learning) and more advance in design of product including the presentation as part of Project-Based Learning.

In Curtin University Malaysia, the Programme Outcomes (PO) are the foundation toward achievement of Curtin Graduates Attributes upon graduation, achievement of Programme Educational Objectives in few years, and a contributing factor towards the achievement of the University's Vision and Mission. In order to achieve the POs, we have the following model where each assessment contributes the Course Outcomes (CO), and the CO then contribute to the PO. The PO for Environmental Engineering Programme are presented in Table 1. The CO of Green Engineering Principles and Applications course are addressed to PO1, PO2, and PO3.

In Curtin University Malaysia, it is mandatory for lecturer to explain the course outline to the students in the first week of academic semester including the learning activities conducted throughout the course, learning resource, their

assessments and its map to the CO. The CO, teaching and assessment approach for the Green Engineering Principles and Applications is presented in Table 2.

Green Engineering Principles and Applications has four assessments that linked to the CO and finally address the PO achievement of the programme. The assessment structure on students are as follows:

1. Assignments (10%) addresses CO 3 and evaluate PO3.
 2. Quizzes (20%) addresses CO 1 and CO2 and evaluate PO1 and PO2.
 3. Projects (30%) addresses CO3 and evaluate PO3
- Final examination (40%) addresses CO1 and evaluate PO1 and PO2.

Table 1. Program Outcomes (POs) for Environmental Engineering Degree Programme

PO– 1	Engineering Knowledge Integrate mathematics, sciences, and knowledge from environmental engineering sub-disciplines to design and evaluate complex environmental engineering problems
PO– 2	Problem Analysis Analyse and formulate solutions for complex environmental engineering problems
PO– 3	Design of Solutions Integrate learning with client requirements to produce feasible, practical, and environmentally sustainable solutions to complex environmental engineering problems
PO – 4	Investigation Utilize research based knowledge and methods to investigate and synthesize information to formulate solutions for complex environmental engineering problems
PO – 5	Usage of Modern Tools Identify and apply suitable modern engineering and IT tools, including prediction and modelling, to complete complex environmental engineering analyses successfully
PO – 6	The Engineer and Society Practice environmental engineering with a global perspective and appropriate standards pertaining to health, safety, legal and cultural issues to solutions for complex engineering problems
PO – 7	Environment and Sustainability Understand the impact of engineering solutions on society and the environment and produce sustainable solutions to complex engineering problems
PO – 8	Ethics Demonstrate ethical principles in the context of environmental engineering practice
PO – 9	Individual and Team Work Apply knowledge of environmental engineering principles as a member and leader in a team, in managing projects in a multidisciplinary environment
PO – 10	Communication Communicate effectively and professionally to stakeholders on complex environmental engineering activities
PO –	Project Management

11	Apply project management principles as a member and leader in a team, in managing all projects in a multidisciplinary environment
PO –	Life-long Learning
12	Recognise the need for and be prepared to continually build upon knowledge and skills acquired during the undergraduate learning

Table 2. Mapping of CO for the Green Engineering Principles and Applications Course.

No	Course Outcomes (COs)	Teaching approach	Assessment
CO1	Identify principles that underpin sustainable or cleaner production.	Lecture & Tutorial	Examination
CO2	Apply the methodology of life-cycle analysis for various engineering processes towards minimizing environmental impacts.	Lecture & Tutorial	Examination
CO3	Evaluate current practices in reducing waste from the process industry.	Project based learning	Technical Report & Oral presentation

Assignment component of the Green Engineering Principles and Applications course contributes to 10% of the total assessment. The assignment is performed individually to write a review about the pollution prevention in worldwide. This assignment is following the aspect of active learning term of problem-based learning and interactive class learning. Project component contributes to 30% of the total assessment. The project is performed in groups of three members, and each group is required to write up one report and do a presentation. The project is following the aspect of active learning in term of interactive class learning and project based learning through discussions among the students and lecturers during the project presentation.

Course development

As the principal portion of this course development, active learning approach is focusing on heavily participation of student in class activities rather than being passive receptors of material. As the primary knowledge creators and focus, the students are required to involve in solving of real-life problem as well as treatment according to the principles of green chemistry. They are also expected to interact with other students as well as the lecturer in analysis and conclusion of the experimental outcomes. The following are the aspects of active learning engaged in Green Engineering Principles and Applications:

1. Problem-Based Learning (PBL): student is required to identify two chemical process industries in term of source reduction according to the parameter such as material substitution, process substitution, and process elimination. Student is also required to investigate the pollution (air, water, and solid) from the industry and provides a summary of the outputs, quantities and concentrations of reported contaminants from major operations. Student should recommend the pollution prevention for the particular industry.

2. Interactive Class Learning: the lecture promotes the some application of green chemistry principles to the students and they are required to discuss the risk, hazard, and exposure; solvents: are they necessary?; plastic bags and microbes; and provide better solution of the problem in correlated of twelve principle of green chemistry. The students are then requested to propose scientific analysis for the problem.
3. Project-Based Learning: A group project is formed among the students to prepare a design of product that has heavily influenced human life and following the principles of green engineering. The following list presents some possible scopes:
 - Consumer goods
 - Home appliance
 - Household goods

The design should meet the scope and assessed with three selection criteria as follows:

- The design of product should be inventive, systematic and of scientific value.
- The design of product should be beneficial for human health and environmental.
- The design of product should be applicable and a significant impact to industry or society.

CO and PO Attainment

In calculating student's attainment of the PO, the attainment of each assessment is determined by the percentage of the students achieving 50% or above. The CO attainment is then calculated from weighted average of the assessment attainment. Finally, the programme-level PO attainment can be determined by averaging the PO attainment of each student in the cohort. The sample of CO attainment for the Green Engineering Principles and Applications course in academic session 2018 as shown in Fig. 1.

- a. **PO1:** The mark of overall PO1 (76%) is achieved for the course which is more than 50%.
- b. **PO2:** The mark of overall PO2 (100%) is achieved for the course which is more than 50%.
- c. **PO3:** The mark of overall PO3 (100%) is achieved for the course which is more than 50%.

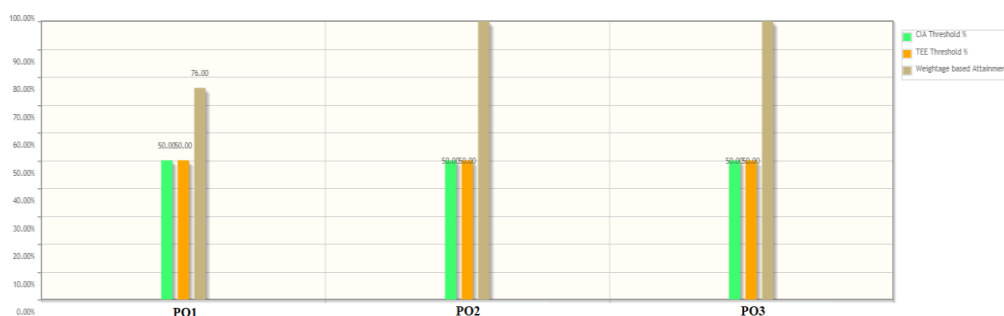


Figure 1. Course Outcome Attainment

Student evaluation**Table 3. The evaluation of course summary report of Green Engineering Principles and Applications**

eVALUate Unit Summary Report Evaluation period: 2018 Semester 1			
Unit Name: Green Engineering Principles and Applications		Response Rate: 100 %	
Unit Code: ENEN3001			
eVALUate quantitative items	Percentage Agreement	Percentage Disagreement	Percentage Unable to Judge
1. The learning outcomes in this unit are clearly identified.	100	0	0
2. The learning experiences in this unit help me to achieve the learning outcomes.	100	0	0
3. The learning resources in this unit help me to achieve the learning outcomes.	100	0	0
4. The assessment tasks in this unit evaluate my achievement of the learning outcomes.	100	0	0
5. Feedback on my work in this unit helps me to achieve the learning outcomes.	80	0	20
6. The workload in this unit is appropriate to the achievement of the learning outcomes.	100	0	0
7. The quality of teaching in this unit helps me to achieve the learning outcomes.	100	0	0
8. I am motivated to achieve the learning outcomes in this unit.	80	0	20
9. I make best use of the learning experiences in this unit.	80	0	20
10. I think about how I can learn more effectively in this unit.	80	0	20
11. Overall, I am satisfied with this unit.	100	0	0

The evaluation and feedback of the course delivery by the students is an essential part for development of course in the future. The students are required to answer eleven question that related to teaching and learning process corresponds to course outcome at the end of the semester. The evaluation of course summary report of Green Engineering Principles and Applications over semester 1, 2018 is given in Table 3. All students agree that learning experience, learning recourse, assessment task, the workload and quality teaching in this course support the students to achieve the learning outcome. In general, all response and comments of students showed that they are very motivated, happy and satisfied with course structure and teaching methods. Improvement of students' performance and retention of information was reflected in the final evaluations.

Benefits of active learning in Teaching and Learning Process

The benefit of active learning is to emphasize the student to be engaged with the content in order to learn and to be a main creators and focus of knowledge (Cattaneo, 2017). On the contrary, in the conventional teaching and learning procedure, instructor is emphasized to be an expert of everything and student passively receiving the materials. The active learning approach during the Green Engineering Principles and Applications course capable to inspire and encourage the students to improve their participation in the classroom and meeting, actively involved in group discussion and also develop their critical thinking. Students are perceived to be a part of classroom community and finally they will feel respected and appreciated. Active learning improves the students' performance on course

assessments, students' perceptions of inclusiveness in the classroom, enhance their retention of information, and escalate standardized exam scores (Freeman et al., 2014; Marteel-Parrish, 2014). This approach also provides the connection between students and instructors, thus instructors are able to evaluate students' understanding in real time. (Styers, Van Zandt, & Hayden, 2018; Ulrich et al., 2017). The concept was supported by previous study that learning outcomes is totally improved when the students are linked with course content (Haak, HilleRisLambers, Pitre, & Freeman, 2011; Matsuda, Azaiza, & Salani, 2017). In the engineering education, work effectively as a team member, is one of the important parameter for engineers beside possess in-depth technical knowledge, because a team working needs following skills such as leadership, communication, discussing, arguing, willingness to give opinion or ideas, and organising meetings (Andersen, 2003; Johnson, Sanderson, Wang, & Parker, 2017). The active learning process enhanced the students' skills to interact and communicate orally with each other thus very beneficial for a team working succeed the projects.

Conclusions

The active learning approach in the Green Engineering Principles and Applications course is able to improves the students' performance on course assessments, students' perceptions of inclusiveness in the classroom, enhance their retention of information, and escalate standardized exam scores as well as enhance the connection of students with course content, thus improving overall learning outcomes. All response and comments of students in the course evaluation showed that they are very motivated, happy and satisfied with course structure and teaching methods. Improvement of students' performance and retention of information was reflected in the final evaluations. Overall, the active learning approach of solving real-life problems had enable the students to achieve the CO and PO as outlined in the Environmental Engineering undergraduate programmes offered at the Curtin University Malaysia.

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