ACTIVE LEARNING STRATEGIES IN ENVIRONMENTAL ENGINEERING COURSE: A CASE STUDY IN CURTIN UNIVERSITY MALAYSIA

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ABSTRACT

The current teaching approach of the undergraduate subjects is very dependent on conventional methods, without any participation and contribution of the students during the learning process. Active learning refers to 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 the compulsory course in the environmental engineering department, Curtin University Malaysia. Green engineering is a compulsory unit in 3rd year of Department of Environmental Engineering, that approach of the design, process, product and commercialization that following environmentally conscious attitude, principles and values combined with multi-disciplinary engineering science to minimize pollutants and promote local and global sustainability. A simple approach that combining the classical lecture-presentation and active engagement of the students with the course materials through Problem-Based Learning, Interactive Class Learning and Project-Based Learning has been developed. Introducing the active learning to the students on solving any problems improve the students' ability in achieving the course outcome and thus the program outcome of the Department of Environmental Engineering, Curtin University Malaysia. The attainment of each assessment by the students and student evaluations indicated that the students' achievement, and retention of information have greatly improved. This can be judged by high student attendance and participation, high grades, and large student satisfaction.

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Keywords: Environmental engineering, Interactive Class Learning, Problem-Based Learning, Project-Based Learning

INTRODUCTION

Environmental engineering is an engineering course that combines broad scientific subjects like hydrology, hydraulics, chemistry, biology, ecology, geology, microbiology, meteorology, toxicology, and epidemiology and mathematics to provide solutions that will protect and also improves the health of living organisms and improve the quality of the environment. Sustainable engineering is a multi-disciplinary concept to engineering problems by looking at the interaction between the technical, social, economic and ecological systems in all future technological endeavors. There are some pressing challenges that rapid population growth induces the environmental pollution, depletion of materials and

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energy and damage to the 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 the destruction of social and environmental. The situation allows us to make products at a possible low price. We have to study the complete lifespan of the product and also observe communal aspects than only then just the cost of resources and energy (Sheldon, 2016). Several engineering and science academic institutions in many countries have implemented green chemistry/engineering as a main topic in their core program of undergraduate or a postgraduate course. Besides that a lot of funding has been invested in green chemistry research and training in many countries (Andraos & Dicks, 2015; Armstrong et al., 2018; Karpudewan et al., 2016; Rauch, 2015; Tarasova et al., 2015; Wang et al., 2018). Green Chemistry subject is applied to the course schedules at all levels, from secondary school, university and PhD school as well as professional training, and enlightenment of the general public. In China, this course was a compulsory subject for the students majoring in chemistry or materials in The University of Science and Technology of China and the doctoral program by Sichuan University, China. However, the Green Chemistry subject in Russia was taught based on the activities of D. Mendeleev University of Chemical Technology of Russia, Lomonosov Moscow State University, Gubkin University of Oil and Gas, as well as other federal and state universities (Tarasova et al., 2015; Wang et al., 2018).

The current condition of teaching approach in all level of education is very dependent on traditional or conventional lecture-explanation of the class material and home assignments, with a few involvements of the students in all class activities (Afrasiabifar & Asadolah, 2019; Jafari, 2014; Wilson et al., 2017). Conventional lectures are conducted as the lecturer in front of the classroom educating students on the lecturer approach. The classroom has the same routine activities where the lecturer shows full supervision and arrangement and students just sit listening to the explanation of whether they understand or not. The lectures are the center of all educational activities. Most students get bored and they don't know what question needs to be asked. On the other way, the students process information differently, whether they understand right away, or need more depth explanation (Keegan et al., 2012). The concept of active learning was founded and popularized by previous researchers and

defined as a learning approach in which involvement of the student's in-class activity is intensively implemented.

Active learning is originated on constructivism, a learning theory that confirms the student to be involved with the content to learn the subject and focusing the students to be the main creators of information and science. (Bonwell & Eison, 1991; Cavanagh, 2011; Hyun et al., 2017; Lumpkin et al., 2015). This approach was established to answer the conventional or traditional learning process that the students as a passive participant in receiving all the information or knowledge. Active learning significantly improves the students critical thinking skills during their participation in a class activity such as flipped classroom, case studies, class debates, gaming, the 1-minute paper, think–pair–share activities, or real-life problem discussion. 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 (Sharpton et al., 2019; Styers et al., 2018). 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. It is very few studies on the impact of active learning on improving student performance in the Environmental Engineering program. We expect this study can be an example of the application of active learning in other engineering courses. This study aims to evaluate the application of active learning in teaching 3rd-year compulsory course in the environmental engineering department, Curtin University Malaysia.

METHODS

Course Overview

Green engineering is divided into 5 topics. The first topic provides background on the practices and principles of green chemistry and engineering, the impacts of chemistry in natural

systems, and the use of Green Engineering 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 (Bernard et al., 2018; Mohamad et al., 2018; Xue & Hauskrecht, 2018). The Twelve Principles of Green Engineering as a foundation of sustainability was originally developed by Paul Anastas and Julie Zimmerman as follows (Anastas & Warner, 2000): Inherent rather than circumstantial, prevention instead of treatment, design for Separation, maximize efficiency, output-pulled versus input-pushed, conserve complexity, durability rather than immortality, meet need and minimize excess, minimize material diversity, integrate material and energy flows, design for commercial, renewable rather than depleting. The second presents systematic and generally applicable techniques for cost-effective pollution prevention that are neither simple rules of thumb or heuristics nor all-inclusive sophisticated mathematical optimization programs. This topic also explores the strategy for reducing waste that created and released into the environment, particularly by household, agriculture, and industrial facility. The concept of source reduction, recycling, treatment, disposal as well as their calculation was deeply investigated in this topic. The third topic provides a continuous application of an integrated preventive environmental strategy applied to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment. The concept of waste elimination and reduction, non-polluting production, production energy efficiency, safe and healthy work environment, environmentally sound product and environmentally sound packaging were intensively studied in this topic. The fourth and fifth topic provides an interdisciplinary framework for designing and operating industrial systems as living systems interdependent with natural systems, and assessment of the interaction between anthropogenic systems and their environment. Green Engineering Principles and Applications (GEPA) (ENEN3001) is a 25 credit value (Australian University system) that equal to the four-credit-hour course (Australian University system) and contains lectures (4 hours per week) and tutorial (1 hour per week). The number of the student enrolled this course in 2017 and 2018 was 14 students and all student was the respondent for this course evaluation.

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 problems in the class as part of the PBL (Problem Based Learning) and more advance in the design of product including the presentation as part of Project-Based Learning. In Curtin University Malaysia, the Programme Outcomes (PO) are the foundation toward the achievement of Curtin Graduates Attributes upon graduation, achievement of Programme Educational Objectives in a 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 to the Course Outcomes (CO), and the CO then contributes to the PO. The CO of both courses is addressed to PO1, PO2, and PO3. PO1 is an engineering knowledge that integrates mathematics, sciences, and knowledge from environmental engineering sub-disciplines to design and evaluate complex environmental engineering problems. PO2 is a problem analysis that emphasis analysis and formulate solutions for complex environmental engineering problems. PO3 is a design of solutions that integrate learning with client requirements to produce feasible, practical, and environmentally sustainable solutions to complex environmental engineering problems.

In Curtin University Malaysia, lecturer must 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 mapping of CO and PO, teaching and assessment approach for the Green Engineering Principles and Applications is presented in Table 1. Green Engineering Principles and Applications has four assessments that linked to the CO and finally address the PO achievement of the program. The assignment component of the Green Engineering Principles and Applications course contribute to 10% of the total assessment. The assignment is performed individually to write a review about the pollution prevention worldwide. This assignment is following the aspect of active learning terms of problem-based learning and interactive class learning. The 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 sof interactive class learning and project-based learning through discussions among the students and lecturers during the project presentation.

Table 1. Mapping of CO and PO for the Green Engineering Principles and Applications Course.

No	Course Outcomes (COs)	Graduate attributes addressed	Teaching approach	Assessment	Programme Outcomes
1	Identify principles that underpin sustainable or cleaner production.	Apply discipline knowledge, Information skills, Technology skills	Lecture, Tutorial, Problem based learning	Examination & assignment	PO1 (Engineering knowledge), PO3 (Design of solution)
2	Apply the methodology of life-cycle analysis for various engineering processes towards minimizing environmental impacts.	Information skills, Professional skills	Lecture & Tutorial, Interactive Class Learning	Quiz & Examination	PO1 (Engineering knowledge), PO2 (Problem analysis)
3	Evaluate current practices in reducing waste from the process industry.	Thinking skills, International perspective, Professional skills	Project based learning	Technical Report & Oral presentation	PO3 (Design of solution)

Implementation of Active Learning

As the principal portion of this course development, active learning approach is focusing on heavy 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 a 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 the analysis and conclusion of the experimental outcomes. The following are the aspects of active learning engaged in GEPA.

First, Problem-Based Learning (PBL): the student is required to review a topic in the area of Green Engineering and Green Chemistry. The purpose of this assignment is to review the current literature on a selected topic (bioenergy, bioplastic, biomass, biopesticide, biodegradation, bioremediation, biomaterial, biocomposite, etc), describe the major trends in a selected area, elaborate several important solutions to past challenges, and identify the major challenges to be addressed in the future. When describing the challenges that researchers and practitioners will face, the student needs to critically analyze the current theories, processes, and methodologies and identify promising directions that future research could take.

Second, Interactive Class Learning (ICL): the lecture exhibits the product that implements the green chemistry principles to the students and the student need to demonstrate the concepts of the state-of-the-art in technology and human development, precisely define the problems under study, accurately connect them to possible solutions from the literature, and demonstrate accurate and critical use of the research literature.

Third, Project-Based Learning: This activity was performed in a group formed among the students. The student was required to conduct an experiment to evaluate all materials for the feasibility of natural dyes as a substitute for synthetic dyes. Upon completion of the evaluation, the student is also required to submit a technical recommendation about a natural dye extracted from agricultural biomass. Some agricultural biomass and waste such as leaves, peel, wood, and root were screened to know their ability as natural dyes. Several parameters were examined such as wavelength (UV Vis Spectrophotometer), Rf value (TLC/paper chromatography), functional group (FTIR), pH, melting point, and color index.

CO and PO Attainment and Student Evaluation

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 the weighted average of the assessment attainment. The calculation of CO and PO attainment was performed by IonCUDOS, an OBE platform that helps to institutionalize OBE practices, achieving transparency, optimizing data inputs, standardizing computation of attainments, isolating areas for improvements, trends from large historical data from batches, and generating Self-Assessment Report (SAR) promptly.

The evaluation and feedback of the course delivery by the students is an essential part of the development of course in the future. The students are required to answer eleven questions that related to the process of teaching and learning corresponds to course outcome at the end of the semester. The evaluation of the course summary report of GEPA semester 1, 2017 and 2018 is conducted by the "eVALUate" system.

RESULTS AND DISCUSSION

IonCUDOS software maintains the Program Education Objective (PEO), PO, CO and their respective mappings and attainment calculations of every program of the institute/university for every curriculum on per year basis. This software is used by Curtin University Malaysia due to its efficiency in achieving the error free attainment calculation as well as reducing the manual calculation using spreadsheets. The other benefit of IonCUDOS is security and productivity. This software helps the institution to secure and safe the data and provide access to the various stakeholder in a level based and privilege based manner. 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 both course in academic sessions 2017 and 2018 as shown in Fig. 1. The mark of overall PO1, PO2 and PO3 were achieved for the course which is more than 50%, which is the threshold of Continuous Internal Evaluation (CIE) and Term End Evaluation (TEE).
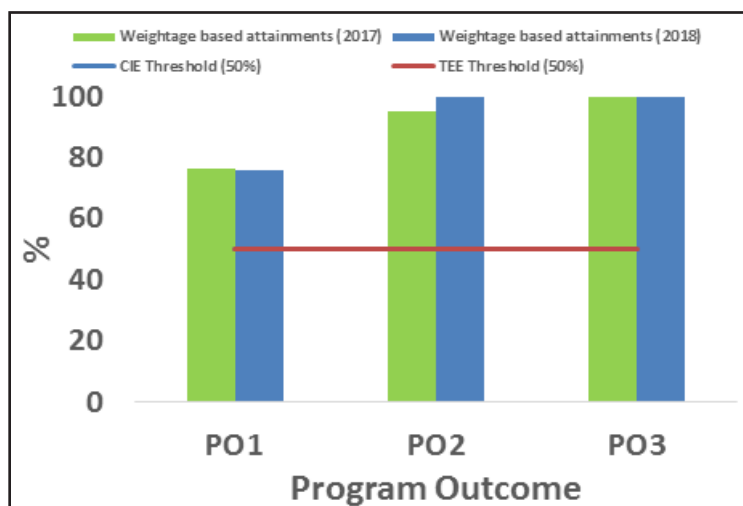

Figure 1. Course Outcome Attainment from 2017-2018

The evaluation of course summary report of GEPA semester 1, 2017 and 2018 is conducted by the "*e*VALUate" system as shown in Table 2. "*e*VALUate" is Curtin university's online system for gathering and reporting student feedback on their learning experiences. Students can give feedback about their course and their lecturer in two separate surveys every semester. The eVALUate Unit Survey asks students their perceptions of what helps and hinders their achievement of unit learning outcomes, their motivation and engagement, and their overall satisfaction with the unit. The eVALUate Teaching Survey also asks students to give feedback to individual teachers on their teaching effectiveness. The *e*VALUate Unit Survey is automatically available online for all undergraduate and postgraduate coursework units at all of Curtin›s Australian campuses and the offshore campuses including Miri Campus, Malaysia. 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 responses and comments of students showed that they are very motivated, happy and satisfied with the course structure and teaching methods. Improvement of students' performance and retention of information was reflected in the final evaluations.

The advantages of active learning implementation for students is to develop collaborative skills, increase engagement, encourage risk-taking, improve critical thinking and content knowledge, increase retention, foster real problem solving, and positive attitude towards learning in comparison to traditional lecture-based delivery. The outcome of active learning is also to improve

student perception and enthusiasm for learning in both students and lecturer. Active learning takes students from their comfort zone by creating an environment where risk-taking is encouraged.

Active learning shifts the focus of learning, from passively and possibly unquestioningly digesting data and knowledge to being accountable for actively engaging with sources and perspectives.

Table 2. The Evaluation of Course Summary Report of the Course from 2017-2018

Course name:	Green engineering Principles and Application		
Enrolment (2017-2018):	14 Students		
eValuate quantitative item (Response rate: 78.6%)	Agreement (%)	Disagreement (%)	Unable to judge (%)
Learning outcome in this course are clearly identified	100	0	0
The learning experiences in this course help me to achieve the learning outcomes.	100	0	0
The learning resources in this course help me to achieve the learning outcomes.	100	0	0
The assessment tasks in this course evaluate my achievement of the learning outcomes.	100	0	0
Feedback on my work in this course helps me to achieve the learning outcomes.	90	0	10
The workload in this course is appropriate to the achievement of the learning outcomes.	100	0	0
The quality of teaching in this course helps me to achieve the learning outcomes.	100	0	0
I am motivated to achieve the learning outcomes in this unit.	90	0	10
I make best use of the learning experiences in this unit.	90	0	10
I think about how I can learn more effectively in this unit.	90	0	10
Overall, I am satisfied with this unit.	100	0	0

However, in the conventional teaching and learning process, students are always dependent on their lecturer in every study related matter. The conventional classroom process doesn't inspire critical thinking skills, the ability to actively apply information extended through experience and reasoning. Instead, conventional lecture style confirms the role of lecturer as knowledge master and students as repositories. This method of learning process doesn't allow students to intensively understanding required for complex concepts and lifelong learning.

The implementation of active learning approach in a 3rd-year course GEPA was very essential for boosting up the confidence level of students, hence improving their involvement in the classroom activities and actively participated in the scientific discussion. Students are supposed to be a part of classroom community and finally, they will feel respected and appreciated. In the active learning, students are constantly interacting with the material and making a personal connection to the content. This helps them develop a stronger understanding of the material and apply it in the real-world and consequently, the students' performance on course assessments and exam scores was improved (Freeman et al., 2014; Lee & McManaman-Bridges, 2019; Powell et al.,

2019). Active learning frequently requires students to make connections between new material and their current mental models, extending their concept. Lecturer may design learning activities that let the students oppose misunderstandings, facilitating students to rebuild their mental models based on more precise understanding. In either case, approaches that promote active learning promote the kind of cognitive work identified as necessary for learning by constructivist learning theory (Carbogim et al., 2019; Gordy et al., 2019; Johnson, 2019; Maldonado & Harabagiu, 2019).

CONCLUSION

We have implemented active learning techniques in the 3rd year unit such as Green Engineering Principles and Applications course such as PBL, ICL, and Project-Based Learning, which are currently being massively introduced in some courses in Environmental Engineering program to enhance the quality of engineering graduates. The active learning approach to solving real-life problems had enabled the students to achieve the CO and PO (>75%) as outlined in the Environmental Engineering undergraduate program offered at the Curtin University Malaysia. A bottom-up and top-down approach are taken to ensure a

successful outcome. The active learning approach in both courses have improved 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.

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