

Sustainability Education for First Year Engineering Students using Cooperative Problem Based Learning

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Abstract

The issue of sustainable development has become one of the main priorities all over the world. There is a need to instill sustainability awareness among the younger generation in order to ensure sustainable production can be achieved in the near future. This paper describes strategies and components of teaching and learning involved to instill sustainability awareness in first year engineering students in Faculty of Chemical and Natural Resources Engineering, University Teknologi Malaysia (UTM) using cooperative problem based learning. A nine-week project with the theme of water conservation was introduced. The students were given a role to assist consultants to solve a “water sustainability” problem in their residential college area. The students were required to analyse the water system of their dormitory building, propose all possible alternatives to reduce and conserve water usage from an engineering perspective, and organize a water campaign to promote water sustainability awareness to all UTM students. The cooperative problem based learning method acts as a scaffolding to trained the students to identify the learning issues for themselves and to go through learning, solving and implementing engineering components such as data collection method, conversion units, interpolation and forecasting which is the main basic knowledge as an engineer together with their team mates. This project also enhances students engineering solving capabilities, communication skills (team communication, technical report writing and oral presentation) and interpersonal skills.

Keywords: water conservation, sustainability awareness and education, first year experience, problem based learning, cooperative learning

1. Introduction

Issues of environmental sustainability are growing widely. Due to lack of awareness and ignorance of previous generation on importance of environmental sustainability, we now faced with various issues such as global warming, water scarcity, air, water and land pollution and dying of flora and fauna. In view to this scenario, the need for inculcation of sustainability into the conscience of the future generation through education is critical. As such, all engineering programmes in Malaysia are required to instill the awareness of sustainable development in students for the programme to receive accreditation [1]. This is also in line with the Malaysian government initiative to introduce environmental awareness in the higher education syllabus where the prime minister, Dato' Sri Mohd Najib Bin Tun Haji Abdul Razak, has announced in the Malaysia Green Forum 2010 on 26 April 2010 that “... the government is working hard with other stakeholders in developing and introducing green topics in the school syllabus and curriculum of higher learning institutions.” [2].

In this paper, environmental sustainability is instilled to a batch of 280 first year chemical

engineering students in Faculty of Chemical and Natural Resources Engineering, University Teknologi Malaysia (UTM) in the ‘Introduction to Engineering’ syllabus via a nine week project involving water sustainability.

The subject is chosen because the need for water sustainability is crucial throughout the world. By the year 2050, the United Nation estimates that there will be an additional 3 billion people who will suffer water stress all around the world [3]. In Malaysia, though it is thought that Malaysia is rich in water resources since it receives an abundant amount of rain every year (with the average annual rainfall of 2,400 mm for the Peninsular Malaysia, 2,360 mm for the state of Sabah and 3,830 mm for the state of Sarawak [4]), lately, the water supply situation for the country has changed from one of relative abundance to one of scarcity. Population growth and urbanisation, industrialisation and the expansion of irrigated agriculture are imposing rapidly increasing demands and pressure on water resources, besides contributing to the rising water pollution. Another major water issue in Malaysia that needs to be urgently addressed is the high domestic water usage per capita. In Malaysia, the average water usage is about 300 liters of water per capita per day (LPD). In

urban sector, it has been estimated that the average person uses is about 500 LPD [5]. United Nations recommended the international standard for water use is 200 LPD. However, Malaysians used 100 LPD more than the amount suggested by the United Nations. This clearly shows that Malaysians do not practice sustainable water consumption.

Two main outcomes were targeted from this project. One is to instill water conservation awareness and the second is for students to identify the learning issues related to environmental sustainability and engineering for themselves and to go through learning, solving and implementing engineering components such as data collection method, conversion of units, making simplifying assumptions to make estimation, interpolation, forecasting etc which is the main basic knowledge as an engineer. Cooperative problem based learning (CPBL) was used as teaching method and the effectiveness of instilling water sustainability consciousness will be assessed through various mechanism such as problem identification, peer teaching notes, e-learning forum, project report, and presentation.

2. Design of the Learning Environment

To ensure inculcation of sustainable development, the CPBL approach was chosen as the framework for the teaching and learning activities and assessment tasks to ensure alignment with the learning outcomes. The CPBL model is a combination of PBL and cooperative learning to emphasize learning and solving problems in small student teams (consisting of 3-5 students) in a medium sized class, of up to 60 students for one floating lecturer/facilitator. More detailed description of the model can be seen in [6] and [7].

The CPBL model embodies the implementation of Bransford's "How People Learn" (HPL) framework [8] and constructive alignment [9, 10]. While both concepts contain different elements at a glance, some aspects have similarities and overlaps since both originate from constructivism. Constructive alignment emphasizes on employing learning and assessment activities that are aligned to the intended learning outcomes. It is important to clearly relay these outcomes, as well as the learning process and assessment to students to engage them. Assessment is criterion referenced, rather than norm referenced, to encourage a collaborative rather than a competitive environment. A criterion referenced assessment, which can be rubrics designed based on the SOLO taxonomy, will also provide information on expectations and formative feedback.

The HPL framework consists of four criteria essential for a learning environment [8]. They are:

- Knowledge centered – establish outcomes that illustrate the integration and connections of knowledge that is grounded in the foundation principles within the context of the discipline that the learner should be able to achieve.
- Learner centered – ascertaining prior knowledge, abilities and background of learners to help them make the connection as well as engage them to what they are learning and understand themselves as learners.
- Community centered – development of learning communities that provides a safe environment for active participation as well as inquiry, and social learning networks that extends beyond the boundary of the classroom.
- Assessment centered – provide formative assessment that mirrors the learner's progress to allow improvements.

In CPBL, the problem crafted serves to engage students to learn new knowledge through solving the problem. The problem, therefore, is designed to encompass the content outcomes in the context of the function of the knowledge in the discipline. The realistic (or real) problem must be contextualized in a scenario that students can be immersed in. Providing context will actually reveal to learners the importance of the knowledge learned, as well as the situation in which the knowledge is applied. This provides a purpose and motivation, and consequently engages learners. Other than using new knowledge learned, the problem should also contain knowledge known to the learners, which will serve as familiar territory or spring board that students can start from to extend their knowledge into new territory. Thus, a realistic, contextualized, unstructured problem provides knowledge centered as well as learner centered aspects of the CPBL learning environment.

Taking these principles as the underpinning principles in designing the learning environment, the problems should challenge and engage the students, while the technical content required must be appropriate for first year students. This is to ensure that students would not get bogged down with complex content that they are not equipped to handle, which can lead to frustration. Appropriate scaffolding activities must also be put in place to support students in developing and acquiring the necessary skills and content.

3. Problem Crafted

3.1. Setting The Scenario

Students were divided into team of three or four to have a mixture of different gender, race and academic ability. On the fourth week of the semester, students were given a letter that appoints them as assistant consultants by a well known water

consultant firm. The students were then instructed to solve water problem in Tun Dr Ismail College (TDIC), a student residential college in Universiti Teknologi Malaysia (UTM) where the students live. The TDIC principal communicates with the water consultant firm via letters, which the firm then forwarded to the students for further action along with a memo.

3.2 Description Of Project

The overall project is divided into four main parts. The descriptions of the content of each case study are as follows:

Letter 1 (Part 1):

The TDIC principal requested the consultants to:

- Obtain and update (or draw if unavailable) the TDIC plumbing and sanitation diagram.
- Perform water balances (estimate the water flow rate inlet and outlet) and identify all the factors of water loss or water wastages of the hostel water system.
- Identify how much TDIC is paying per month currently to buy clean water.
- Plot the graph for daily water consumption (for a week).
- Calculate the average water consumption a typical student in the hostel used per day. What can the team comment on TDIC current water usage performance? They should compare the result with:
 - o Typical Malaysian water consumption per person usages
 - o Five other countries water consumption per person usages
 - o Bare minimum water usages for a typical person
- Identify what contamination constitutes in the hostel wastewater.
- Brainstorm all the possible alternatives to reduce and conserve water usage in the hostel.

The team must come up with the report and present their findings in 4 weeks.

Letter 2 (Part 2):

In the second letter, the TDIC principal requested the team to:

- Propose solutions on how water can be saved and conserved for the hostel
- Perform economic analysis and feasibility study on the proposed action and justify your order of implementation. The idea must be practical and have a payback period of less than 5 years.
- Predict how much TDIC will pay for water consumption if there is an increased of 100 occupants in the hostel next year and the water tariff also increases by 30% if the water savings solutions are implemented. Compare the result if the solutions were not implemented.

For this part, the team must come up with the report and present their findings within 2 weeks.

Letter 3 (Part 3):

For the third letter, the TDIC principal wants the consultants to:

- Identify if the TDIC water storage is over or under design for the hostel water usages.
- Identify where clean water is bought for UTM and how the clean water is processed.
- Identify if the contaminant in TDIC wastewater that your team has identified in Part 1 is treated before discharge. If yes, identify if the treatment is sufficient to treat all the type of contamination. If not, discuss the possible impact of the contamination towards our environment.
- Identify the importance of water conservation towards a student, TDIC, UTM, Malaysia and globally considering the present and future state.

The team was given 1 week to complete this task.

Letter 4 (Part 4):

In the final letter, the TDIC principal wants the consultants to:

- Create a set of ethical guide for student behavior towards water in the hostel (e.g. No student shall use a non-biodegradable detergent for washing clothes). Create a set of posters or banners or signboards with this ethical guide to be hanged around TDIC.
- Organize a water campaign at TDIC to promote water sustainability awareness. Obtain student feedback and comments before and after the campaign.

The team was given 2 weeks to complete this task.

3.3 Teaching & Learning Activities

The T&L activities were designed to ensure alignment to outcomes and assessment. The activities employed to support the students are as follows:

- i. *Problem identification* - Each team were required to do problem identification that uses the KNL-table to identify what they know, what they need to know and the learning issues. The team has to submit this to the lecturer for the lecturer to assess the level of understanding. An overall class problem identification is also conducted to ensure proper understanding among all teams
- ii. *Meeting minutes* - Each team has to produce meeting minutes for each of their meeting inside or outside class in order for the lecturer to know that the team is not doing last minute works, the students are in the right direction, all students attend the meeting and tasks are delegated equally.

- iii. *E-learning forums* - Forum in e-learning have been initiated to provide an opportunity to the student to extend the discussions beyond the normal classroom time. Besides that, this forum was very useful, particularly to the reserved students to actively participate in the discussion. Normally, the lecturer will initiate the discussion about certain topics (such as 'Part 1 of CPBL Project, what have I learned?') and the students were posting their opinion regard to the issue. Student also used this platform to ask questions if they encounter any problem in solving their project as well as responses to the question raised in the forum. This activities capable to enhance their understanding and clarifying their thinking about the project and therefore encourages learning.
- iv. *Study skills - sessions* to equip students with study skills such as method to find information, drawing mind maps, enhancing critical and creative thinking skills, enhancing reading and listening skills etc were held in class as part of the scaffolding strategy.
- v. *Seminars* - Seminars were organized where speakers from industries and academia are invited to give a talk related to the project such as the state water department authority, Syarikat Air Johor.
- vi. *Plant visits* - To educate students' the complexity of water and waste water treatment and provide them with the practical experience on the scale of industrial processing, students went on trips to Syarikat Air Johor (SAJ) water *treatment plant*. In the plant, student were introduced with the process and equipments involved in the process such as aerator that was build like a waterfall to ensure that all the water getting the oxygen. In addition, students also traced the waste water treatment system in UTM.
- vii. *Water campaign* - After completing the project, only 25 groups were selected out of 50 groups. This is the most rewarding stage where the selected groups were required to present their finding in the poster presentation. The representatives from industry were invited e.g. Dow Chemicals Sdn. Bhd., Petronas and SAJ to assess student performance. DOW Chemicals sponsored the prizes for the top three winning teams during this event. In this phase the student were trained further in presentation skills and exhibition preparation have to be made.

3.4 Assessment Method

The project accounts for 40% of the total marks for the ITE subject. In the project, to align assessment according to the teaching and learning activities and learning outcomes, marks are given based on four types of assessments i.e. problem identification, peer teaching notes, progress reports/presentations/checks and final report. The divisions on the marks are as shown in Table 1. In addition, to ensure accountability of each team member, peer rating and feedback were instituted. An autorating factor was calculated for each student based on the peer rating received from his/her team mates.

Table 1. Division of project marks.

Problem identification	20%
Peer teaching notes	10%
Progress reports/presentations/checks	30%
Final report	40%

For each part of the project, in a team, students must submit their problem identification in the beginning of the project. During the project, student must do peer teaching notes based on the notes given by the lecturers to teach their peers the study skills that they have to learn. The peer teaching notes is assessed based on the quality of their notes and their presentations to the class. Project report must be submitted at the end of each project part. Report mark is a team mark and to ensure fairness in grading, the marks are multiplied with peer rating index. Students also have to present their findings and each student is assessed based on their communications skills. The progress presentation was 5 minutes per team followed by question and answer session for 5 minutes, while the duration for the final presentation was 10 minutes. As part of the formative assessment, feedbacks were given by lecturers for the students to improve their report. The lecturers ensures that student try to think outside the box, comment on students presentation performance, comment on logic of the work and many more. Other teams were also required to give comments and feedbacks.

4. Results and discussion

It was interesting to observe the students behavior in completing the PBL problem. In the earlier stage, students seems lost and do not know what to do. They begin to brainstorm in their teams and among other teams. And then they begin to interview and meet the people related to water management in UTM. They also interviews students and observe the water habits that other students are practicing in hostel. They began to realize how students are wasting water and how the water and wastewater is being managed internally in a building and outside. At some parts of the study, they realized that their

results were wrong and have to redo. But it can be observed that student becomes more determined and efficient through time. Students also claimed that they become more water conscious at the end of the assignment.

5. Conclusion

It can be concluded that environmental sustainability project by using cooperative problem based learning approach embedded into first year programme has effectively increased the student environment consciousness and at the same time equip the students with the desired introduction to engineering knowledge. It is best to instill the feel of becoming a real engineer at the beginning of the study in order for students to be motivated in learning the future fundamentals in chemical engineering subjects. This experience will enable the students to relate their new knowledge with what they will be learning such as mass and energy balances, design project etc. Indeed, this is a positive beginning in inculcating consciousness towards sustainable development throughout the chemical engineering curriculum to produce ethical and responsible engineers of the future.

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