Using Problem-Based Project to Enhance Students' Learning Experience

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***Abstract*—Some students may find difficulties in developing a sense of mission in coursework in large class setting, leading to emergence of inattentive attitude or even absenteeism which pronouncedly impairs teaching and learning progress. There is a need to foster student's engagement by active learning via a cross-departmental problem-based learning project as a part of continuous assessment. This problem-based learning project involved interactive activities and real-life practices to increase the chances of communication and collaboration between individuals, and also demonstrated the solid function of engineering disciplines in the community. By applying the Kolb's experimental learning approach and Onion Model, this project embedded a range of activities such as discussion and Q&A sections to four taught subjects. The achievements of this project included significant enhancement in course participation, team building, and self-confidence, which were assessed via observation, interview, and questionnaire survey before and after the course. As revealed by the more positive changes in class participation based on the questionnaire results, the problem-based project proved to be more effective for engaging students in learning activities in large class than in small class. The students appreciated the project flexibility in design, exploration of engineering practice, application of diverse knowledge, addressing issues of modernization, etc., and found the real-life projects interesting and inspiring. However, high task complexity, high workload, and insufficient time in class were also recognized as the project limitations. These findings suggest that problem-based project can serve as a useful tool to provoke interactions and facilitate active learning in large class.**

***Index Terms*—problem-based learning, experiential learning, student engagement, large-class teaching, self-directed learner**

I. Introduction

Some students have difficulty in engaging in the lectures because of the absence of linkage between the theoretical information delivered and the real world. The large class setting further restricts instructor from offering care and assistance to every single student actively. Because of the deficiency of student-instructor interactions and group activities among students, many students perceive the lecture content as a necessity for examination instead of lifelong knowledge for their career which actually benefits themselves beyond the course. This project aimed to foster student's engagement in large class by active learning via a cross-departmental problem-based learning project as a part of continuous assessment. We liaised with local NGO and identified Nepal as our target community, which is one of the poorest countries in the world. It was heavily struck by the catastrophic 7.8-magnitude earthquake in 2015. The locals, who suffer from the loss of shelters and daily facilities since then, need the voluntary help from professionals to recover and improve their community and infrastructures without financial pressure. The PolyU students were given the opportunity to engineer solutions to issues on water supply, geological profiles, construction, environmental and health impacts, etc., in Future Village, Nepal, based on the information collected during our earlier Serving Learning Trip in January 2017 (a standalone project supported by PolyU OSL). More than 250 students were engaged in this cross-departmental course, as the collaboration between The Department of Civil and Environmental Engineering and The Department of Land Surveying and Geo-Informatics involving four different subjects.

The interactive activities and real-life practices designed for this project can increase the chances of communication and collaboration between individuals, and also demonstrate the solid function of engineering in the community. We hope to intrigue students as described in the following objectives.

- Improve the quality of student learning experiences in large classes by using active learning through problem-based learning activities.
- Promote collaboration among students from the same and different disciplines.

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- Help students to develop a self-directed and reflective learning attitude.

The achievement of this project was evaluated in terms of the student improvement in course participation, team building, and self-confidence, which were assessed via observation, interview, as well as questionnaire survey before and after the course.

II. Methodology

A. *Data Collection in Nepal*

A group of 34 students visited Future Village (FV, a grass-rooted registered charity organization in Katunge Village, which is 100 km northwest far from Kathmandu, Nepal) in January 2017 for a Service Learning trip. During their stay, information was collected such as local household profiles (i.e., number of families and inhabitants in Katunge Village), living conditions (i.e., air quality, source of water, common illness, structure of shelters, interior design), water supply facilities (i.e., materials and size of pipelines, location and size of water tanks and pipe network in village), local farming practices (i.e., types and rotation of crops and animal grazed), and geographical information of major land use (i.e., natural resources, medical centre, settlements, and water sources). The collected information (Fig. 1) was incorporated into the current problem-based learning project, which was introduced as a continuous assessment in four selected subjects.

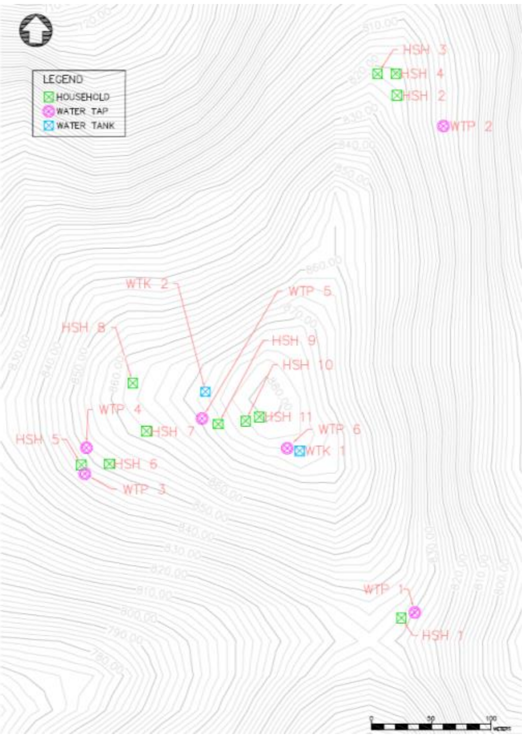

Figure 1. Contour map of Katunge Village produced by student teams of service-learning project.

B. *Subject Deliverables and Assessment Rubrics*

Students enrolled in the four selected subjects were required to provide solutions to the problems in water supply, geological profiles, construction, and environmental and health impacts in FV. The students were provided baseline details for current conditions and proposals of three scenarios. At the end of the project, they produced written report/essay and oral presentation as the deliverables, accordingly to the design flowchart in Fig. 2.

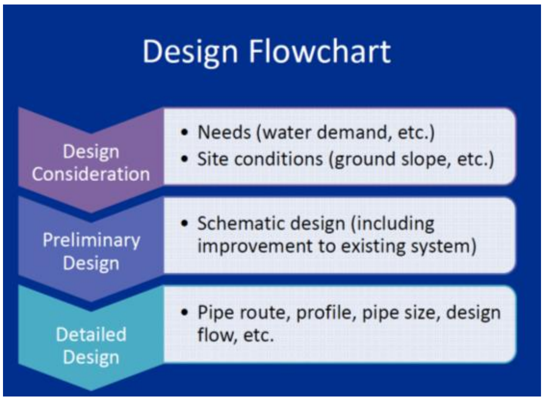

Figure 2. Design flowchart of the project.

Assessment of the student work was done by a common preliminary rubric structure, as shown in Table 1. The major criteria were (1) Content, including introduction, application of subject knowledge, evaluation of proposed solutions, and conclusions; (2) Organisation and Presentation, including coherence, presentation, and references.

C. *Evaluation of Learning Outcomes*

Seven intended learning outcomes (ILOs) were set according to four successive levels: reaction, knowledge and skills gained, behaviour, and performance competence.

ILO1: Participate in teaching and learning activities actively (Level 1 – Reaction)

ILO2: Describe and apply available engineering techniques to solve problems (Level 2 – Knowledge & skills)

ILO3: Work successfully as a team with a mix of disciplines and nationalities (Level 2 – Knowledge & skills)

ILO4: Perform research independently (Level 2 – Knowledge & skills)

ILO5: Recognize the role of engineers playing in community (Level 3 – Behaviour)

ILO6: Demonstrate self-confidence (Level 3 – Behaviour)

ILO7: Prepare an engineering report (Level 4 – Performance competence)

To evaluate the ILOs, in-class discussion observation (i.e., Level 1 – Reaction), group interview (i.e., Level 1 – Reaction; Level 2 – Knowledge & skills; Level 3 – Behaviour) and pre- and post-Project Questionnaires (i.e., Level 1 – 3) and Final Performance Observation (i.e., Level 4 – Performance Competence) were conducted before introduction of problem-based learning project and after submission of project assignment, respectively. These ILOs were derived from the Kolb's experimental learning approach [1]-[2]and Onion Model [3]-[4] as shown in Fig. 3 and Fig. 4.

TABLE I. ASSESSMENT RUBRICS

Criteria	%	Description
Technical Content		
Introduction	10	• Identify the problems • Explain the project objectives
Application of the Engineering Knowledge	25	• Identify and apply relevant engineering knowledge to address the problems • Explain the feasibility of the proposed approaches
Evaluation of Proposed Engineering Solutions	25	• Evaluate the proposed solutions • Compare the effectiveness of different solutions
Conclusions	10	• Summarise key findings • Provide conclusions and recommendations
Organisation and Presentation		
Coherence	15	• Structure the technical contents in a logical and consistent manner • Quote up-to-date and relevant references
Presentation	15	• Deliver the ideas and arguments in a clear and convincing way • Engage the audience and manage time properly throughout presentation
Total	100	

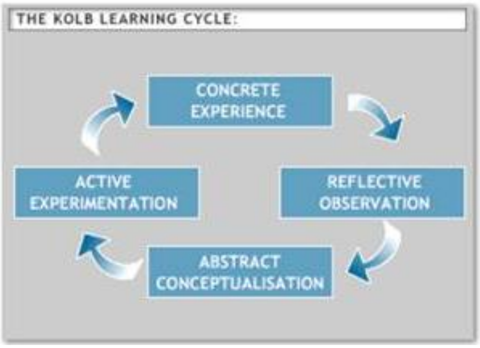

Figure 3. Kolb's experiential learning cycle [1].

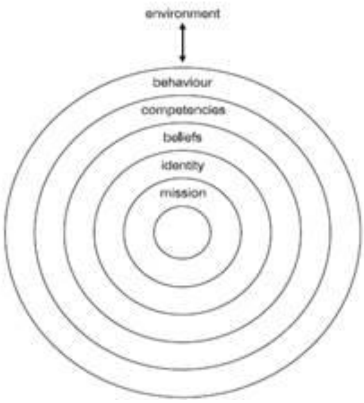

Figure 4. Onion model [3]-[4]

1) In-class discussion observation – attributes and actions

Discussion atmosphere and instant reaction reflects students' understanding of problem and the extent of engagement in project. Through students' actions/apparent behaviour throughout the discussion, their attributes (e.g., problem-solving and interpersonal skills) and learning performances were evaluated. The observation recording protocol was built on top of existing model adopted by Purdue University [5]. The number of particular behaviours and vocabulary discussed were recorded during 30-minute discussion in 12 groups (4-5 persons in a group) from the subject, 'CSE30337 Water Treatment System'.

2) Pre- and post-project questionnaires – reflection

The questionnaires aimed to evaluate student's participation in learning activities, application of engineering techniques, team work, ability to conduct independent research, recognition of roles of engineer and self-confidence, through collecting students' summative feed-back both before and after problem-based learning project within same group of students.

The design of the questionnaire survey was based on the ILOs of this project. Questions relating planned formative and summative peer-review were removed due to limited class hours, while questions that promoted self-directed learning and effective team work were included in the two questionnaires. The questionnaire survey included seven questions using five-point Likert rating scale, with 1 representing strongly disagree and 5 representing strongly agree.

Q1. I participate in teaching and learning activities actively. (ILO1)

Q2. I am able to describe the real-life problems clearly with my engineering knowledge. (ILO2)

Q3. I am able to apply available engineering techniques to solve real-life problems. (ILO2)

Q4. I work effectively as a team with my group mates. (ILO3)

Q5. I can identify and analyze the engineering knowledge by myself. (ILO4)

Q6. I recognize my roles as an engineer serving our community. (ILO5)

Q7. I have confidence in applying engineering knowledge to solve problems. (ILO6)

Questionnaires were given out to the students of CSE30337 Water Treatment System (same group of students as CSE30307 Landslide Hazard), LSGI3612 Drainage System, and LSGI23651A Water Supply Infrastructure before and after the courses. There were totally more than 250 completed surveys collected for data analysis.

3) Group interview – reflection

It collected formative feedback from students on class room practice, self-evaluation on their in-class performance, competence and self-assurance in handling the project tasks and collaboration between group members. Students' spontaneous responses gave a hint of the difficulties they encountered and the method they used to resolve the problems.

III. RESULTS AND DISCUSSION

A. *Subject Deliverables*

Enhanced students' learning in a large class can be achieved by adopting the Kolb's experimental learning approach [1]-[2] and Onion Model [3]-[4] to facilitate students' learning experiences and self-development (Fig. 3 and 4). Students were expected to transform their service experiences to knowledge and assist their personal development through service experience and reflection processes. Under experiential learning approach and onion model, problem-based learning activities were designed to assist the participated students to have deeper reflection on possibilities of problems solving and self-beliefs and personal development [6]-[7].

The results of the in-class discussion observation and pre- and post-project questionnaire are shown in Table II and III, respectively. These improvements can be illustrated by the results of observation and questionnaire survey from CSE30337, LSGI3612, and LSGI23651A. For the in-class discussion, students were observed with frequent improvement and revision under the category of process vocabulary; and frequent searching and discussing under the category of process behaviour.

B. *Class Participation*

Significant increase in the student participation in both CSE30337 (CSE30307) and LSGI3612 were noticed by observation as the students were more proactive to discuss among themselves in the classes. According to the pre- and post-project questionnaire results, students from CSE30337 and LSGI3612 indicated an increase of 14.6% and 22.6%, respectively, in class participation after the problem-based learning project. In the group interviews, all students agreed that they participated in teaching and learning activities more actively than other courses without problem-based project.

Applicability of own knowledge in coursework and their impression on cases was the major motivation for their engagement. The real-life example reflected up-to-date situation in Nepal and required student to collect extensive information to support their discussion. A group explained, "*There was much room for discussion, it was more interesting and more real-life based (than other exercises).*" As they found the project interesting and practical, comparing to other courses without problem-based teaching components, "*The project has high applicability, unlike other projects in freshman seminar.*" With a sound logic ground, students reckoned that "*It (the project) enhances my engineering sense and allows me to master engineering skills.*"

Observation on the behaviour of students and counts of vocabularies they used during group discussion suggested their level of indulgence. In CSE30337 as the representative large class, most groups discussed problems with attentive reply and developed reasoning. The groups with more counts of "(g) discussing" (under process behaviour in Table II) mentioned less process vocabularies (i.e., Client/User, Ideas/Alternatives and Improve/Revise). This implied that these groups covered fewer topics but carried out more in-depth discussion. Among these topics, local water demand and villagers' consumption habits (under Client/User) was the most concerned. Table II shows the results of in-class discussion observation.

Table III indicates that there were significant improvements for CSE30337 students in the aspects of participation, application of engineering techniques, teamwork, independent research, recognition of roles as engineers, and self-confidence. This implied that the problem-based project was more effective to engage students in learning activities in large class (CSE30337) than in small class (LSGI3612), as revealed by the more positive changes in class participation based on the questionnaire results. This was probably because the small class (LSGI2651A) was more manageable to provoke interactions in ordinary classroom settings.

TABLE II. RESULTS OF IN-CLASS DISCUSSION OBSERVATION

Observation Item	Count in groups
1. Process Vocabulary	
a. Criteria/Constraints	0
b. Client/User	4
c. Objectives	3
d. Materials	5
e. Ideas/Alternatives	4
f. Measurement	4
g. Prototype/Model	1
h. Test/Try	0
i. Results	1
j. Performance	0
k. Explain	2
l. Improve/Revise	8
m. Optimize	1
n. Plan	1
o. Report	3
p. Reflect	0
2. Process Behaviours	
a. Touching	8
b. Searching	8
c. Manipulating	0
d. Sketching	1
e. Predicting	4
f. Comparing	4
g. Discussing	22
h. Observing	1
i. Testing	1
j. Recoding	0
k. Organizing	0

TABLE III. QUESTIONNAIRE RESULTS FROM CSE30337, LSGI3612, AND LSGI23651A

A. Participation			
	Pre-project	Post-project	Change(%)
CSE30337	3.65	4.19	**14.64**
LSGI3612	3.39	4.15	**22.57**
LSGI2651A	3.93	3.80	-3.52

B. Application of engineering/surveying techniques			
	Pre-project	Post-project	Change(%)
CSE30337	3.52	4.08	**16.06**
LSGI3612	3.56	3.77	6.01
LSGI2651A	3.82	3.74	-1.95

C. Team work	Pre-project	Post-project	Change(%)
CSE30337	3.80	4.13	**8.47**
LSGI3612	3.89	4.08	4.84
LSGI2651A	4.00	4.02	0.46

D. Independent research	Pre-project	Post-project	Change(%)
CSE30337	3.62	4.05	**11.88**
LSGI3612	3.61	4.00	**10.77**
LSGI2651A	3.87	3.87	0.02

E. Recognition of roles of engineer/surveyor	Pre-project	Post-project	Change(%)
CSE30337	3.62	4.18	**15.36**
LSGI3612	3.83	3.92	2.34
LSGI2651A	4.00	3.78	-5.56

F. Self-confidence	Pre-project	Post-project	Change(%)
CSE30337	3.58	4.07	**13.74**
LSGI3612	3.72	3.77	1.26
LSGI2651A	3.80	3.74	-1.67

C. Knowledge Application

As observed during the in-class discussion, half of the groups spontaneously and actively searched for information on local conditions, geographical location, calculation formulae, etc., which they thought maybe helpful for their project. There were also half of the groups thought of ways to improve the estimation of water consumption in scenarios.

The questionnaire results indicated there was more than 6% increase in agreeing the opportunity given by the problem-based project to apply knowledge in CSE30337 and LSGI3612, as shown in Table III. Similarly as reflected by the following quotes during the group interview, most of the students claimed that they can apply and practice the surveying/engineering techniques that they learned from lectures in a real-life context.

"It gives much flexibility for us to design, big differences to the usual project. Good to let us apply different knowledge, and relate the knowledge that we have learned to the problem in reality."- Student A

"The project provides a precious opportunity to me to explore the engineering practice of the water supply system. I can also apply what I learned in the subject. All of the learning outcomes have been fulfilled."- Student B

"An eye and mind opener to realise the leap in technology to attempting to address issues related to modernization and how advance some are there and many who are very much lagging behind."- Student C

D. Team Work

According to the questionnaire results, all interviewed classes reported positive change in team collaboration, while most noticeable improvement was recorded in CSE30337. Collaboration and constant communication were inevitable in managing complex problems, students were asked to identify problems, discuss methodology among them and allocate work accordingly. Interview Group A stressed the importance of peer support as the motivation of each member to complete the project.

E. Independence in Research

The results indicated that students were motivated to be a self-directed researcher, although the self-direction was to some extent limited by the subject lecturers. The students were offered with opportunities to decide the direction of the project instead of being restricted by the subject lecturers to stick to the topic of the project. This approach enables students to learn independently [8].

F. Roles of an Engineer/a Surveyor, Meaning of Work, and Thought-Stimulation

The questionnaire results indicated that most students were satisfied with opportunities to apply the engineering knowledge and stimulate their eagerness to explore more under their discipline. There were seven students being interviewed and they mentioned about the meaning of work which gave them extra motivation to complete project tasks, quoting from interviews as follows:

"It is a very meaningful project that triggers my interest in designing water supply system" - Student D

"Very interesting and inspiring; Suggest to assign this project to student every year" - Student E

''Stronger sense of their roles in engineering subjects than in surveying subjects: nature of topics introduced, room for application of knowledge''- - Student F

G. Challenges and Recommendations

Data collected from Nepal during short service trip may not be sufficient enough for project completion. Multiple assumptions had to be made by course designers or even students themselves. The assumption may accumulate hence lower level of certainty in real-life project. Engagement of stakeholders (i.e., FV representatives, student volunteers that visited Nepal) would create a platform for students to acquire more accurate information, questions regarding local situation could be addressed by relevant parties or their representatives.

Due to large class size in CEE classes, relatively short presentation time was allowed for each group. Given such short time, students could not fully prove their understanding of problem and deliver their findings thoroughly. Longer presentation time or less complexity in questions may allow greater room for students to discuss.

Since the introduced problem contained greater complexity than ordinary introduction of theories and examples, students came across more questions and sought help from academic staff. The extra demand was not expected. Therefore, longer consultation time could be assigned both in class and after class for groups to raise questions, but then staff resources would be another limiting factor.

H. Limitations of Project and Future Study

Short discussion and observation time was recognized as a limitation of this part of study. Since the scenario and topic was brand new to students, most time was spent to understand the question itself and acquaint information on weather, geography and living environment. A longer discussion and observation time would give a broader glimpse of the depth of knowledge applied and creation of atmosphere among group members, quoting from interviews as follows:

"More information about the case's situation should be provided, otherwise many assumptions have to be made and make the project not meaningful."- Student G

''High task complexity and high applicability; drawback''- Student H

''Good for letting students apply engineering knowledge but high workload'' - Student I

Another limitation was insufficient time allowed for presentations in large classes. This restricted the students' opportunities for introduction of findings which demonstrate their techniques owned. Repetitive requests on extension of presentation time were reported in questionnaires.

IV. Conclusions

With the consideration of difficulties encountered by students in developing a sense of mission in coursework in large class setting, active learning is promoted to foster student's engagement to avoid inattentive attitude that impairs teaching and learning progress. This cross-departmental problem-based learning project introduced active learning and real-life practices as a part of continuous assessment to increase the chances of communication and collaboration between individuals, and also demonstrated the solid function of engineering in the community. The seven intended learning objectives were derived from the Kolb's experimental learning approach and Onion Model by embedding a range of activities, such as discussions, and questions and answers (Q&A) sections, to four taught subjects at undergraduate level. Overall, the students were engaged in the project with positive feedback corresponding to the intended learning objectives. There are improvements in course participation, team building, and self-confidence, which were assessed via observation, interview, as well as questionnaire survey before and after the courses, particularly for the large class (>180). The students expressed appreciation of the project flexibility in design, exploration of engineering practice, application of diverse knowledge, addressing issues of modernization, etc. In general, students found the real-life projects interesting and inspiring, but there were also identified limitations including high task complexity, high workload, and insufficient time in class. These findings suggest that the problem-based project can be conducive to provoke interactions and facilitate active learning with better course participation of students, yet further improvements and additional efforts are required for future investigations.

Acknowledgment

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