Integration of Flipped Classroom Approach and Project-based Learning in an Undergraduate Engineering Course

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Abstract
Encouraged by the increasing numbers of successful cases both on Flipped Classroom approach and project-based learning around the world, the authors transformed the instructional method of an undergraduate engineering course at the fall semester of 2013. After 80% of original course slides were converted into video clips, students of the course were instructed to facilitate those course materials before the classes. In the formal course time, planned group discussions, presentations, or quiz on the course contents were undertaken by the students. Two weeks of traditional lecture format were delivered for the purpose of comparison. A course project of designing an ecological-friendly urban river reach was scheduled through 8 one-hour sections supplemented by discussion sheets or PPT files. When most of the students spent half to one hour per week to pre-view the videos, the average scores of 5 group quiz at flipped weeks were close to that of the group quiz at one traditional lecture week. However, 3 quiz for individual student were apparently lower for about 20 points out of 100 scale. With questionnaire of Self Directed Learning Readiness Scale applied at the beginning and the end of the semester, the result indicated that more than 80% of the students had increased their scores. From course feedback questionnaire, over 75% of the students confirmed that both flipped-classroom approach and project-based learning had positive effects on their learning in this course.

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Introduction

As an introductory course, "Ecological Engineering" is planned to provide students the fundamental concept of “the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both” (Mitsch & Jorgensen, 2004); therefore, the course covers several application domains from river, slope land, unban, road, and to water quality. This course was initiated at 2002 as college selective course where the invited speakers presented their expertise for about 120 students. Two year later, it was categorized as a selective course for junior students of Department of Water Resources Engineering and Conservation with about 50 participants for years. Since 2006, six weeks of total 18 course weeks were designed and implemented as online-learning lectures supplemented by course materials, presentation slides, group discussions, homework, and online quiz on a learning management system. With gradual modifications of course activities both in face-to-face and e-learning environments, the end-of-semester appraisal scores of this course by students at 2011 and 2012 improved to 4.7 on 5-point scale and it becomes as a top 10% course in the university. At fall semester of 2013, the course activities of "flipped classroom" and project-based learning were simultaneously merged into this course to achieve the course goal of enhancing students' team-work skill. To document the process for future adjustments, this paper of action research collected various information from students along with their academic performance.

Course Design and Evaluation

In this section, two major modifications in the course design of this course, i.e. flipped classroom approach and project-based learning, are first described and followed by the illustration of evaluation on the learning characteristics of participants.

1. Course design of flipped learning

According to Flipped Learning Network (2014), flipped learning moves direct instruction from the group learning space to the individual learning space, and transforms the resulting group space into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. Therefore, all the lecture units have to be produced and available before class time, and appropriate course activities have to be planned and implemented to reflect major content of those units. In this course, PowerPoint slides and supplemental screen presentations of each lecture were recorded by PowerCam (FormosaSoft Corp., 2014). By this free software, both the indicator motion of presenter and animated functions in PPT slides can be recorded along with presenter's vocal instruction. The video clip will be automatically divided and marked into sections based on the pages of original PPT file. The edited video clips were upload to learning management system and FCUTV channel of our university (Figure 1) one week before the lecture such that the enrolled students can preview the video and the other course materials.

Three types of course activities were applied in the classroom for flipped learning, including group presentation, group quiz, and group discussion. Two weeks of traditional face-to-face lecturing were also implemented for comparative purpose.

The operation procedures, cognitive level based on Bloom's taxonomy (Krathwohl, 2002), and assessment of these activities are tabulated as Table 1.

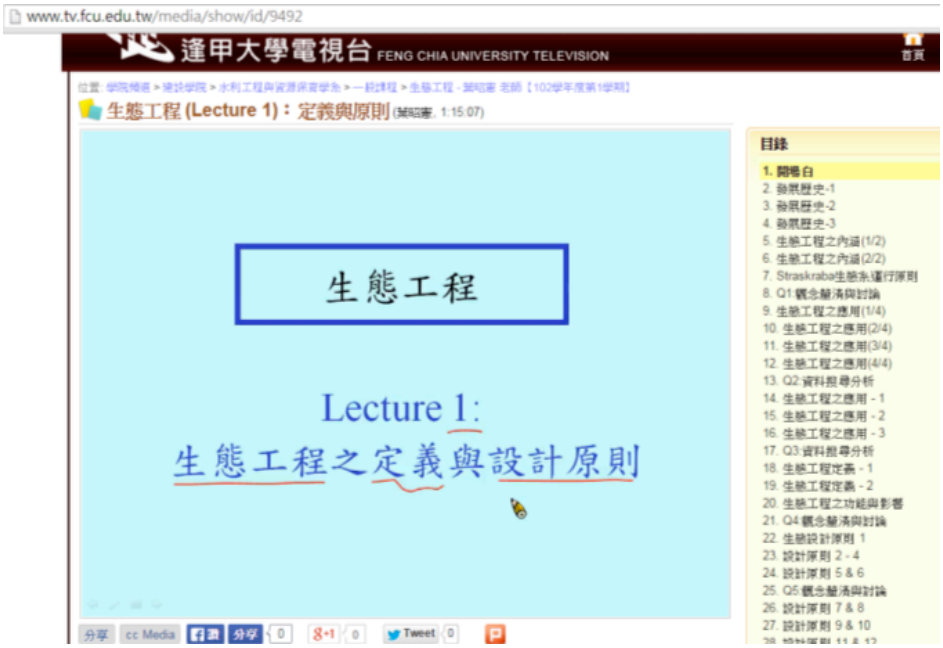


Figure 1 Course lecture was recorded as video clip and uploaded in FCUTV channel.

Table 1 Four types of course activity in this course.

Activity	Operation Procedures	Cognitive Level	Assessment
Group Presentation	(1) Randomly designate one of 6-8 lecture units and its discussion agenda to one group. (2) All groups make 20 minutes discussion. (3) Each group makes 10 minutes presentation.	Analysis & synthesis	Peer & instructor
Group Quiz	(1) Members make 20-minute reviewing on the lecture contents. (2) Apply group multiple-choice quiz. (3) Lecture on the problems what most students failed.	Comprehension & application	Written exam
Group Discussion	(1) Members discuss all the agendas provided at course hours. (2) Write the answers on the glass wall of classroom or the discussion board of BB.	Analysis, synthesis, & evaluation	Peer & instructor
Traditional Lecturing	(1) Oral lecturing the contents by instructor. (2) Apply multiple-choice quiz.	Knowledge & comprehension	Written exam

2. Course design of project-based learning

Even defined differently in many literature, project-based learning can be characterized as a student-centered instructional approach that engages students' interest and motivation around the complex activities of a project to solve real life problem through sustained, in-depth, and cooperative investigation and results in a product, presentation, or performance (Bransford and Stein, 1993; Harris and Katz, 2001; Moursund, 2001; Liu and Hsiao, 2002; Köse, 2010; Center for Occupational Research and Development, 2012). Therefore, the project of this course was set as designing an ecological-friendly urban river reach such that the course content can be integrated with the knowledge learned from previous related courses. In order to provide appropriate instructions to perform the operational steps of project-based learning (Nobori, 2012; Markham *et al.*, 2003), eight one-hour sections were scheduled within the semester, i.e. Table 2, and they were supplemented by discussion sheets or PPT files.

Table 2 Flipped learning activities and PBL sections in the Course Schedule.

Week	Lecture	Flipped Activities	PBL Sections
01	Course delineation		W1: Grouping & Targeting
02	No class (University holiday)		
03	Lecture 1	Group presentation #1	
04	Lecture 2	Group quiz #1	W2: Issues Analysis
05	Lecture 3	Group presentation #2	
06	Lecture 4	Group quiz #2	W3: Information Collection
07	Lecture 5	Quiz #1	
08	Midterm exam		
09	Practice on survey instrument		W4: Midterm Report
10			W5: Field Survey
11	Lecture 6	Group presentation #3	
12	Lecture 7	Group quiz #3	W6: Demand Analysis
13	Lecture 8	Group presentation #4	
14	Lecture 9	Group quiz #4	W7: Alternative Evaluation
15	Lecture 10	Quiz #2	
16			W8: Project Presentation

3. Evaluation on student and course

Since flipped learning moving direct instruction to the individual learning space (Flipped Learning Net, 2014), whether if student can finish the previewing of video clips before class should be the key factor. In a broad meaning, this individual learning seems to be related to student's self-directed learning readiness that is the result of an unique developmental journey where learners develop skills, knowledge, and attitudes as they engage in increasingly advanced forms of self-direction (Tsay *et al.*, 2000). To understand the potential effect of self-directed learning for student, a modified Self-Directed Learning Readiness Scale (MSDLRS) questionnaire (Deng, 1994) was employed at the first and final week. Besides, an anonymous end-of-

semester questionnaire was also distributed to enrolled students as reference of course improvement for next school year.

Implementation and Results

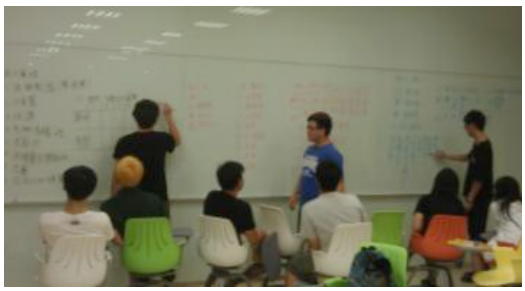
Except two weeks for traditional lecturing, i.e. Week #4 and #7, seven video clips were made for eight weeks of flipped learning. As shown in Table 3, the length of video clips ranges from less than 40 minutes up to almost 80 minutes depending on the number of slides in original PPT files. At each week of flipped learning, answer sheets for anonymous questionnaire on previewing time were collected from students and the distributions of the previewing time were found as Table 4. Most students spent less than one hour each week on watching the video before the class no matter what the length is. Photos taken during the course sections of project-based learning are assembled in Figure 2.

Table 3 Production of lecture units for flipped learning.

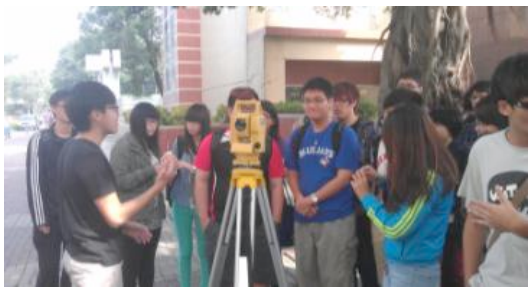
Week	Lecture	PPT Slides	Length of video clip
03	#1	33	1hr15min07sec
05	#3	35	47min12sec
06	#4	30	48min24sec
11	#6	160	38min19sec
12	#7	48	46min07sec
13&14	#8 & #9	85	52min54sec
15	#10	65	1hr19min50sec

Table 4 Previewing time for each week's flipped learning.

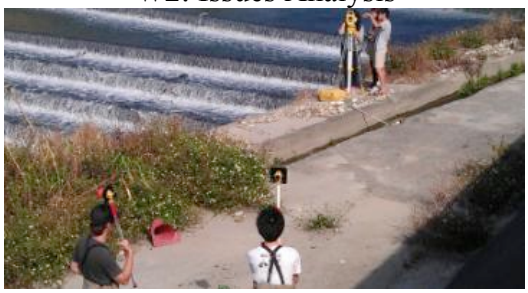
Week	Self-report on previewing time (Hour)						Average time	Ratio to video length
	None	< 0.5	0.5-1	1-2	2-4	> 4		
3	0	7	15	2	1	0	0.90	0.72
5	1	5	8	3	1	4	1.40	1.78
6	0	7	15	2	1	0	0.76	0.95
11	0	3	5	4	0	1	1.12	1.76
12	2	5	6	4	2	0	0.93	1.22
14	1	3	13	3	0	0	0.75	0.87
15	2	1	13	2	0	0	0.72	0.54



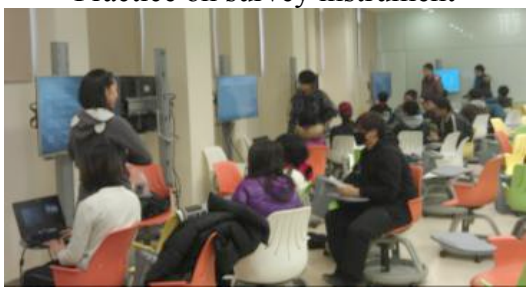
W2: Issues Analysis



Practice on survey instrument



W5: Field Survey



W8: Project Presentation

Figure 2 Photos of project-based learning sections.

1. Learning performance

In this course, three kinds of tests were applied under the environment of flipped learning, face-to-face lecturing, or on-line learning, Table 5. The average group scores of multiple choice tests and fill-the-blank tests are around seventy in flipped learning, they are very close to that of multiple choice test in face-to-face lecturing. However, three multiple choice tests for individual students had average scores around fifty, about 20 lower than those of group tests. The differences between highest and lowest scores in group tests are almost half of that in individual tests. The results indicated that difference on student's learning performance came from how many students answered the questions, not because the type of test or course design.

Table 5 Tests scores under different environments, question types, and response form.

Where	Sym.	Question Type	Response Form	No.	Average	Difference
Flipped learning	FG1	Multiple choice	Group	9	58.3	28
	FG2			7	82.1	20
	FG3	Fill the blank		6	67.5	48
	FG4			7	79.9	31
Face-to-face	TG	Multiple choice		6	70.0	24
	TI		Individual	24	47.9	70
On-line	OI1			15	52.7	80
	OI2			17	48.1	75

2. Self-Direct Learning readiness

There were initially 29 students enrolled in this course, six students drop-off during the semester. Based on the 5-point scale MSDLRS questionnaires responded at first

week, the average points of these drop-off students are higher than those of completed students in all six categories (Table 6). While the difference of average points in "Independent Learning" between two groups of students is less than one tenth, the biggest difference in six categories comes from the most important category, i.e. "Effective Learning". At final week, 17 completed students answered the category questions of "Effective Learning". Even though three students gained lower points comparing to that of first week, eight students improved more than one point and four of these improving students increased their points more than two. This result confirmed that integration of flipped learning and project-based learning in this undergraduate engineering course had positive effect on self-directed learning readiness for most students.

Table 6 Student responses from MSDLRS questionnaire at first week.

Category	Completed Students (23)	Drop-off Students (6)	Difference
Effective Learning	2.59	3.27	-0.68
Enthusiastic Learning	2.04	2.43	-0.39
Learning Motivation	2.39	2.74	-0.35
Active Learning	2.43	2.70	-0.27
Independent Learning	3.26	3.33	-0.07
Annotative Learning	2.44	2.87	-0.43

3. Learning preference

A self-developed questionnaire for defining preference on the course design was distributed to students at final week, seen as Table 7. The distribution of average preparing time per week is close to those of weekly surveys in the Table 4. Almost all the preference or acceptance questions received more than 77% positive response (including positive and very positive), except the preference on group presentation which also had 54% positive response. For project-based learning, even more than two third of the students did not have any similar experience, about 85% students supported the conclusion that executing project does help on understanding course content. While over 73% students gave positive answers on most questions, only 60% of students liked project-based learning and recommended it for next year. Besides, there were three open questions in that questionnaire. On flipped classroom, most students expressed positive attitude, however some suggested that awareness of auto-learning should be emphasized before the course. On project-based learning, all students expressed positive attitude and some suggested that it should be applied to other courses. On overall experience, most students enjoyed this course, however, there were three students against on the design of grouping for its unfairness.

Table 7 Students' preference on flipped learning and project-based learning.

Flipped Learning						
Average time of preparation before class (hour/week)		None	< 0.5	0.5~1	1~2	> 2
		0	1	13	8	4
Scale		Very negative	Negative	Neutral	Positive	Very positive
Group Presentation	Preference	0	3	9	11	3
	Acceptance	0	0	6	16	4
Preference on group quiz		0	1	4	13	8
Acceptance on peer assessment		0	1	4	15	6
Preference on flipped learning		0	3	3	18	2
Effectiveness appraisal		1	0	5	16	4
Recommendation for next year		0	4	2	12	8
Project-based Learning						
Experience of similar learning approach		None	Once	Twice	Once / semester	Twice / semester
		18	3	0	4	1
Scale		Very negative	Negative	Neutral	Positive	Very positive
Executing project does help on understanding course content.		0	0	4	16	6
The discussion agendas can guide the project.		0	1	4	14	5
Group discussion helps you to finish the project.		0	0	5	13	6
Preference of this method		0	2	7	10	5
Effectiveness appraisal		0	0	5	14	5
Recommendation for next year		0	1	7	10	6

Conclusions

After integrating on flipped learning and project-based learning into this course, more than 53% of the students expressed positive response on this design. About 43% of the students increased their Modified Self-Directed Learning Readiness score more than 1. Difference on student's learning performance came from how many students answered the questions, not because the type of test or course design.

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