FLIPPING THE CLASSROOM: A MODULE REDESIGN TO FOSTER ACTIVE LEARNING IN MATERIALS SCIENCE

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ABSTRACT

Flipped classroom is a learning pedagogical model which inverts the traditional learning approach of classroom lecture into out-of-classroom self-directed learning. This approach gives students the flexibility to study at their own pace in a specified time duration, thus being more responsible towards their learning. This paper aims to describe our journey in piloting flipped classroom as an active learning (CDIO Standard 8) approach for teaching of Materials Science module in the School of Engineering (SEG) at Nanyang Polytechnic, Singapore and the outcome after one cycle of implementation.

The flipped classroom implementation in SEG aimed to cater for the learning needs of students who came from diverse academic backgrounds. As the flipped classroom approach is different from the other learning experiences that the students had experienced in their previous training, the response and performance of the students under the new approach are measured to gauge its effectiveness in meeting the students' learning needs.

In this approach, the classroom sessions for students allow them to have more interactions and learning activities and for lecturers to conduct assessments on the learning outcomes. In the pilot implementation, students were engaged in classroom activities incorporated with real-world applications to enhance students' understanding of the learning materials, to increase students' interests on the engineering science subject matters, and to simulate professional engineering practices.

The strategies in implementing the classroom activities, from the aspect of planning the learning materials and of conducting the activities, will be highlighted in the paper. This paper also examines the outcomes in terms of students' interest and perception towards the active learning approach. Reflections on the strengths and areas for improvements in our approach will be shared together with the future course of action to enhance our students' learning at our polytechnic.

KEYWORDS

Flipped Classroom, Active Learning, Materials Science, Constructive Aligned Curriculum, Standard 8

Note – In the context of Nanyang Polytechnic, the term 'course' refers to a 'program' while the term 'module' refers to a 'course'. For example, *Diploma in Nanotechnology and Materials Science* is a course; *Materials Science* is a module.

BACKGROUND

In August 2014, the Applied Study in Polytechnics and ITE Review (ASPIRE) Committee, chaired by Senior Minister of State, Ministry of Law and Ministry of Education, provided recommendations for Polytechnics and Institute of Technical Education (ITE) and systems to make changes for enhancing career and academic progression prospects for Polytechnic and ITE graduates. Applied learning and lifelong learning were among the recommendations.

Applied learning involves the transfer and application of knowledge, skills and positive attitudes to work, which include collaboration, teamwork and keeping abreast with the latest knowledge, skills and technology developments. Lifelong learning covers a virtuous circle of working, gaining experience and learning new skills during the duration of our lifetime. These two components have also been stressed by education institutions globally. The latest volume of NMC Horizon Report: 2014 Higher Education Edition (Johnson, L., Adams Becker, S., Estrada, V. & Freeman, A., 2014) has shown that more skillsets are acquired from informal learning experiences than in universities, and education paradigms are shifting to include online learning, hybrid learning, and collaborative models. The Organisation for Economic Co-operation and Development (OECD) and the Centre for Educational Research and Innovation (CERI) also shared their findings, showing that (1) more effective learning would occur if each learner receives a customized learning experience; (2) info-communication technology (ICT) had become increasingly important to acquire knowledge; and (3) formative assessment should be used to evaluate learners' conceptual understanding and to help them assess their own learning progress. The report stressed the importance of lifelong learning and called for new approaches for the 21st Century learners.

In the School of Engineering at Nanyang Polytechnic, we adopted the CDIO standard in 2011 and started to review and revise our approaches basing on the 12 standards. Among these 12 standards, we have identified Active Learning (CDIO Standard 8) as one of the key focus to improve our engineering education, to prepare them to be engineering professionals, capable of carrying out self-directed learning, problems solving and collaborative team work. In experimenting active learning approaches, we need to relook into instructional design to engage students so that they are actively involved in learning concepts and contents instead of letting students to be passive listeners in the lecture theatre. We wanted to apply active learning approaches that involve our students in learning activities that include reading, writing, discussing and problem solving, with the objective of making the acquisition of knowledge and skill-sets more efficient, effective, and interesting.

Given that our students come from a wide range of education background and diversity in their prior learning experiences, with majority of the students coming in with GCE 'O' Level (O-Level)[1] and National Institute of Technical Education Certificate (NITEC)[2], the polytechnic lecturers have to take into consideration the students' diverse background when choosing the pedagogical approaches to plan and deliver their module content. More details of the tertiary education pathways in Singapore can be found in the Ministry of Education website (Ministry of Education, 2014).

[1] Students have four to five years of secondary school education before obtaining the GCE 'O' Level qualification. With GCE 'O' Level qualification, the students are eligible to apply for polytechnic diploma courses if they meet the entry requirement.

[2] Students have four/five years of secondary school education and two years of vocational training at the Institute of Technical Education before obtaining the NITEC qualification. With the NITEC qualification, the students are eligible to apply for polytechnic diploma courses if they meet the entry requirement.

This led us to the questions of finding an optimal approach in providing effective teaching approach to our staff and engaging learning experience to our students, especially the first year Polytechnic students. The problem could be more challenging in coping with students equipped with diverse level of science and mathematics backgrounds, when delivering science (applied science) and engineering mathematics related subjects in the first year program of the course. In addressing these challenges, we pilot flipped classroom in the teaching of a Materials Science module to these diverse learners to explore its effectiveness.

The flipped classroom is a pedagogical model which inverts the traditional learning method of classroom lecture into out-of-classroom self-directed learning, followed by small size group discussion. This approach gives students the flexibility to study at their own pace in a specified time duration, thus being more responsible towards their learning. Our methodology and results are shown in the following sections.

METHODOLOGY

Strategy

The Constructive Aligned Curriculum mentioned in CDIO syllabus (Crawley, E. F., Lucas, W. A., Malmqvist, J. & Brodeur, D. R., 2011), as depicted in Figure 1, has been adopted in redesigning this module. Firstly, we considered what the students should be able to do as a result of attending the module by defining the module learning outcomes (MLOs). The MLO stated in the module syllabus should be constructed with student learning in mind, rather than module content; they must be consistent with and aligned to the Student Learning Outcomes (SLOs) articulated at the course level; and they need to be specific and measurable.

Thus, the MLOs for this module were defined as

1. Students will be able to recognize the structure of materials.
2. Students will be able to differentiate the atomic and crystals structure of materials.
3. Students will be able to describe the various types of imperfections in solids.

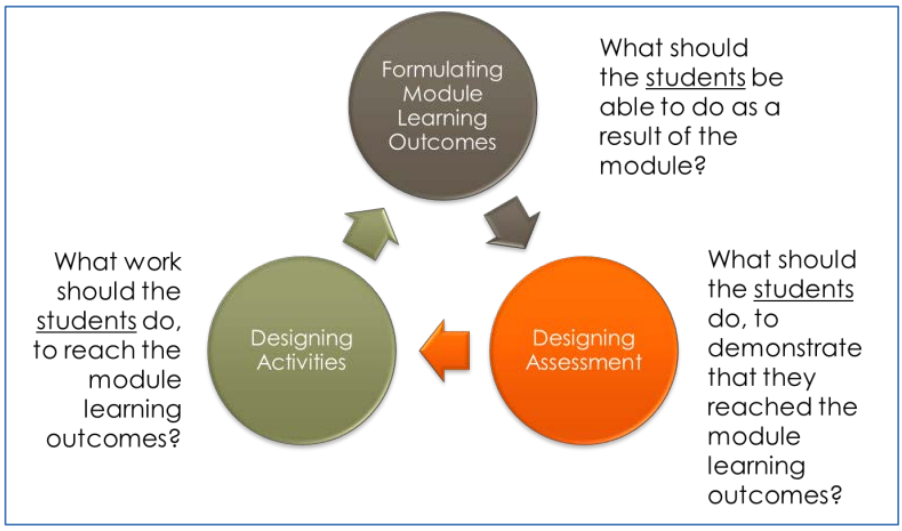

Figure 1: Constructive Aligned Curriculum (Biggs, 2003)

Secondly, we decided on the assessment components that measure the module learning outcomes. The assessment methods were chosen to allow lecturers to decide the teaching effectiveness and also to allow students to review progress and plan further learning. The assessment plan is as shown in Table 1. The assessment components were classified into Class and Test. Within the class assessment, the assessment methods were divided into four: assignment, participation, presentation and quiz.

Table 1: Assessment Plan

Assessment Components	Percentage (%)	Assessment Methods
Class	60	Assignment / Report
		Participation
		Presentation
		Quiz
Test	40	
Total	100	

Finally, the activities that should take place for the students were decided in order to acquire the MLO. The activities are typically carried out in the form of, but not limited to, lecture and tutorial sessions. All these details formed the plan of a module development and delivery which is documented in a table. Table 2 shows the Chapter 1 of this module, as an example of the plan. The cognitive skills level that the student would attain in these activities were classified into four, namely

I. Remembering
II. Understanding
III. Applying
IV. Analysing/Evaluating/Creating

In the Instructional Outcome, the number of hours allotted for lecture is higher compared to tutorial sessions, as this is a knowledge-based module, in which the students were introduced to the principles of materials science as a foundation for advanced modules. However, when teaching a big group of students, lecture as a teaching method may bore them (Mann, S. & Robinson, A., 2009), and considering that this is a first year module, students may probably lose interest in learning the advanced courses in future. Thus, active learning using flipped classroom approach, in which flipped classroom is used to provide a variety of teaching methods during the lecture hours, comes to mind.

When planning the MLO, assessments and learning activities, we used the CDIO Syllabus v 2.0 as a guide for defining the skills that we would like the students to take away as part of engineering education. Table 3 shows the relation of our work on MLO, assessments and learning activities with the CDIO Syllabus v 2.0 (Crawley, E. F., Lucas, W. A., Malmqvist, J. & Brodeur, D. R., 2011).

Table 2: An excerpt of Module Instructional Outcomes (L – Lecture, T – Tutorial, P - Practical)

No	Topics	Instructional Outcomes	L	T	P	Cognitive Skills Level
1.0	**Introduction to Materials Science & Engineering**		**3**	**1**	**0**	
1.1	Definition of materials science and engineering	• Define and explain materials science and engineering • State an overview of the study of materials and its impact on society				I
1.2	Brief introduction to classification of materials and advanced materials	• Explain the classification of different materials • Describe current state of advancements in materials development and new classes of advanced materials				II
1.3	Application of materials in engineering	• Describe the different applications of materials in different fields of engineering • Explain the importance of the appropriate selection of materials to meet the needs of various engineering applications				II

Table 3: Mapping CDIO Syllabus to the components used in the Constructive Aligned Curriculum

	CDIO Syllabus v 2.0*						
	1.1	**1.2**	**2.1**	**2.2**	**2.4**	**3.1**	**3.2**
Module Learning Outcomes	●	●					
Assessment	●	●	●	●			●
Learning Activities	●	●	●	●	●	●	●

* Topics in CDIO Syllabus version 2.0 are as follows:

1.1 Knowledge of Underlying Mathematics and Sciences
1.2 Core Engineering Fundamental Knowledge
2.1 Analytic Reasoning and Problem Solving
2.2 Experimentation, Investigation and Knowledge Discovery
2.4 Attitudes, Thought and Learning
3.1 Teamwork
3.2 Communications

Plan

The class to pilot run the flipped classroom approach was chosen out of convenience, that is, the class of first year students was chosen based on the module group that was assigned to us. The composition of the students is shown in Table 4. It is noted that the composition of the students were diversified, thus it was more insightful to explore how the flipped classroom can impact on the students of different backgrounds as a whole.

Table 4. Composition of Students from Sample Class

Background	**Number of students**
O level	8
NITEC	4
Others	3
TOTAL	15

As a pilot trial for this teaching approach, three flipped classroom sessions were conducted in a semester. Every session occurred approximately once every four weeks, taking into consideration that in every semester, there are fifteen instructional weeks.

When planning for the flipped classroom sessions, the main considerations are what topics to flip and what activities that is suitable for the topics. Three topics with varying difficulties in understanding the concept were chosen; with the easier topic being flipped first while the advanced one the last to flip. The topics that were chosen for flipped classroom sessions, their difficulty levels and activities are as shown in Table 5. The purpose of increasing the difficulty level each time of the flipped classroom sessions is to allow students to be able to adapt to the teaching approach, so that they will be able to learn better when flipped classroom is implemented in the later stages of their studies.

Table 5: Plans for conducting flipped classroom session

Lesson Week No.	Topic	Difficulty level	Learning Activity
3	Chemical bonding	Easy	**Team-based learning** - Understanding bonds for different types of materials
7	Crystals Systems	Average	**Hands-on and Team-based learning** - Making crystals' models and understanding the models' properties
10	Diffusion	Advanced	**Problem-based learning** – Given a number of diffusion cases, identify and explain the mechanism

Implement

The differences between a typical flipped classroom and traditional classroom session are shown in Table 6. Flipped classroom approach gives students the chance to have quality contact time with teacher for consultation on the lesson materials while teacher have the

opportunity to let students learn through other activities beside doing homework only (Fulton, K. P., 2012; Tucker, B., 2013).

When implementing flipped classroom, students were firstly notified about the coming session at least a week in advance, during traditional lecture session in class. The learning materials and short quiz were then uploaded on the learning management system. The learning materials include the prepared lecture slides, video lectures and related materials to the topic to be learnt. Students would need to complete learning the materials before the face-to-face lesson. During the face-to-face classroom session, learning activities were conducted in which the lecturer was the facilitator. Figure 2 shows the students working on a learning activity together as a group. The students also did the tutorial questions in the same class session. Students with queries on the learning materials could discuss with the lecturer personally and for interesting and/or repeated queries on the tutorial questions, the lecturer would discuss with the students in the same class session.

Table 6: Comparison between traditional classroom and flipped classroom

Learning location	**Traditional classroom**	**Flipped Classroom**
In class	Teacher instructs/ lectures in class while students take notes.	Students complete assessments and homework while getting support from teacher.
Out of class	Students complete assessments and homework given by teacher.	Teacher instructs lesson through video, books, websites, etc. while students learn from the sources.

Figure 2: Students working as a group in a learning activity.

Measure

Triangulation is used when measuring and validating the data. Triangulation refers to using more than a method to enhance the validity and confidence of the findings. Thus, two methods have been identified for data collection and analysis (Creswell, J. W., 2014).

The first method was using questionnaires. Two questionnaires were given to the students; one during the middle of a semester and the other at the end of the semester. Questionnaires were designed to gauge the feasibility and effectiveness of flipped classroom, and also the acceptance of the approach by students. The results of the questionnaires were compiled, reviewed and analyzed.

The second method was semi-structured interviews. Interviews were conducted on two students, one from O-Level background while the other is from NITEC background. An interview guide with a list of questions was prepared and during the interview, other questions pertaining to the topic would be asked too, based on the flow of the interview.

RESULTS AND DISCUSSION

Questionnaires/Surveys

Two questionnaires were conducted with the students; one during the middle of a semester (after lesson week 8) and the other at the end of the semester. The mid-semester questionnaires were designed to understand how the flipped classroom approach had impacted the students learning and what needed to be improved, thus questions like the students interest, understanding and their thoughts on the learning materials were asked. Based on the mid-semester survey, necessary changes, if any, were implemented, as discussed later. Therefore, the end-semester questionnaires were designed to understand how effective was the flipped classroom approach for the students learning and whether the combination of flipped classroom and learning activities is feasible for implementations in other advanced modules. There were a total 13 respondents out of 15 students for both questionnaires.

From the mid-semester survey, students were asked to rate on the two sessions where flipped classroom and learning activities were conducted, along with lectures and tutorial sessions that were conducted in traditional way. The results were plotted in graphs, as shown in Figure 3 and 4. In Fig. 3, more students rated their interest for flipped classroom delivery and the learning materials for flipped classroom as more relevant than for traditional lecture. This shows that students are receptive to the flipped classroom approach. However, learning activities are not favoured by students, as shown in Fig. 4. Students rated the traditional tutorials as a better approach to enhance their interest and understanding instead, which could be due to the thoughts of excelling in written tests for their final grade.

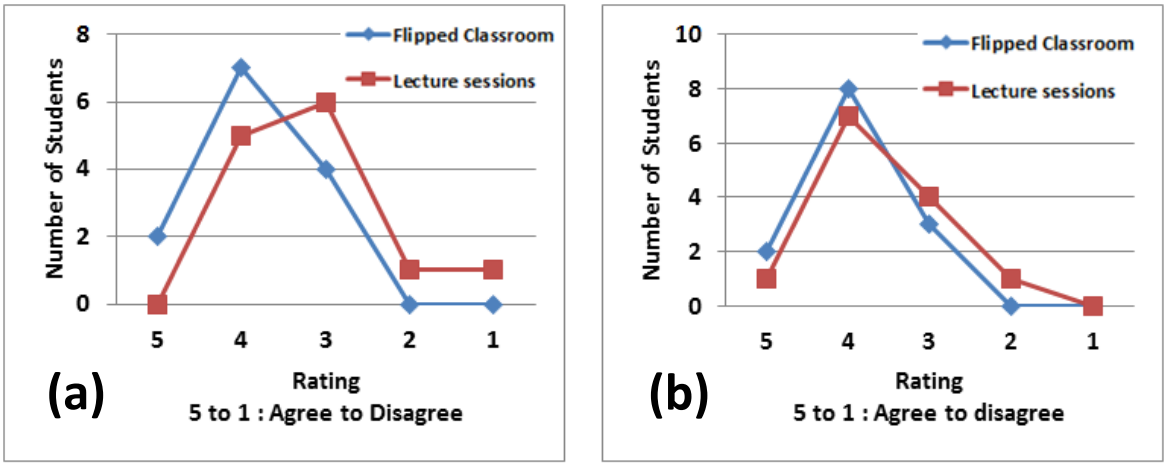

Figure 3: Rating on the (a) interest towards flipped classroom and lecture sessions, and (b) relevance of the learning materials taught using flipped classroom and lecture sessions.

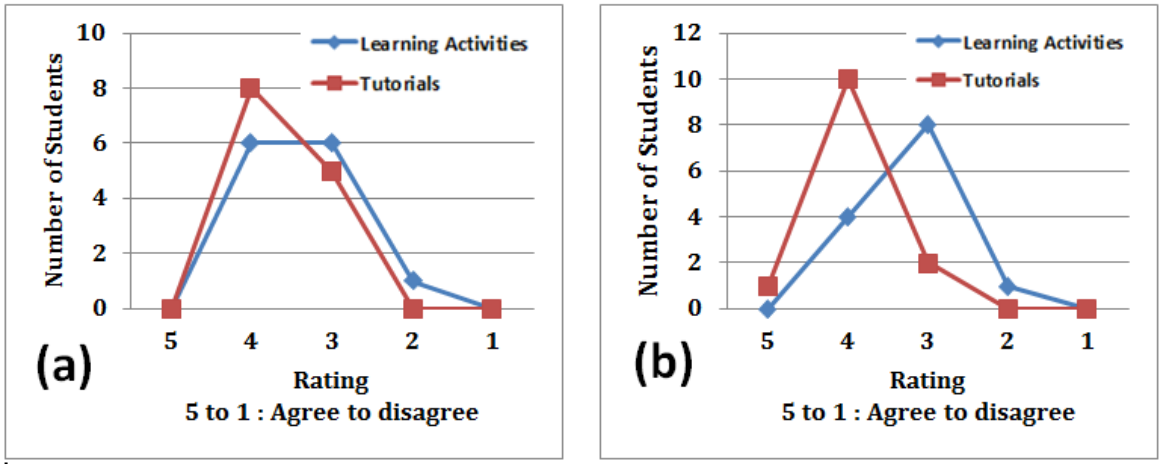

Figure 4: Rating on the (a) relevance of the learning activities and tutorial sessions towards students' interest and (b) understanding on the topics taught.

From the mid-semester survey too, it was noted that students preferred flipped classroom coupled with tutorial sessions. Learning activities during the face-to-face flipped classroom session after the mid-semester were changed to be similar to the tutorial activities, except that students are required to work in groups and problems-based learning were conducted instead. Thus from the end-semester survey, 62% of the students agrees that learning and application of knowledge is more effective in these flipped classroom learning activities than from lecture, while 54% of the students rated 'Agree' for the effectiveness of flipped classroom learning activities as compared to the traditional tutorial sessions. The results for the end-semester survey are as shown in Table 7.

From both surveys, students preferred to have flipped classroom sessions and recommend having more sessions for their future modules. However, there were also comments from those who were not supportive of flipped classroom. These students were worried that their lack of background knowledge to the module may be an issue. This made up of 7% of the

students in the class, similar to a study done by Graham Johnson (Johnson, G. B., 2013). This problem needs to be tackled earlier, preferably at the beginning of the implementation. Measures to boost the confidence of students who lack relevant science background prior to joining the polytechnic will need to be considered.

Table 7. End term survey results

Question	Percentage for Rating (%)		
	Agree	Neutral	Disagree
I can remember the concepts learnt from flipped classroom better than from lecture.	61.5	38.5	0
I find myself learning more effectively in flipped classroom, compared to lecture.	61.5	38.5	0
I find myself learning more effectively in learning activities session, compared to tutorial session.	53.8	30.8	15.4
Learning activities with real-world problems help me to apply the knowledge learnt to practice.	61.5	30.8	7.7
I hope to have more flipped classroom sessions in future semesters for other modules.	61.5	30.8	7.7
I hope to have more learning activities sessions in future semesters for other modules.	69.2	23.1	7.7

Semi-structured interviews

For this interview, a guide with a list of questions was prepared. The interview was planned to be done in 15 to 20 minutes, thus the questions list were kept at four questions. The questions were designed to understand better on the relevance and effectiveness of the flipped classroom approach to the students and to cover the gaps of the questionnaires, if any.

The interviews were done separately with 2 students; one from the O-Level background and the other from the NITEC background, at the end of the semester. The sample interview questions, transcripts of the students' replies and some notes taken during the interviews are shown in the Appendix. The findings from the interview confirmed the results obtained from the surveys. Both students responded positively to the learning activities done in class, and were particularly concerned about the assessments, which affect their overall grade. However, their response towards flipped classroom approach was different from each other. The student from O-Level background seems to be able to adapt to the flipped classroom approach while the student from NITEC background seems to shun away from this learning approach due to lacking of confidence and science background. Student from NITEC background also suggested the assessment weightage for the learning activities conducted during the face-to-face flipped classroom to be higher in order to better reflect their effort, quoting that the assessment was biased towards written tests. With these findings, students will have to be monitored more closely when implementing flipped classroom again, and assessment weightage is to be reviewed to better reflect the learning activities as part of their assessment.

CONCLUSION AND REFLECTION

In this paper, the Materials Science module was redesigned to foster active learning through flipped classroom among first year students. The module redesign is in alignment with Standard 8 on active learning of the CDIO standards. The Constructive Aligned Curriculum was particularly useful when strategizing the module redesign, which covered the formulation of the learning outcomes, and subsequently the assessment and learning activities design.

Two major challenges were faced when working on redesigning the module for the flipped classroom approach. Firstly, the suitability of the learning activities and assessment designed for the students. The learning activities were planned to enhance students' knowledge from the flipped classroom's learning materials and were adapted after the mid-semester, knowing that the students preferred to work on solving problems and questions. The assessment were planned to accommodate the learning activities and considering that the module is knowledge-based, written tests were given an extra weightage. This study has shown that the assessment weightages would need some consideration if we would like our students to be more involved in learning activities. Secondly, preparing the learning materials and also preparing and conducting the learning activities would take up more time and effort from lecturers, than usual. Preparation of learning materials, which include learning videos, lecture slides and other relevant materials for flipped classroom, takes up more time compared to lecture slides alone for classroom lectures. Conducting learning activities in class will also be different from tutorials session as lecturers play facilitators in class walk around the class to engage students in the activities given. Thus, lecturers' readiness to adapt and exercise flexibility in teaching and learning activities is also important for flipped classroom to be effective to students.

The details on the implementation, including the plan of the implementation and measure on effectiveness was presented in this paper. The implementation of the flipped classroom has injected some novelty to the teaching and learning process. As a pilot work, the study was done on a small group of 15 students so far and preliminary results discussed above seem promising. The approach has shown to improve students' learning experiences and increase their knowledge and interest in the subject taught. This work will continue to explore the flipped classroom approach on a larger group of students and possibly on other modules as well. Implementation to every batch of students may result in different outcomes as every batch of students is unique. Therefore, educators have to be flexible to adapt the learning activities for the students to benefit from active learning approaches.

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APPENDIX

Sample Interview Transcript

Note: Only questions in the interview guide prepared and students' responses were presented. Other important points noted during the interview were listed at the end of the transcripts.

Interview Transcript with an O-Level background student

Question: How do you find the flipped classroom sessions conducted as compared to lecture sessions?
Response: Flipped classroom sessions are good in the sense that it gives us the freedom to complete the learning at own time own target. Also, the timing for lecture sessions, which are after lunch hour, sometimes made us tired and sleepy. The learning materials given in the flipped classroom sessions are interesting to me as we have videos and animations to enhance our understanding.

Question: How do you find the group activities sessions conducted during the face-to-face flipped classroom sessions as compared to traditional tutorial sessions?
Response: Both served different purposes to our class learning experiences. Group activities during the face-to-face flipped classroom sessions are livelier than the traditional tutorial sessions as we get into more discussion on the given tasks. Also, presentations on our findings for the given tasks really put our understanding of the modules to test. Traditional tutorial sessions enhance our knowledge that we have learnt and also prepare us for written tests.

Question: Do you find the activities done in group during the face-to-face flipped classroom sessions relevant? Why?
Response: The group activities are very hands-on to enhance our understanding and as platforms for us to apply what we have learnt using real-world examples. This is particularly interesting as we do not have lab/practical sessions for us to experiment what we learn in this module.

Question: In your opinion, how frequent should the flipped classroom sessions be conducted? Why?
Response: Once every two weeks. Flipped classroom gives me flexibility on when to study and I can choose on my own best study time.

Other Important Points mentioned by student and not in the questions above:

- Assessment should cover a semester project assignment. This could keep us committed to working better as a group in group activities sessions.
- When preparing group activities, more time needs to be allocated as students tend to work a little longer to get a work done properly.

BIOGRAPHICAL INFORMATION

Dr Eunice Goh Shing Mei is a Lecturer in the School of Engineering, teaching materials science and engineering subjects. She received her Ph.D. degree from Nanyang Technological University. Her main interests are in the areas of educational research and innovation in materials applications.

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