Scientia Education Investment Fund Grants Final Report

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< Deploying a Peer-to-Peer Learning Platform to Promote Personalized Collaborative Learning >

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1. Executive Summary

This project delivers a fully functional mobile learning platform, namely the P2P Platform, to support peer instruction in the flipped classroom. The project is initiated in the context that the course enrolment is projected to undergo a significant increase in the next few years at UNSW Faculty of Engineering. In the meantime, higher education increasingly calls for a more personalised learning model to replace the traditional model of mass education (i.e., students who have different learning curves were taught in the same pace). A promising strategy to address such a dilemma is to empower students to learn from each other by creating more peer learning opportunities (e.g., peer instruction, peer assessment, and peer mentoring). The focus of this project lies in peer instruction. Unlike the small classes where peer instruction can be conveniently facilitated by the lecturer or demonstrator based on their first-hand knowledge of every student, it is difficult, if not impossible, to manually facilitate peer instruction in a large scale. Therefore, we are motivated to support peer instruction in the flipped classroom through new learning tools. Despite the increasing popularity of flipped classroom in engineering education, to date, there has been little study on the integration between peer instruction and flipped classroom in the context of large-enrolment courses. The P2P Platform is designed to fill in such a gap. By analysing self-learning feedbacks provided by individual students, the platform functions to divide a large class into multiple small cohorts, in which, meaningful peer instructions can be incubated. Meanwhile, the platform functions to compute a set of learning indexes (i.e., pain index, divergence index, diversity index, and inclusion index), which can be used for instructional design purposes.

This project addressed the priority of "*demonstrating the effectiveness of innovative technologies in achieving educational outcomes*". The tangible project outputs include a functional mobile learning platform, 2-3 conference and journal papers, a new instructional model for ENGG1000 that is complemented by new subject materials, several presentations in educational conferences, a workshop, and an internal seminar.

This project reveals some interesting findings. From the pedagogical practice perspective, it showcases that peer instruction can be feasibly integrated with flipped classroom even for a large-enrolment course. A new instructional model of "self-learning + lecture + peer-learning + tutorial + online assessment" is proven effective in enhancing academic performance and building learning community in ENGG1000. From the technological development perspective, the P2P Platform is proven effective in enabling peer learning based on students' feedback in the cyberspace. However, it remains a challenge to inspire initial interest and maintain continuous participation in peer learning throughout the semester, which eventually becomes a student motivation issue. From the instructional design perspective, the set of learning indexes can be calculated based on data analytics of student engagement in the peer instruction process.

Based on the project findings, we recommend that the P2P Platform is most suitable for the large-enrolment courses, where students are characterised by different understandings of the same subject materials. The platform is especially applicable for the first-year introductory courses and purely online courses. The platform can be used to flip a classroom and enable peer instruction. One viable instructional model is "self-learning + lecture + peer-learning + tutorial + online assessment". The platform is potentially beneficial for other teaching and learning activities such as instant polling in class, peer assessment, and team building.

2. Outcomes and Impact

2.1 Project Outcomes

This section summarises the major project achievements. Firstly, a fully functional P2P Platform has been developed, deployed, and tested. Figure 1 illustrates the platform's graphical user interfaces (GUI). It is developed based on the Amazon Web Service (AWS). It can be accessed via either smartphone or computer. A permanent domain name has been acquired: <http://p2p.education>. The platform serves both lecturer and student. It enables the lecturer user to: publish subject materials in different formats; publish feedback questions in different formats; view student feedback in real-time; divide a large class into multiple study cohorts; track the trending of student feedback over time; capture the focus of peer interaction; and calculate the learning indexes. Meanwhile, the platform enables student users to: download subject materials; input individual learning feedback; view collective learning feedback of the class; participate in peer interaction via instant messaging within study cohorts; and network with other students. One key feature of the platform is to divide a large class into multiple small study cohorts, where grouping is automatically performed based on two parallel principles: (1) as much as possible, students who are similar in the previous circle(s) of peer instruction are grouped together; (2) as much as possible, students who are dissimilar in the current circle of peer instruction are grouped together. The platform is piloted in multiple courses at UNSW and University of Southern California (i.e., ENGG1000 and ENGG1200 at UNSW, as well as ENGR345 at USC). The platform has been introduced to a number of engineering educators through publication, presentation, and workshop.

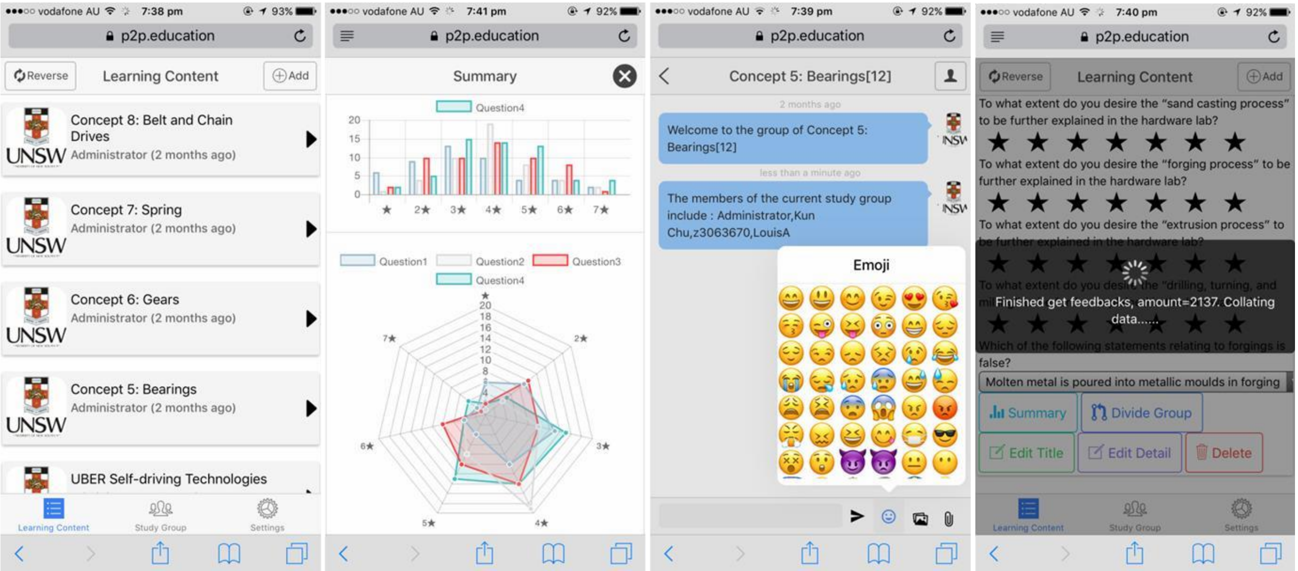

Figure 1. Graphical user interface of the P2P Platform

Secondly, we have investigated the pedagogical integration between peer instruction and flipped classroom in the context of large-enrolment courses, where the P2P Platform serves as a key enabling technology to mediate the learning cycle. Flipped classroom is a student-centred pedagogy, where students play an active role in shifting the instructional focus from "*what students need to learn as determined by the lecturer*" to "*what students want to learn as reflected by the students*". Flipped classroom is characterised by more intensive academic interactions: student-lecturer interaction, student-content interaction, and student-student interaction. Student-content interaction can be enhanced by producing higher quality digital materials (i.e., one of the focuses of blended learning), and student-lecturer interaction can be improved by redesigning the instruction in classroom. Nevertheless, to date, there has been little study on student-student interactions in a flipped classroom -- how students learn from each other through peer instruction. Traditionally, peer instruction is presumed to take place in the face-to-face setting, where a student can conveniently engage in peer discussions with his/her neighbours sitting near them. Made possible by the P2P Platform, peer instruction is expanded to the cyber space and driven by the changing student feedback. The integration between peer instruction and flipped classroom was piloted based on ENGG1000 in 2018 S1. A new instructional model was proposed and evaluated. Moreover, some new instructional contents were developed as well. In order to facilitate self-learning, more pictures, animations, and videos were added to replace the textual descriptions. In order to properly address the difficult concepts that were reflected by student feedback, three detailed guidelines were developed to prepare the demonstrators for the lab tutorials.

Thirdly, a set of new learning indexes is proposed, including pain index, diversity index, divergence index, and inclusion index. The pain index classifies different learning concepts into various categories (i.e., individually painful, individually easy, collectively painful, and collectively easy) that may be addressed by different instructional strategies. The diversity index indicates to what extent diversified opinions are triggered by the subject materials. The divergence index measures the degree of distortion between the original information space (i.e., subject materials for self-learning) and the sampling information space (i.e., the content of peer interactions within the study cohorts). It indicates the disparity between "*what students are expected to discuss*" and "*what students actually discussed*". High divergence may suggest that the subject materials are insufficient, inconsistent, or irrelevant. The inclusion index measures to what extent every student's opinion is considered, discussed, and respected. The inclusion index has two meanings. In the context of peer instruction, it measures to what extent every participant's opinion is included in peer learning. In the context of flipped classroom, it measures to what extent every student feedback is addressed in subsequent instructions.

The specific algorithms of how to calculate the learning indexes are elaborated in a journal manuscript that will be submitted to the IEEE Transactions on Learning Technologies.

2.2 Project Impacts

According to a study conducted based on ENGG1000 in 2018 S1, the integration of peer instruction and flipped classroom, which was enabled by the P2P Platform, led to some positive impacts on student learning such as an improvement of academic performance as measured by the online quiz results and an increasing attachment to learning community as measured by the MyExperience survey results. Students were made aware that peer learning could occur not only within a project team among familiar team members but also within a large class among "unfamiliar" classmates. On the other hand, different students demonstrated different learning curves of taking up the new platform, and the participation in peer learning decreased notably over time. This is an indicator that student motivation should be investigated in combination with technical feasibility. Below are two student testimonials retrieved from the MyExperience survey:

> "*The ability to work in a team and the focus on peer learning was very good. It was a different way to learn and I feel peer learning is a beneficial skill to have…*"

> "*Ang provided very interesting lectures and was able to maintain people's attention. He put a strong focus on peer learning…"*

We solicited inputs from multiple senior engineering educators in terms of their perspectives on the proposed learning indexes. On the one hand, they all agreed that the learning indexes could reveal some key information that would be beneficial for instructional design. On the other hand, the main concern was that to what extent the learning indexes can inform a lecturer what he/she has not already known. In other words, the learning indexes are still descriptive information instead of prescriptive insight. For example, the learning indexes for different concepts in ENGG1000 were very similar to each other (i.e., no statistically significant differences were discovered). One possible explanation is that the 8 concepts (e.g., gear, shaft, bearing, etc.) covered in ENGG1000 are all basic mechanical components and hence naturally identical to each other. In the future, we will continue to explore how and in what ways the learning indexes can be leveraged to support specific decision making in instructional design. Similar to many other machine learning algorithms, the accuracy of learning index is greatly affected by the quantity and quality of student data. Nevertheless, student participation in peer learning has been declined throughout the semester. Therefore, we will continue to explore the possibility of computing the proposed learning indexes based on the data directly collected from Moodle instead of the P2P Platform, which is more reliable and consistent data source.

In terms of the impacts on higher education, to our best knowledge, the P2P Platform is the first mobile learning tool designed to support virtual peer instruction in the flipped classroom, especially for large-enrolment courses. Within the one-year project period, different dimensions of this project have been introduced to the international engineering education community through a number of publications, presentations, and workshop. The intellectual merits of this project were highly regarded by many engineering educators. For example, below is a comment left by one of the reviewers during the double-blind paper review process of the 125th ASEE (American Society of Engineering Education) Annual Conference:

> *"A very good paper! Implementation of diversity-driven groups based on feedback is excellent and very useful. It would be interesting to see how this will apply to an engineering fundamentals course such as Statics, or Electrical Circuits. It may be necessary to adapt this process to hybrid one, in which the instruction provides sufficient background material (concepts of force, free body diagrams, static equilibrium, etc.) before a P2P process is implemented."*

2.3 Strategic Priority and Future Application

This project was proposed to address the priority of "*demonstrating the effectiveness of innovative technologies in achieving educational outcomes*". We believe that this goal has been successfully fulfilled. The P2P Platform is proven effective in complementing flipped classroom, enabling peer instruction, building study cohorts, and eventually improving academic performance as well as student satisfaction. The set of learning indexes is useful for understanding the collective student feedback. In the future, we will continue to demonstrate the platform's applicability for instant polling, project team building, and peer assessment.

In terms of the future applications, the platform is suitable for the large-enrolment courses, where students are characterised by greatly diversified learning curves and different understandings of the same subject materials. The platform is especially suitable for the first-year introductory courses, where students are most keen to acquaint peer classmates, develop social network, and build a learning community. The platform is also suitable for the purely online courses developed based on the PLuS Alliance, where virtual interaction is the "inevitable reality" for all kinds of learning activities. In the future, the platform will continue to be deployed in large engineering courses such as ENGG1000 (1,500 students) and MMAN2100 (450 students).

3. Dissemination Strategies and Outputs

Our dissemination strategy was to situate this project in the emerging trend of data-driven learning, peer-to-peer learning, and personalised learning in higher education. We endeavored to introduce this project to a broader audience of students and educators through publication, presentation, and workshop. The dissemination activities and events that have been successfully implemented include the following:

- The P2P Platform has been piloted in several engineering courses at UNSW and USC such as ENGG1000, ENGG1200, and ENGR345. Until June 2018, more than 800 students have registered accounts at <http://p2p.education>.
- One peer-reviewed conference paper has been published in the 125th ASEE Annual Conference & Exposition. This paper formally presents the P2P Platform in terms of its system architecture, key function, GUI design, complemented by a simple case study.
- One journal paper has been published in the *Interactive Learning Environments*. The findings in this paper inspired us to utilise the P2P Platform to support peer instruction in the flipped classroom. In other words, it consolidated the pedagogical foundation of this project.
- The P2P Platform was presented during the World Engineering Education Forum (WEEF) in Kuala Lumpur, Malaysia, November 2017. The platform was introduced to appropriately 40 international engineering educators including the CEO of Moodle.
- The P2P Platform was highlighted as one of the key enabling technologies of international joint courses during the PLuS Alliance Forum in July 2017, UNSW Teaching and Learning Forum in October 2017, and 28th AAEE Conference in December 2017.
- The P2P Platform was presented to appropriately 50 "data-driven" educators during the EduData Summit at MIT in Boston, USA, June 2018.
- The P2P Platform was presented to appropriately 30 engineering educators at the Computing and Information Technology Division during the 125th ASEE Annual Conference & Exposition in Salt Lake City, USA, June 2018.
- Our proposal to organise a special workshop for the 29th Australasian Association of Engineering Education (AAEE) Conference has been formally accepted by the organising committee. As a part of the workshop, a full conference paper will be published as well.
- The project deliverables added important evidence to the application of Dr. Ang Liu for the Senior Fellow of Higher Education Academy in June 2018.

The dissemination activities and events that are being planned in the near future include:

- One journal paper will be submitted to the *IEEE Transactions on Learning Technologies*, no later than August 2018. This paper will elaborate the pedagogical foundation, key functionalities, core algorithms, and learning indexes of the P2P Platform, including a detailed empirical study.
- The P2P Platform will be presented during the Engineering Education Showcase in July 2018.
- One special workshop will be organised during the 29th AAEE Conference in December 2018.
- One Connection Seminar will be organised at UNSW in October 2018.

4. Evaluation of Project Outcomes

The P2P Platform is evaluated based on the flagship first-year course at UNSW Faculty of Engineering: <ENGG1000 - Introduction to Engineering Design and Innovation>. In 2018 S1, this course had an enrolment of 1,344 freshmen. The course was composed of more than 10 design projects, and the platform was evaluated based on the Project DELTA that was chosen by 282 students. The students were divided into 47 project teams, each with 6 students. The teams were tasked to design a vehicle that could collect up to 5 plastic balls while navigating through a track. ENGG1000 was characterised by an enormously large class of students with diversified cultural, national, and disciplinary backgrounds. It was difficult, if not impossible, for the lecturer to know every student well enough to support their learning respectively. Moreover, one of the most rewarding experiences of ENGG1000, based on the reflection of former students, was the opportunity to acquaint more peers and expand the network. These attributes made ENGG1000 a highly suitable testbed.

Students were required to complete a total of 3 learning modules for the technical stream of mechanical engineering, where the classroom was flipped and the P2P Platform was deployed to enable peer instruction. An empirical study is conducted based on these 3 learning modules. An ethical approval to conduct this study (HC180095) has been obtained in advance.

Evaluation Methodology

Each module included the following instructional activities: a lecture session led by the lecturer in the classroom (i.e., one hour), a tutorial session led by the demonstrators in the laboratory (i.e., one hour), and an online quiz done by students individually on Moodle (i.e., one hour). The three modules covered a total of 8 concepts of basic mechanical components. The 1st module covered the concepts of "*material*", "*processing*", and "*fastener*". The 2nd module covered the concepts of "*shaft*", "*bearing*", and "*springs*". The 3rd module covered the concepts of "*gear*", "*drive system*", and "*break*". Each concept was further decomposed into more specific sub-concepts. For example, the subject of "*material*" included "*aluminum*", "*steel*", "*copper*", "*plastics*", etc. For each module, it went through three phases to complete an entire learning cycle, as shown in Fig. 2.

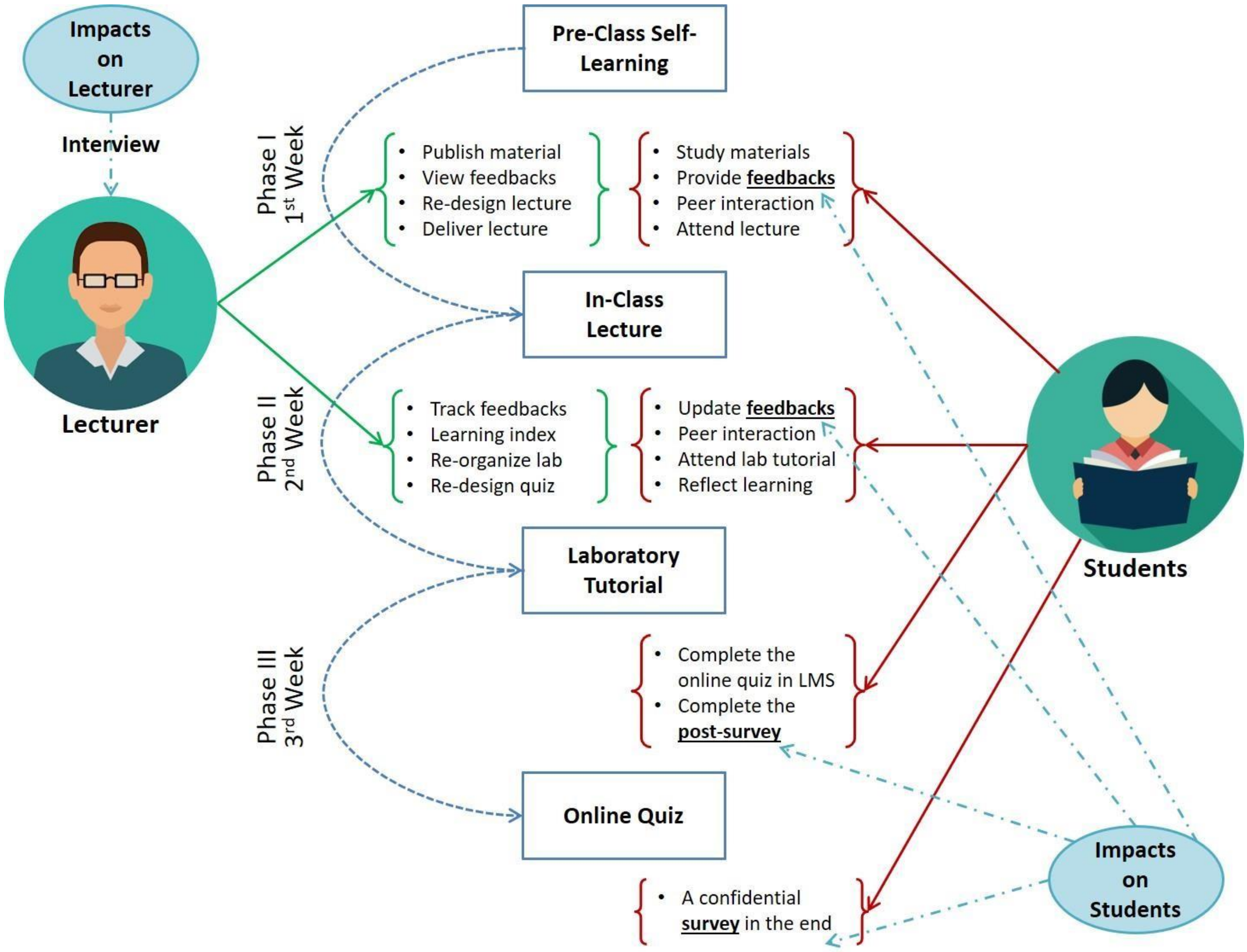

Figure 2. Illustration of the evaluation methodology

In Phase I, the lecturer published a collection of subject materials on the P2P Platform. For each concept, the materials included a book chapter, some PPT slides, and relevant videos (i.e., Youtube videos that illustrated the mechanisms of different mechanical components). Students were instructed to study these subject materials by themselves and then provide individual feedback based on the P2P Platform. Near the end of Phase I, a lecture was taught in the classroom in the fashion of PPT presentation, when the lecturer focused on explaining the more "painful" concepts as reflected by collective student feedback. Multiple study cohorts were built right before the lecture. The focused lecture concluded the Phase I.

In Phase II, students were encouraged to participate in peer interactions within the study cohorts, and then update their learning feedback on the subject materials. Meanwhile, the lecturer tracked the changes of student feedback and learning indexes, based on which, to adjust the lab tutorial and online quiz accordingly.

Near the end of Phase II, a tutorial session was organised in the laboratory, where 5 stations were set to display the sample components that corresponded to the subject materials. An experienced demonstrator was designated to host every station, and students took turns to visit all 5 stations within one hour. Students spent 10-12 minutes at each station to inspect the mechanical components in person and listen to the demonstrator's further explanations. Three detailed guidelines were developed to prepare the demonstrators, in particular, for those more "painful" concepts as reflected by student feedback.

In Phase III, students were tasked to complete an online quiz, on an entirely individual basis, to examine their understandings of the module. Students were given 6 days to reflect their learning and then complete the quiz at their own choice of time. The quiz included 20-25 multi-choice questions, and the time limit was one hour. The "study cohort" function of the P2P Platform was disabled to prevent peer discussion of quiz questions. The online quiz was carried out based on Moodle instead of the P2P Platform.

Data Collection and Analysis

Both quantitative and qualitative data were collected and analysed. For each concept, students were encouraged to provide individual learning feedback by answering multiple lead-in questions (i.e., 3-4 rating questions plus 2-3 multi-choice questions) on the P2P Platform. The rating questions were all related to a student's subjective perception of the subject materials (e.g., "*to what extent did you find <shaft> difficult to understand*"), while the multi-choice questions were previously used quiz questions. The rating questions remained largely unchanged for the 8 concepts, while the multi-choice questions were phrased differently for each concept. Group formation was automatically performed based on student answers to these questions. Students were allowed to update their answers throughout the learning process. The lecturer was interviewed three times by an educator ethnographer in terms of how he had perceived student feedback, learning index, and peer interaction. Two demonstrators were engaged in developing the detailed tutorial guidelines. Data regarding student satisfaction was obtained from the MyExperience survey. It should be noted that, since ENGG1000 was composed of more than 10 design projects, the MyExperience surveys were conducted for different projects independently on top of the course survey. As a result, we have access to the raw data (still confidential data) to perform further data analysis (i.e., ANOVA and correlation analysis).

Evaluation Outcomes

We compared the results of the three quizzes (that were completed in Phase III) between 2018 S1 and 2017 S2. The same set of questions was used for the quizzes except for the Quiz II (i.e., due to an unexpected printing issue, 5 quiz questions were excluded in the question sheets distributed during the 2nd tutorial in 2018, hence, these 5 questions were removed from the Quiz II). As illustrated in Figure 3-A, a significant increase in the quiz performance was observed (i.e., 7.53 vs. 8.14 for Quiz I, 7.74 vs. 8.18 for Quiz II, and 7.63 vs. 8.23 for Quiz III). Meanwhile, the standard deviations for all three quizzes decreased notably.

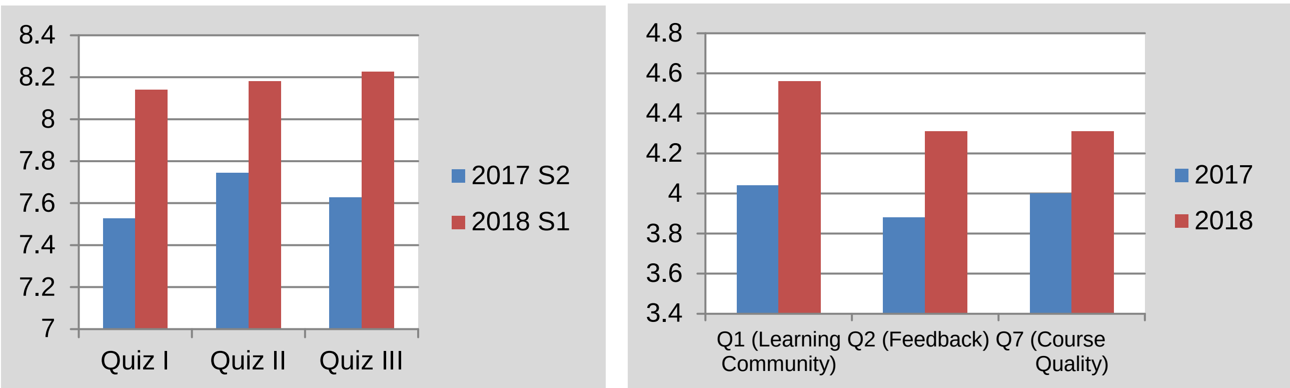

Figure 3. Comparison of quiz performance between 2018 and 2017

According to the results of the MyExperience survey, firstly, there was a statistically significant score increase (i.e., from 4.04 to 4.57) for Q1 (i.e., *"I felt part of a learning community"*). Secondly, there was a notable score increase (i.e., from 3.88 to 4.31) for Q2 (i.e., "*the feedback for this component of the course helped me learn*"). Lastly, there was a moderate score increase (i.e., from 4.00 to 4.31) for Q7 (i.e., "*overall I am satisfied with the quality of this component of the course*"). The correlation between Q1 and Q7 was 50.87%, whereas the correlation between Q1 and Q2 was 77.8%. The scores for other questions in the survey remained unchanged. Furthermore, there was a notable improvement in project performance against the same task from 2017 to

2018. Nevertheless, the effectiveness of team project was affected by many factors, hence, its success cannot be simply attributed to the new instructional model.

Based on the above results, backed by the informal interviews of some course participants, it can be concluded that the new instructional model, enabled by the P2P Platform, has triggered a notable improvement in academic performance and student satisfaction. It should be made clear though such an improvement must be attributed to the new instructional model (i.e., self-learning + lecture + peer learning + lab tutorial + online quiz) as a holistic approach, for which, the P2P Platform had played a mediating role.

There are several limitations that may have constrained the new instructional model from fully realising its effectiveness. Firstly, in 2018 S1, the lab tutorials took place in parallel with regular operations of the new Maker Space in Willis Annexe. Many students complained that the background noises (i.e., generated by the running machines in the Maker Space) were too loud to listen to the demonstrator's explanations, which greatly affected student satisfaction with the tutorial sessions and possibly the whole instructional model. Secondly, the 3 quizzes only counted 20% of a student's final grade, and students were allowed to choose the best two results from the 3 quizzes to calculate the final grade (each for 10%). This was diagnosed to be one of the main reasons why student participation in peer learning decreased over time, especially near the end of the semester. It was not uncommon that some students would simply skip the Quiz III. Lastly, the total lecture time was reduced from 6 hours in 2017 to 3 hours in 2018 due to the classroom availability. These limitations as well as uncertainties, once again, suggest that the new instructional model should be designed, as an integrated system, that concerns technology, pedagogy, content, instruction, and assessment.

Lessons learned

Some lessons learned from this project are presented for other academics who are interested in designing a similar instructional model. Peer learning cannot be naturally stimulated by deploying a new platform. But rather, many aspects of the instruction should be adapted as well. Most importantly, reasonable expectations should be set in terms of the amount of subject materials for self-learning, the number of feedback questions to ask, and the difficulty level of follow-up assessments. For example, some students in ENGG1000 felt overwhelmed by the amount of work for a 20% assessment (i.e., 8 book chapters, 300 PPT slides, 40 feedback questions, and 70 quiz questions). Some specific suggestions are raised to facilitate the pedagogical integration between peer instruction and flipped classroom.

- It is necessary to clearly explain to the students the motives and benefits of different kinds of peer learning (e.g., peer instruction, peer assessment, and peer mentoring) in the beginning.
- It should be made visible to the students how, and in what ways, various aspects of instruction (i.e., lecture and tutorial) have been dynamically adjusted according to the changing student feedback.
- Based on our experience, it is suggested that no more than five feedback questions should be asked per week. Too many quiz questions would discourage student participation in the long run.
- The subject materials for self-learning should be concise, interactive, and structured. They should be divided into independent modules, and each module should be attainable in no more than 60 minutes.
- The self-learning materials should be a combination of videos and additional readings (e.g., book chapters). PPT slideshow (or its PDF equivalents) is not a good format for effective self-learning.
- It should be emphasised that the platform cannot be used to discuss quiz-related questions.

It takes some time for students to learn to use a new tool and more time to develop a habit for the new instructional model. Students tend to be frustrated by unexpected technical issues. This is especially true for the first-year students who are still inexperienced in technology-enhanced learning. One of the biggest challenges is to maintain student interest and participation in peer learning on a weekly basis throughout the semester. For example, 2137 feedbacks were collected for Concept 1, while only 630 feedbacks were collected for Concept 8. An underlining assumption of effective peer instruction is that most students should participate. Otherwise, the knowledge gap will not be significant enough to accommodate peer instruction. Some suggestions are raised to motivate student participation in the technology-enhanced peer instruction.

- It is necessary to showcase, in details, how to use the platform during the first few lectures.
- It is worthwhile to repeatedly remind students, by emails or Moodle announcements, at the major milestones of the new learning cycle. Over time, it helps students to develop a long-term habit.
- It is important to carefully manage student expectation, since the very beginning, that the new model is driven by student feedback. Hence, every student is expected to participate consistently.

- It is helpful to task the study cohort to discuss a specific topic to initiate the discussion. By doing so, this task serves as an icebreaker for promoting more peer interactions.
- It may be helpful to offer some bonus marks to the students who actively help others to learn. Such a record might be used to select qualified demonstrators for the future course offering.

5. Financial end of life summary

In comparison with the originally proposed budget, we successfully received large discounts for educational projects from Amazon Web Service (e.g., 30 GB of Amazon Elastic Block Storage, 750 hours of Amazon EC2 Microsoft Windows Server, 750 hours of Amazon EC2 Linux t2.micro instance usage, etc.), which significantly reduced the cost of project activities. Furthermore, the Viterbi iPodia Program at the University of Southern California shared 50% of the cost of hiring a professional software developer for developing the P2P Platform. Based upon the approval, the saved budget was used to compensate an education ethnographer for her time devoted to methodology design, data analysis, research meeting, and manuscript writing (i.e., personnel cost).