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P2P Platform for Peer Instruction in Flipped Classroom

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P2P Learning Platform for Peer Instruction in Flipped Classroom

Flipped classroom is gaining increasing momentums in engineering education. Peer instruction is an indispensable piece of flipped classroom. Through peer instruction, not only students can learn from each other outside classroom, but also instructor can focus on the truly difficult concepts in class. In practice, nevertheless, it is challenging to implement peer instruction in the large classes, where the participating students are characterized by diversified backgrounds and different understandings. This paper presents a peer-to-peer learning platform to facilitate the peer instruction process in the context of flipped classroom. Based on learning feedback provided by individual students, the platform functions to divide a large class into multiple small study groups, within which, students can engage in peer instruction to learn from each other. Meanwhile, the platform will provide instructor with the aggregated, analyzed, and visualized student feedback, which can be used to redesign instruction in classroom. Made possible by the Viterbi iPodia platform at University of Southern California, this platform has been tested based on a technology-enabled international course that was attended by 138 students from 8 global universities.

Introduction

The instructional strategy of flipped classroom is increasingly embraced by the engineering education community [1-2]. According to the survey conducted by Bishop and Verleger [3], a typical flipped classroom consists of two necessary components: interactive learning activities inside the classroom, and computer-based learning activities outside the classroom. In comparison with the traditional instruction strategy, flipped classroom represents a more student-centered paradigm, in which, students are enabled to play more active roles in driving the direction of instruction from “what they need to learn as determined by the instructor” to “what they want to learn as initiated by the students”. Flipped classroom can be regarded as a particular kind of blended learning, which is made possible by the digitalization of learning contents as well as various learning tools (e.g., lecture video production and editing tools). In practice, flipped classroom can be conveniently launched based on learning management system (LMS), which has been broadly used to publish, store, and manage learning materials. In light of the increasing popularity of mobile devices, some efforts are also devoted to developing mobile tools to support the application of flipped classroom [4].

Despite some obvious benefits such as the greater flexibility, depth, and effectiveness of learning [5], the application of flipped classroom faces many challenges and constraints, such as how to guide a student to study by him/herself, how to support instructor to prepare for teaching in classroom, and how to address the contradiction between the productivity of student’s self-learning and the efficiency of instructor’s preparation. These challenges are especially true for those large classes that enroll more than 100 students, in which, the interactive instruction (either instructor-student interactions or student-student interactions) in classroom is eventually constrained by physical space and lecture hour. In addition to improving student-content interactions, another possible solution is to empower students to teach (or learn from) each other during self-study outside the classroom, and then co-construct new understandings during face-to-face interactions inside the classroom.

Peer instruction is an important foundation of flipped classroom. As the name suggests, peer instruction is an inherently student-centered approach that leverages peer interaction to drive the direction, pace, and intensity of instruction. According to Mazur [6], a complete peer instruction process includes the following steps: (1) instructor announces some questions; (2) students provide individual answers to the questions; (3) students discuss their answers with each other; (4) instructor reviews student answers; (5) students provide their answers again after the peer interactions; (6) instructor revises the instruction delivery according to the changes of student answers. The applications of peer instruction can be found in the courses on different disciplinary subjects such as psychology, science, mathematics, computer science, and engineering [7-11]. Peer instruction is useful for improving students' critical thinking, problem-solving, and decision making [9]. It should be noted that peer assessment is another commonly employed peer-to-peer learning approach [12-14]. In comparison with instruction, assessment has arguably lower requirements for a student's communication and presentation skill. In practice, peer assessment is more widely employed in higher education than peer instruction. However, peer assessment is not within the scope of this work.

Peer instruction can be potentially leveraged to promote diversity and inclusion. The importance of diversity has long been realized by the engineering education community [15]. Student diversity can be regarded as a particular kind of learning resource that can be exploited through peer instruction. In the simplest case, given a new learning concept, if student A considers it easy to understand, while student B considers it difficult to interpret, then the two students can be matched to learn from each other (i.e., student A teaches student B). In a more complex scenario, students with diversified backgrounds can co-construct new contextual understandings through peer-to-peer interactions. Within a small class where the instructor knows every student well enough, peer instruction can be directly facilitated by the instructor by means of manually forming study groups. However, this is no longer feasible for a large class that enrolls more than 100 students.

Against this background, this paper presents a peer-to-peer learning platform (hereafter referred to as the "P2P" platform), which is designed to facilitate peer instruction in the context of flipped classroom. This platform is named P2P (that represents "peer-to-peer" in "flipped classroom") because it is intended to promote peer instruction in flipped classroom. The P2P platform is situated for the large classes, where students are characterized by diversified backgrounds and different understandings. A featured function of the platform is to divide a large class into multiple small groups based on student feedback.

The P2P platform has been piloted based on a technology-enabled international course that enrolled 138 students from 8 global universities. Some lessons learned from applying the platform in this course will be shared. To the authors' best knowledge, no existing tool is readily available to support peer instruction in the flipped classroom. It should be noted that the P2P platform is different from the surveying/grouping tools that are built-in the learning management system that are primarily intended to facilitate team formation for project-based learning.

Key functions of the P2P platform

Figure 1 illustrates a complete peer instruction process made possible by the P2P platform. Before every lecture in classroom, the instructor publishes a set of digitalized learning contents on the platform based on what he/she thinks students need to learn, together with a set of content-related questions that are intended to solicit students' feedback. Next, individual students are tasked to individually study the learning content and then provide their individual feedback. Next, based on student feedback, the P2P platform automatically divides the large class into multiple small study groups, in which, students will learn from each other through peer-to-peer interactions. Afterward, students revise their learning feedback according to the new understandings of learning content. Finally, based on the aggregated student feedback, the instructor adjusts the instruction content, priority, and strategy in classroom in order to focus on what students want to learn. The ability to synthesize what students need to learn (i.e., learning content published online without student feedback) with what they want to learn (i.e., teaching content delivered in class driven by student feedback) is a key feature of the P2P platform.

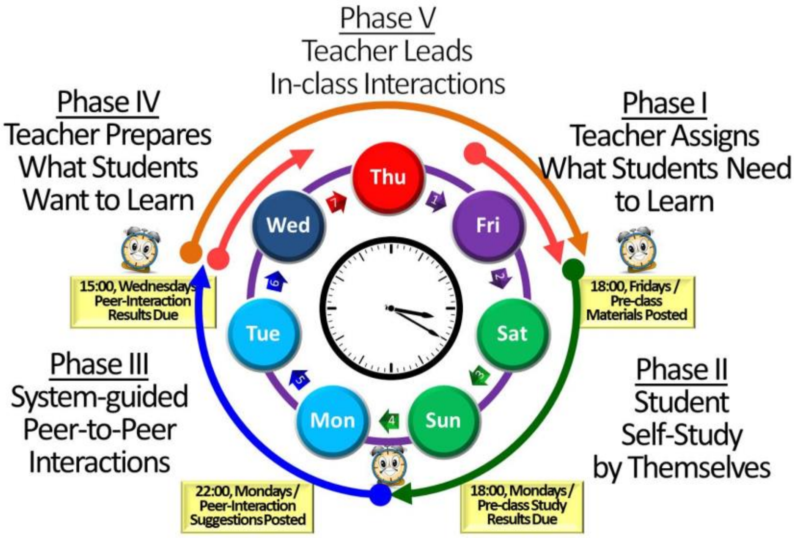

Figure 1. Illustration of a complete peer instruction process

The P2P platform consists of three main sections, namely, "learning content", "study group", and "settings". In the learning content section, the instructor will publish learning contents in various formats (e.g., book chapter, PDF document, PPT slide, short video, picture, external link, etc.). Then every student will download the learning content, then study by themselves, and finally provide learning feedback through a variety of questions in different formats (e.g., rating question, quiz question, and multiple-choice question).

Figure 2 illustrates the graphical user interface of the learning content section. In this particular case, a total of three modules of learning content (i.e., "*Concept A – Mass*

Customization", "*Concept B – Industry 4.0*", and "*Concept C – Blockchain*") are published. For each concept, a short description, relevant learning material (i.e., the PDF document), and multiple feedback questions (e.g., how painful do you think of this concept) are published. As illustrated in Figure 3, the instructor can customize the feedback questions in terms of both contents and formats. For example, some commonly applicable feedback questions include:

- *"How painful do you feel about this concept?"*
- *"To what extent you want to the concept to be further clarified?"*
- *"To what extent are you confident in your understanding of the concept?"*
- *"To what extent are you able to teaching this concept to your peer classmates?"*

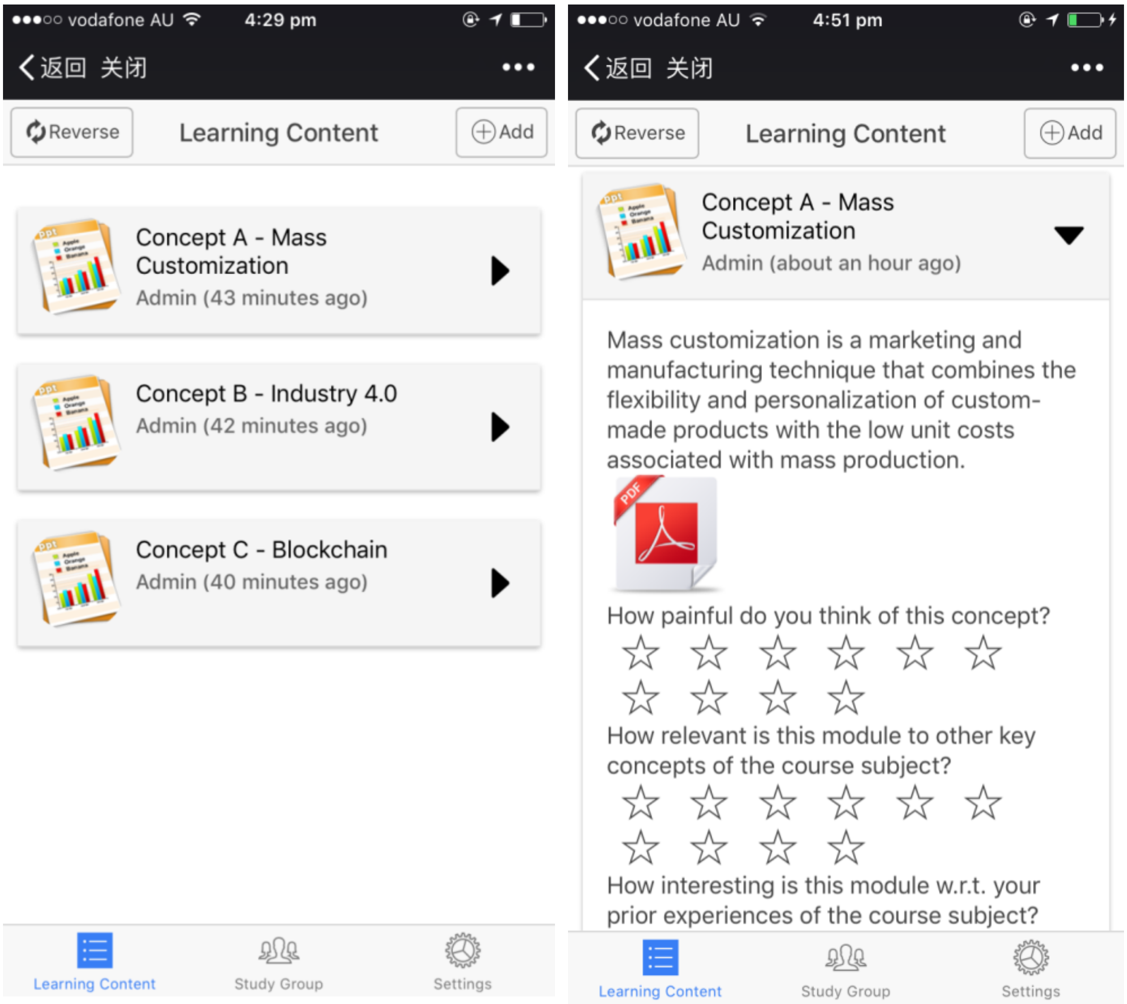

Figure 2. GUI design of the "learning content" section

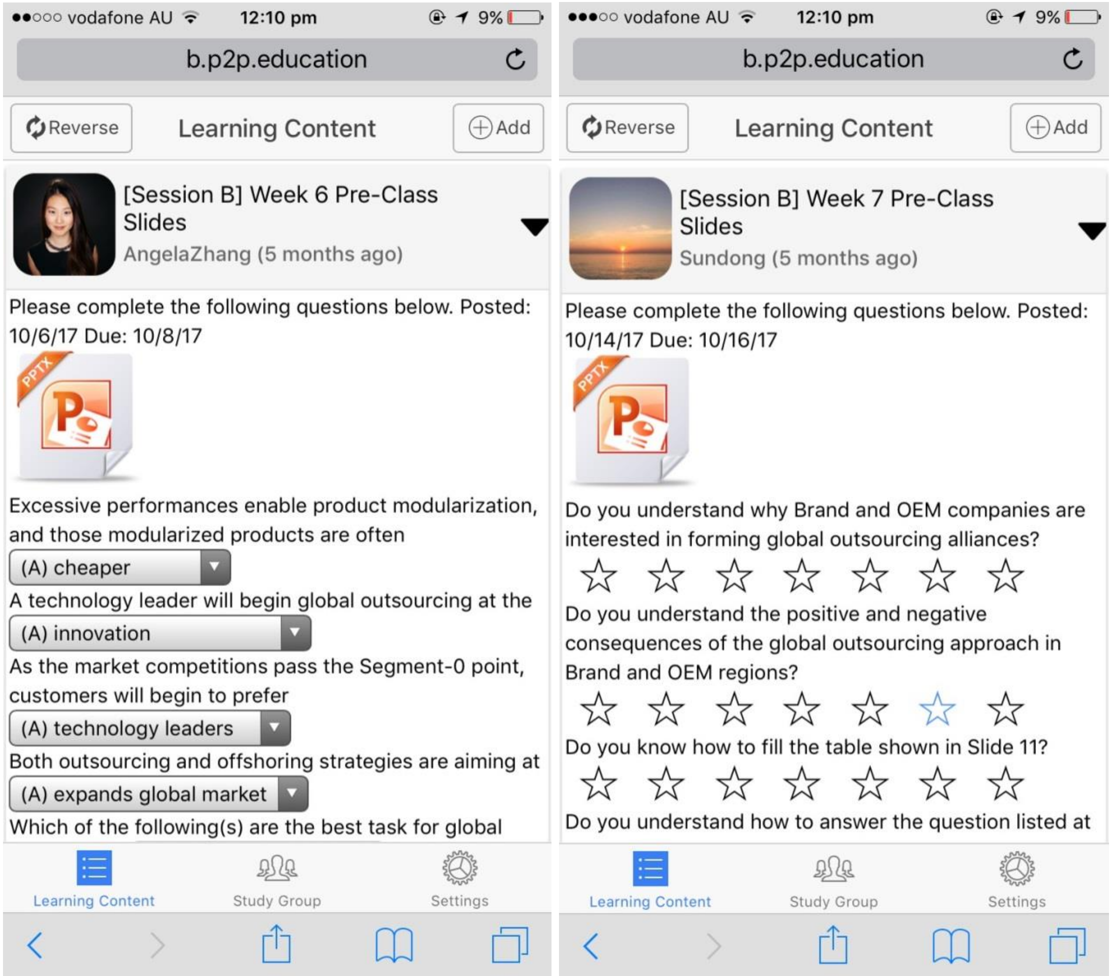

Figure 3. Illustration of feedback questions

Throughout the peer instruction process, students are enabled to update their feedback, while the instructor can track the dynamic changes of student feedback in real time. As illustrated in Figure 4, all the individual student feedbacks are collected, aggregated, and visualized via different formats such as line chart, pie chart, network chart, etc. The instructor can view the aggregated result constantly, while students can only view the result after they provide their own feedback. By doing so, the purpose is to avoid mutual influences between different students' feedback. In addition, based on the discussion contents within study groups, a word-cloud can be generated for the instructor to capture the frequently emerged keywords in the peer-peer interactions.

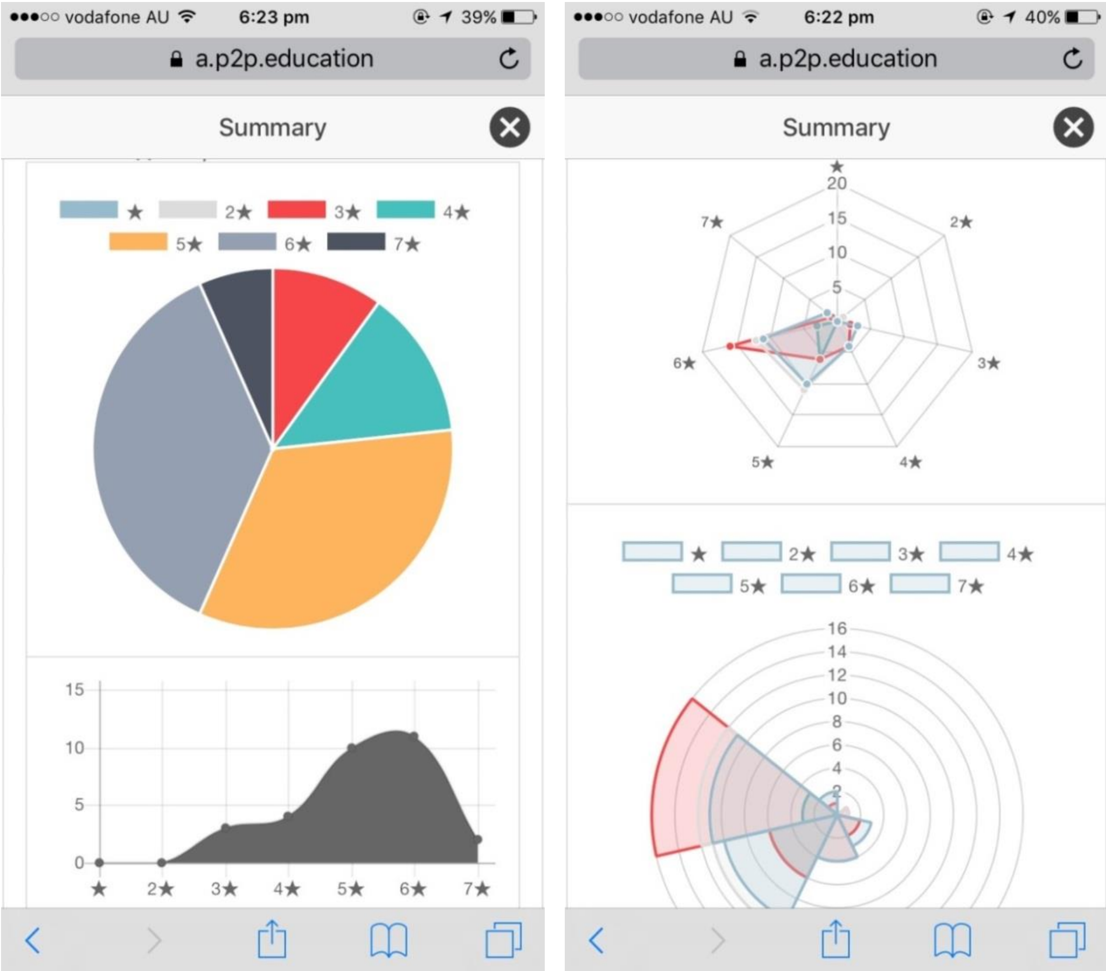

Figure 4. Visualization of student feedback

Figure 5 illustrates the default data visualization format, where the X-axis represents the rating categories (or answers to quiz questions), whereas the Y-axis represents the number of students who vote for each rating category (or the quiz answer). In this particular case, the blue curve, grey curve, red curve, green curve, and yellow curve each represents the distribution of student feedback for five feed questions: "*do you understand the importance of recognizing the Segment-Zero SIP as early as possible?*"; "*do you understand what happens before competitions enter the Segment-Zero SIP?*"; "*do you understand what happens when competitions enter the Segment-Zero SIP?*"; "*are you clear on what happens after competitions pass the Segment-Zero SIP?*"; "*can you understand the changing nature of competitions due to Segment-Zero in a mainstream market?*".

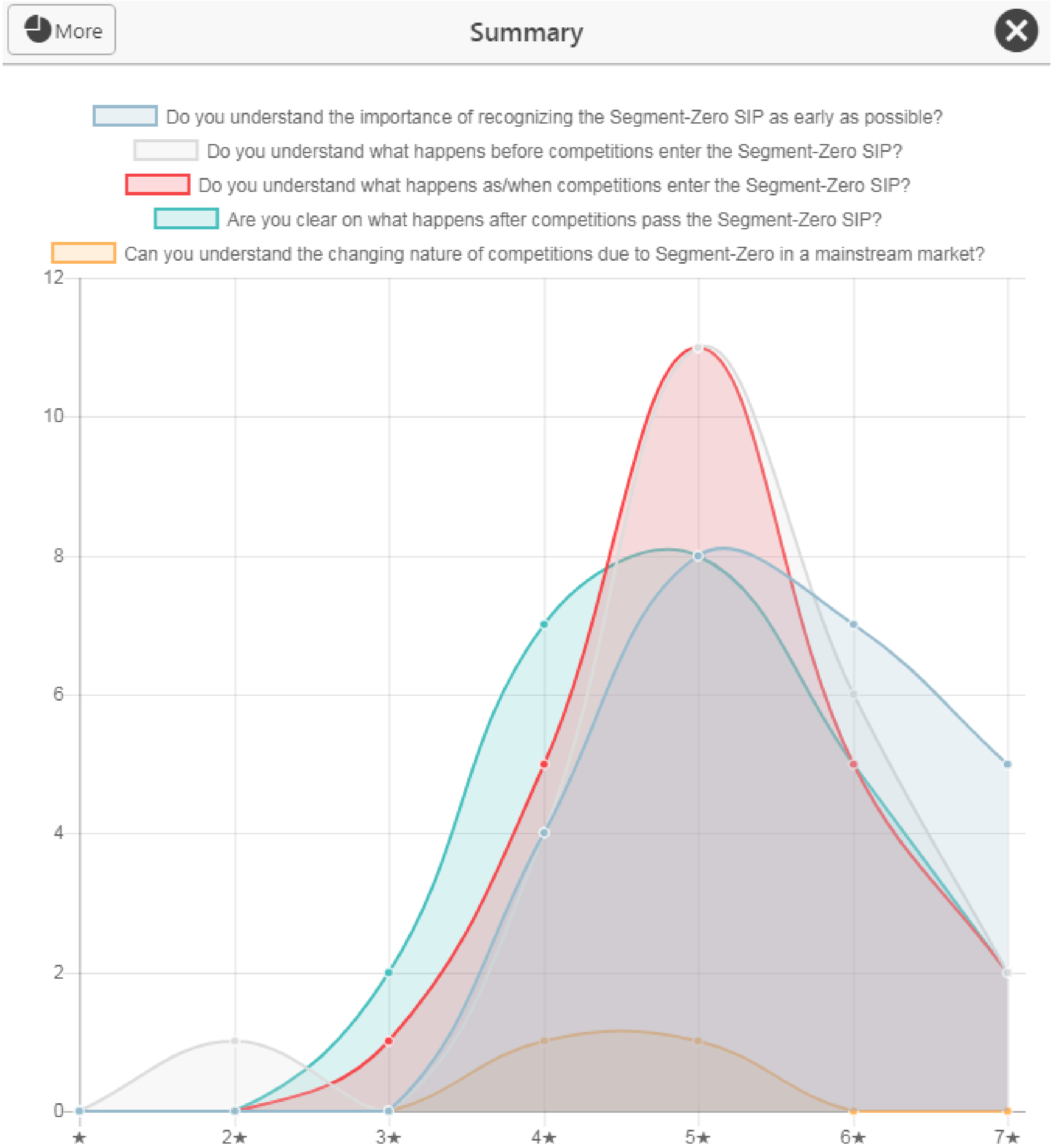

Figure 5. Data visualization of student feedback

Once enough student feedback is collected, the instructor can divide a large class into multiple small study groups. The function of "divide group" is only accessible by the instructor. If the instructor is unsatisfied with the grouping result, the groups can be reformed. The default setting is to divide the class into the groups of 3-5 students (i.e., no less than 3 student and no more than 5 students). The group size is purposefully set to be relatively small, as a way, to prevent social loafing [16]. If multiple concepts are assigned, the same student will be placed into different study groups that correspond to each concept.

Within a study group, students can interact with each other through a variety of communication functions such as location sharing, audio messaging, text messaging, and document sharing. Figure 6 illustrates the graphical user interface (GUI) of the “study group” section.

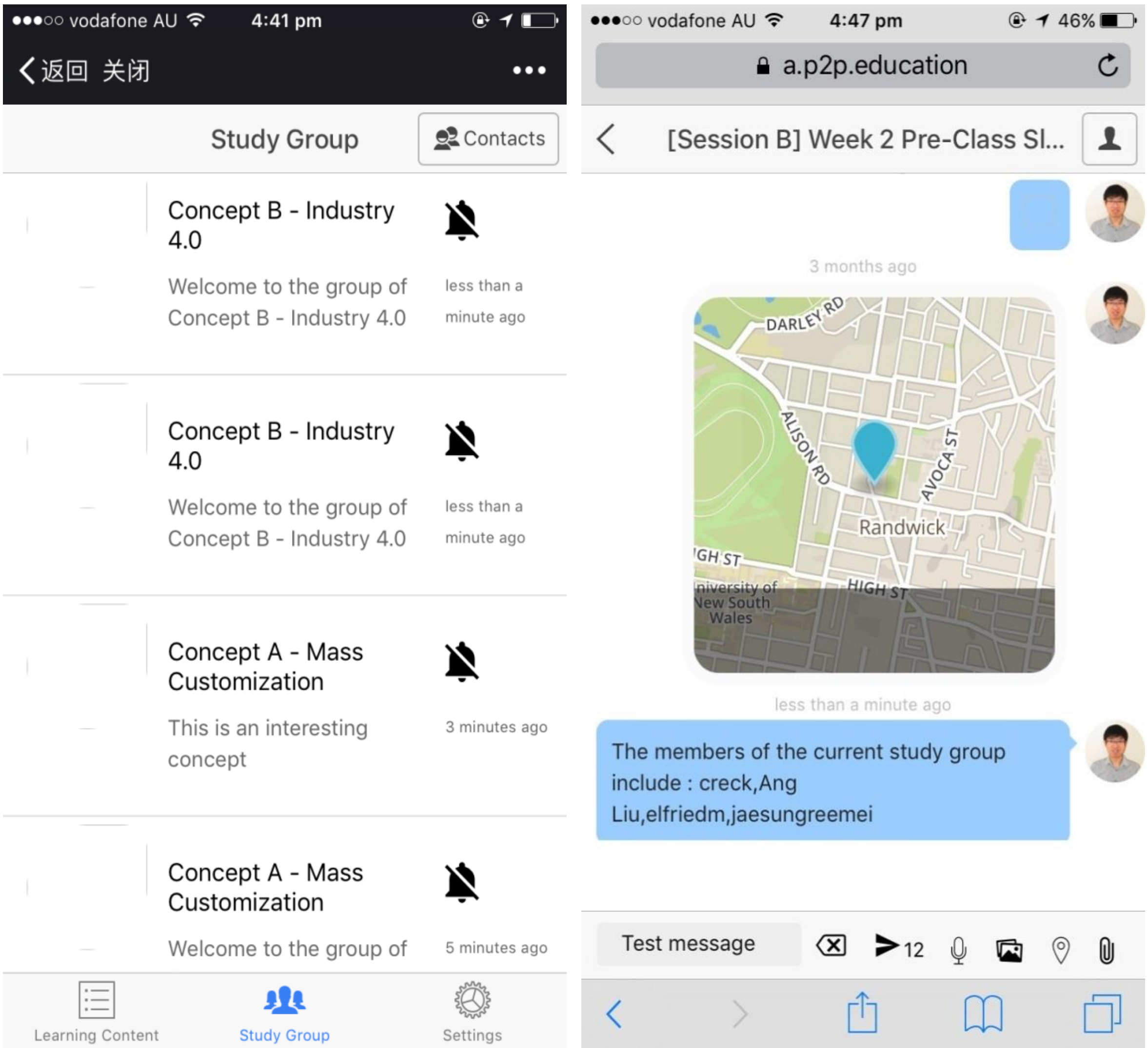

Figure 6. GUI design of the “study group” section

The study groups are formed in light of student similarity. In the P2P platform, the similarity between two students is calculated in consideration of three types of information. Firstly, it considers the demographic information of students such as their university, nationality, discipline, grade year, etc. The demographic information is provided by students in the personal setting section. Secondly, it considers student answers to the same set of feedback questions (e.g., rating and quiz questions). Specifically, a student’s answers to a set of feedback questions are treated as a vector, and the similarity between two students is calculated by means of measuring the cosine degree between the two vectors of answers. Since the answers to the feedback questions are all structured data, they are suitable for the cosine similarity algorithm. Lastly, the text-based messages posted by students in their study groups are analyzed and compared based on the measure of TF-IDF (i.e., term frequency-inverse document frequency). TF-IDF is broadly used by the content-based recommender systems to compare the similarity between two pieces of textual contents [17-18]. The more frequently two students use the same set of keywords, the more similar they are considered. It should be noted that, in consideration of ethics, the content analysis of group discussions can be disabled in practice. The instructor is enabled to select whether he/she prefers to place the most similar/different students in the same study group.

Figure 7 illustrates the system architecture of the P2P platform. The platform was deployed based on the Amazon Web Service (AWS). The relevant AWS services include Elastic Compute Cloud, Simple Storage Service, CloudFront Documentation Service, Simple Notification Service, Glacier, Redshift Data Warehouse, Elastic MapReduce, etc.

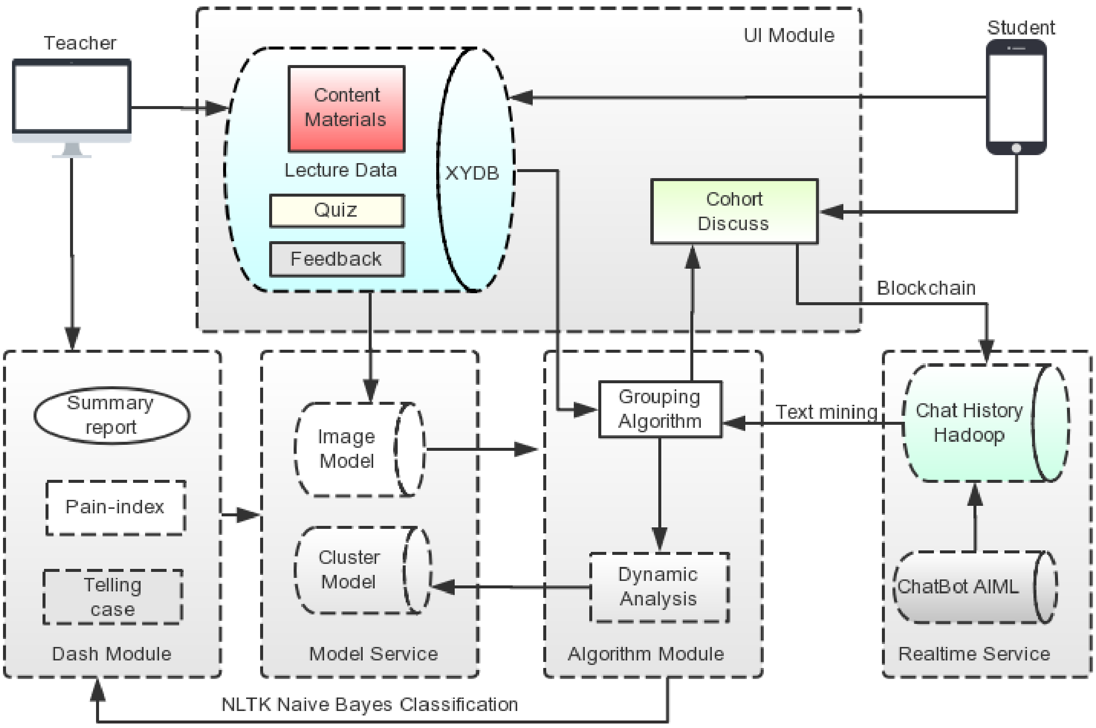

Figure 7. System architecture of the P2P platform

The P2P platform can be conveniently installed and easily accessed via both computer and smartphone. For example, Figure 2, 3, 4, and 6 are screenshots on a smartphone, whereas Figure 3 and 5 are screenshots on a laptop computer.

Application of the P2P Platform

The P2P platform was piloted based on a technology-enabled international course in the 2017 Fall semester. This course was jointly offered by 8 global universities in USA, China, China-Taiwan, Mexico, South Korea, Israel, Germany, Greece, and Australia. It was made possible by the Viterbi iPodia Program at University of Southern California [19]. A total of 138 students participated in the course from their local campuses. Due to the large time difference, the class was organized into two parallel sessions (i.e., Session A and Session B). Session A included students from USA, China, China-Taiwan, South Korea, Australia, and Mexico. Session B included students from USA, Germany, Greece, and Israel. The platform was piloted in both sessions.

This international course was made possible by a variety of learning technologies [20]. Different from a typical distance education course that is featured by the many-to-one connections (i.e., many distance students are all connected to the centralized classroom, instructor, and learning management system), this course is characterized by a multi-layer connection structure. Firstly, the local classrooms on different universities campuses were connected through the video-conferencing technology, so that the globally distributed small classes can learn together at the same time. Secondly, the global virtual teams were connected through the web-conference and social-networking tools (e.g., Slack, Skype, WeChat, etc.), so that the team members can collaborate with each other on the same project. Thirdly, the individual students were connected through the P2P platform, so that the culturally diversified students are enabled to learn from each other via peer instruction.

The students were tasked to follow the above-explained peer instruction process (i.e., self-learning, feedback provision, peer interaction within study group, and feedback update) on a weekly basis. 20% of a student's course grade was determined based on his/her participation in the peer instruction. The 20% was equally distributed to 10 weeks (i.e., 2% for each week). Student would receive the full mark for a certain week, only he/she studied the learning content, provided learning feedback, and contributed discussions within the study groups.

The course focused on the subject of "*principles and practices of global innovation*". In addition to the weekly peer instruction, the other course assessments included team project and cross-cultural exercise. This course was characterized by a large class of students with highly diversified cultural, institutional, and disciplinary backgrounds. As a result, it was difficult, if not impossible, for the instructor to know all the students and address their unique learning needs respectively. In addition, because the students were all globally distributed, it was impossible for them to engage in face-to-face interactions. All these special attributes made this course a suitable testbed of the P2P platform.

Figure 8 illustrates the distribution of devices used by students to access the platform. It was shown that approximately 15% of the students accessed the platform via smartphones (i.e., iOS App 5.76% + Mobile Safari 5.47% + Chrome Mobile 4.03%). This was lower than the expectation since smartphone is becoming an integral part of student's daily life. The main reason was that most of the students still preferred to use laptops to download, view, and study the learning contents that were in the format of PPT slides.

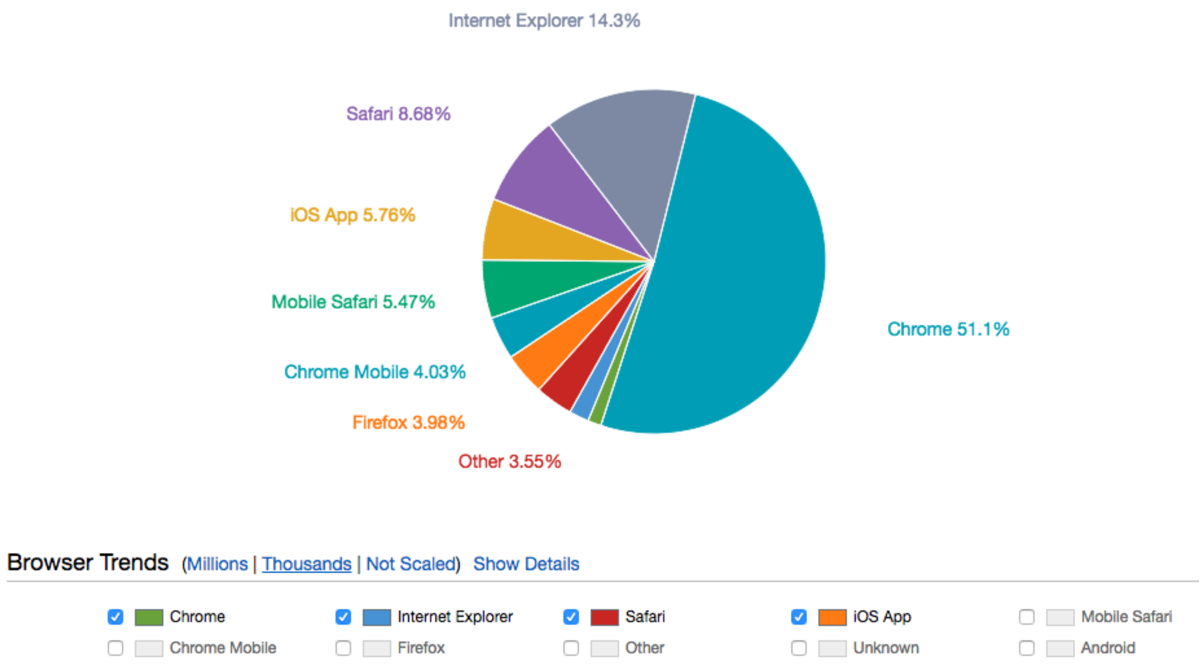

Figure 8. Summary of browser trends

Figure 9 illustrates the word-cloud of the peer-to-peer interactions within study groups through the whole semester, while Figure 10 illustrates the distance between different keywords. It was clear that the peer instruction heavily focused on the key concepts covered in this course, such as "*product design*", "*market competition*", "*segment zero principle*", "*crossing the chasm*", "*technological S curve*", and so forth.

Figure 9. Word-cloud of peer interactions within study groups

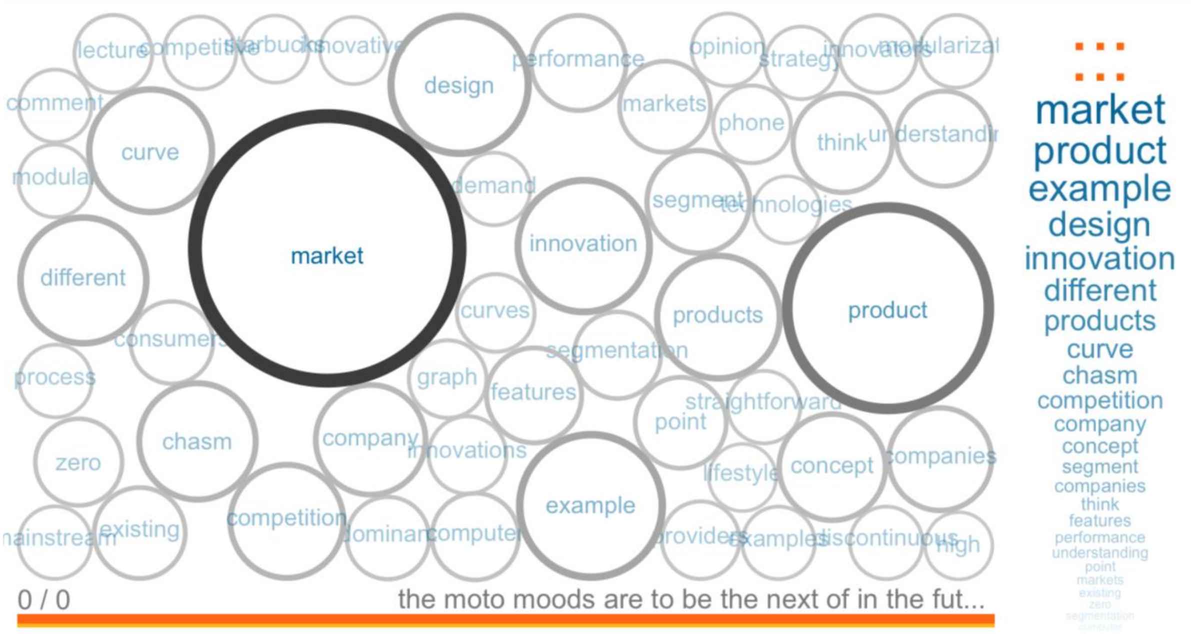

Figure 10. Distance between keywords of peer discussions

Lessons Learned about Peer Instruction

At the conclusion of the course, multiple course participants were interviewed to solicit their feedback on the P2P platform. Some interesting lessons were learned in terms of how the platform was used in practice.

Generally speaking, student feedback was mostly positive. According to students, it was "*fairly straightforward*" to learn to use the platform, especially since a detailed user guide had been provided. It was helpful to view the feedback of other students, which oftentimes triggered a student to revisit a concept that he/she considered difficult in the first place, since the other students "*found the same concept easy*". It was very helpful to deepen a student's understanding of a difficult concept by explaining the concept to the peers, because "*teaching is surprisingly the most effective way of self-learning*". It was suggested that peer instruction improved not only student understandings of difficult concepts but also their mutual understandings of each other, since "*one of the most rewarding experiences was to know more counterparts from other countries*". It should come as no surprise that the peer interactions within the study groups comprised a number of social interactions. However, they were by no means the focus of interactions, which was evidenced by the word-cloud as shown in Figure 9. Although the P2P platform was equipped with certain social-networking functions (e.g., adding a peer student as personal friend and initiating a private conversation), they were rarely used in practice.

Student participation was most active in the middle of the semester (i.e., week 5-8) after they developed a routine habit of using the platform. Some students admitted that, from time to time, their feedback was provided in a somehow arbitrary manner simply to "*sign up the attendance*". It was not uncommon that some students had provided feedback without carefully studying the learning contents. This was evidenced by the abnormally short intervals between the time-point of downloading learning content and the time-point of providing learning feedback. From time to time, students within a study group would exchange contact information and switch to another smartphone app (e.g., Facebook Messenger and WeChat) for direct interactions, because of the inadequacies of the platform's communication functions.

It should be noted that some difficulties of using the platform were caused by the nature of this course. According to some students, time difference made it difficult to interact with their peers in real-time. As a result, the interaction became largely discontinuous, which was a great hindrance to the peer instruction, since students only had 3 days before the teaching in classroom. Furthermore, according to some students whose first language is not English, sometimes they hesitated to engage in a live interaction, especially when "*the purpose was to explain a difficult concept to the native English speaker*". As a result, it was not uncommon that some students simply chose to intentionally "*ignore the group messages*".

Last but not least, some suggestions were raised by students with respect to how the instruction should be restructured. Firstly, it was suggested that a short video should be provided to complement the PPT slides and PDF documents. Secondly, it was unclear to the students that how and in what ways the instruction in classroom had been adjusted as a result of their feedback. According to the students, "*knowing the difference will definitely motivate us to treat the feedback more seriously*". Finally, it was suggested that those "*truly helpful students should be rewarded with extra credits*", though the extra credits should be given in a transparent manner such as "*a dynamic ranking of the most helpful peers*".

Lessons Learned about Teaching

According to the instructor, overall, the P2P platform was effective in realizing the peer instruction process. It was straightforward to learn to use the platform as an instructor. It was helpful to be able to track the dynamic changes of student feedback throughout the learning process. Based on the aggregated feedback, the instructor obtained some general hints with respect to which concept should be further clarified in class.

The instructor was not entirely satisfied with the clarity of student feedback. Firstly, it seems that most of the feedback was "*fairly predictable with traceable patterns*". For example, students tended to consider the slides with complex animations difficult to understand. Secondly, the feedback was still vague and general. For example, as shown in Figure 9, although it was speculated that students desire more "examples", it was unclear which kind of examples were desirable. Lastly, the instructor agreed that the quality of student feedback was affected by not only how the learning contents were presented (i.e., how the slides were modularized, segmented, and animated), but also how the questions were asked. An underlying dilemma was how to manage the abstraction level of feedback questions. On the one hand, if the question was phrased to be too general, the feedback would be short of clarity. On the other hand, if the question was phrased to be too specific, it would trigger a wide range of feedback (i.e., a normal distribution curve with a high deviation).

According to the instructor, the P2P platform was somehow functionally coupled with the learning management system (LMS). From time to time, students needed to visit the LMS to watch the lecture recordings to reflect the previous concepts during the self-study of new concepts. Once students developed a routine habit of using the platform, it was also used by the instructor to make important course announcements and conduct course surveys.

Conclusion, Limitation, and Future Work

This paper presents a new learning platform to facilitate peer instruction in the context of flipped classroom. The platform is developed for the large classes of students with diversified disciplinary, culture, and national backgrounds. The key functions of the platform include:

- Enable instructor to publish modularized and digitalized learning contents together with a variety of content-related questions;
- Enable students to provide individual feedback based on self-study;
- Aggregate individual student feedback and visualize the analysis result;
- Divide the class into multiple study groups of 3-5 students with diversified feedback;
- Support online peer-to-peer interactions within the study group

Some limitation should be considered. Firstly, since the P2P platform was only being piloted based on the international course, no quantitative research (e.g., a survey of the class) had been conducted to solicit student feedback. In fact, the platform was iteratively improved during the piloting process. Together with the constructive feedback solicited from the other engineering educators in the ASEE community, the platform will continue to be improved. Last but not least, the authors chose not to overly elaborate the core algorithms behind the platform, as well as a set of learning metrics (e.g., pain index, diversity index, and inclusion index) that are still being optimized. But rather, this paper focuses on the pedagogical foundations of the platform, the key functions of the platform, and how the platform was used by students and instructor.

Overall, the P2P platform achieves to realize the complete peer instruction process. Students were able to use the platform, in an expected way, to engage in peer instruction. The instructor received some meaningful feedback in terms of how students understood the learning contents and how their understandings changed over time. There are some remaining issues that should be noted. Firstly, the quality of feedback was greatly affected by how and in what ways the feedback questions were asked. Secondly, it is necessary to create a proper mechanism for students to develop a routine habit of participating in peer instruction on a regular basis. Thirdly, students should be properly motivated to actively contribute to the peer instruction process.

With respect to future work, the platform will continue to be improved by adding new functions, for example, students will be enabled to rate the effectiveness of peer instruction, vote for the most helpful peer, receive notifications when new groups are formed, and so forth. In light of the functional coupling between the P2P platform and the learning management system, the platform will be embedded into one of the mainstream LMSs such as Moodle. The improved platform will be tested in more engineering courses. In the 2018 spring semester, it will be tested in a cornerstone design course (i.e., ENGG1000: Introduction to Engineering Design and Innovation) that enrolls over one thousand freshmen at University of New South Wales in Australia. Based on this course, a mixed-methods research, which combines both quantitative and qualitative methods (i.e., online survey + focus group), will be conducted to answer two research questions: (1) “to what extent students are satisfied with the peer instruction process enabled by the P2P platform?” and (2) “in what ways the instructor use the information (learning feedback and learning index) provided by the P2P platform to redesign the teaching activities?”. Additionally, it is interesting to apply the platform to some fundamental engineering courses such as statics and electrical circuits, for which, the instruction process should be adapted towards a hybrid model where sufficient background materials should be provided prior to the peer instruction.

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