Systematic and quantifiable approach to teaching elite students

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Abstract

Flipped classroom activities for elite CUHK freshman engineering mathematics course was statistically analyzed in order to discover early performance indicators, importance of group formation and performance relationships among activities. Review activity took place prior to the midterm and correlated with the total class grade. Class forum activity also correlated with the total class grade while project activity and question creation game activity only correlated with the midterm. Student groups were statistically identifiable due to unique sets of in-class assignments.
Key Words: e-learning, flipped, web enabled

Introduction

The model of flipped classroom has been a sweeping pedagogic practice in the past decade worldwide. In a flipped classroom, traditional in-class activities transpire out of class, while graded homework activities take place in-class (Baker, 2000; Ash, 2012; Bergmann & Sams, 2012; Tucker, 2012; Bishop & Verleger, 2013; Chen et al., 2014; Fautch, 2015; Yu & Wang, 2016). Students are expected to cover class content autonomously before class, usually with the assistance of technology enhanced, student controlled, and instructor-provided videos or other forms of knowledge (O'Neil et al., 2012). During in-class sessions, students bring their understanding of the content they studied into the classroom and get involved in active learning and meaning construction. Via teacher-facilitated learner-centered tasks, students are expected to deepen their knowledge obtained before class (Jong, 2017).

In the past decade, numerous educational practitioners and researchers have been trying to use video clips to flip their instruction and examine the effectiveness this pedagogic approach. Numerous studies, especially empirical studies, have been conducted to prove that this model of instruction is superior to a regular lecture-based one (Vaughan, 2014; Tawfik, & Lilly, 2015; Mattis, 2015; Blair et al., 2016; Nwosisi et al., 2016; Shyu, & Jiang, 2016). Mathematics teachers and educators have also applied this pedagogic approach to the learning and teaching of math at various levels (Sahin et al., 2015; Bhagat et al., 2016; Chen, 2016; Muir & Geiger, 2016; Chung & Hew, 2017; Zengin, 2017). Most of the study provided empirical insight into the effectiveness of a flipped math classroom. However, very few studies have ever examined a detailed evaluation mechanism of flipped classroom effectiveness in terms of how students should be organized in both in-class and out-of-class activities. Therefore, this study aims to investigate effective measures in evaluating students in flipped classroom.

Classroom Context

The selection of this course was purposive because this elite freshman linear algebra/vector calculus course was among the first to fully apply the flipped course approach in the university. Coursework of the elite class was supplemented with additional advanced linear algebra, coding theory and basics of analysis. A more elementary version of the course was offered to regular students. Forty-two students completed the elite offering last semester. The internet made the flipped class structure possible as well as attractive. Videos of class material were available and required viewing outside of the classroom. The Piazza (Piazza, n.d.) class forum had over six hundred posts and it was used for a broad range of diverse activities. The collaborative learning environment consisted of in-class exercises (5 hours a week), which were completed in groups of three. Moreover, the groups had to complete advanced projects, for which students could choose from a list of preselected project topics (quantum mechanics, face recognition, image processing, privacy protecting codes, etc.). An online "game" activity was one of the most prominent forum post exchanges. The game consisted of students setting questions for each other based on class materials, and winning points by answering one another's question(s). Prior to the midterm, there was also an opportunity for students to exchange knowledge and earn bonus points by explaining a concept to a classmate. Knowledge exchange was tracked with a coupon system − i.e. answering questions was rewarded with coupons which converted into bonus points.

TABLE I
INDIVIDUAL COUPON PERFORMANCE INDICATOR

Grade	Answered	Asked
Total	p=0.0000104	p=0.297
Final	p=0.00540	p=0.164
Midterm	p=0.0346	p=0.403

*$p<0.05$ is statistically significant

TABLE II
GROUP COUPON PERFORMANCE INDICATOR

Grade	Answered	Asked
Total	p=0.000748	p=0.0396
Final	p=0.0102	p=0.220
Midterm	p=0.194	p=0.192

*$p<0.05$ is statistically significant

Creating balanced groups where individual grades were not strongly correlated with group grades would only be possible with prior knowledge of student or group class performance.

Coupon Review

In order to review the material prior to the midterm, a special review activity was orchestrated where students won a grade boosting coupon if they explained a concept to another student.

- Individual level of understanding for each topic by each student was marked on a scale of one to five in a Google spreadsheet.
- The spreadsheet guided students in search of other students with higher levels of understanding on their topics of interest.
- If two students met and the topic was well explained, then a paper coupon that had bonus points was given to the student that tutored.
- After the coupon exchange Google spreadsheet was updated with new levels of understanding.

Presented p values in Table I statistically relate the number of questions answered and asked by individuals to their graded performance. Group level averages of individual assessment measures in Table II were related to the total number of asked and answered questions by all of the members of the group. Answering coupon questions prior to the midterm was highly correlated with final outcomes for the class as shown in Table I and Table II. The correlation of coupon answer rates with the graded activities increased as the course progressed. However, individual coupon answers were not as predictive of individual final grades as the group total coupon answers were predictive of group average final grades.

Observed group and individual coupon answering metrics were inherently different. Groups would also exchange knowledge without recording the event in the coupon economy system. Groups that asked more questions from other groups were more likely to obtain higher grades but this relationship was not true for individuals. Correlations implied that an unknown group level factor, which grew in importance over time, was captured by the coupon activity. The maximum number of coupons earned by an individual was seven and thus

TABLE III
COUPON AND MIDTERM AS INDICATORS

Value, Indicator	Individual	Group
Total, Coupon	p=0.0000104	p=0.000748
Total, Midterm	p=0.00000000	p=0.00187

*$p<0.05$ is statistically significant

there were only eight levels of discrimination amongst students.

Since the coupon review was most highly correlated with the final grade received for the class, further investigation shown in Table III compared how the coupon review and midterm grades correlate with final grades. Group final grades were group averages of individual final grades and the same is true for group midterm grades, while group coupon was measured as the total number of answered questions by the group members. Earned coupons were rewarded with bonus points which could be earned in many other ways while the midterm contributed more directly to the final grade. Many students who did not need bonus points were motivated by the social status bestowed upon those who were knowledgeable and willing to help others learn. Students reported high levels of satisfaction with the efficacy and rewards obtained during the coupon activity as well as the speed of peer to peer distributed knowledge exchange. In Fig. 1, it can be observed that groups that answered no questions during the coupon review prior to the midterm formed an outlying low performance cluster of groups in terms of total class grades. Coupon review records could have been used to aid in the process of balancing groups.

Question Game

In order to grasp concepts at a creative level students were asked to generate new questions for other students to evaluate and answer.

- Students had to devise questions individually or in groups.
- First question game was conducted amongst individual students and three question games that followed were conducted amongst student groups.
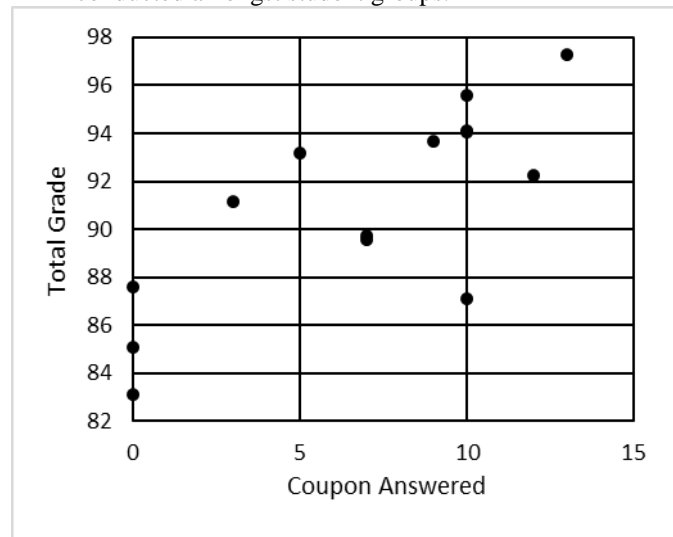

Fig. 1 Total average group grade vs total coupon activity answers by the group

Grade	Contributions	Days Online	Posts Viewed
Total	$p=0.00106$	$p=0.00212$	$p=0.0143$
Final	$p=0.00524$	$p=0.00579$	$p=0.0912$
Midterm	$p=0.0290$	$p=0.0315$	$p=0.247$

*$p<0.05$ is statistically significant

- In the first of three rounds, an individual or a group would come up with a question.
- In round two, the question was checked by three other individuals or groups for validity. Therefore, most of the invalid questions were not seen by the students.
- In round three, anybody aside from the creators of the question could participate in attempting to answer or find a flaw in the question.
- Since the question game was conducted in an online forum, teaching assistants observed the progress and awarded points for productive participation.
- It was known that one of the questions on the final exam came from the game and this incentivized the review of questions as well as the creation of high quality questions.

All of the metrics collected during this activity were not strongly related to the group or individual performance in terms of class grade. Although the quality of generated questions varied greatly, all of the students did have an opportunity to think creatively and constructively about the material that they were given and some of the groups and individuals created high quality questions.

Last three question games were conducted amongst groups. Quality of each question in the game was ranked by Bloom taxonomy. Each group Bloom taxonomy rating was calculated by averaging the Bloom taxonomy scores for their questions. Group Bloom taxonomy ratings had strongest relationship to the midterm ($p=0.0210$), followed by the final ($p=0.165$) and total grade ($p=0.199$) and weakest relationship with the coupon activity ($p=0.303$). Although midterm most strongly relates to the Bloom taxonomy level of game questions, most of the game activities took place after the midterm.

Group Projects

Projects provided a platform for experimentation with presented concepts and more in depth research thereof.
- Activity was designed to simulate real-life usage of learned materials in academic research.
- The project work was reviewed by teaching assistants and professor on a weekly basis and many groups surpassed their targeted goals for the semester.
- A poster session similar to an academic conference was conducted and students had to recall major aspect of several projects on the final exam.

Since talented students were selected for this course, the level of independent study and research for most projects matched
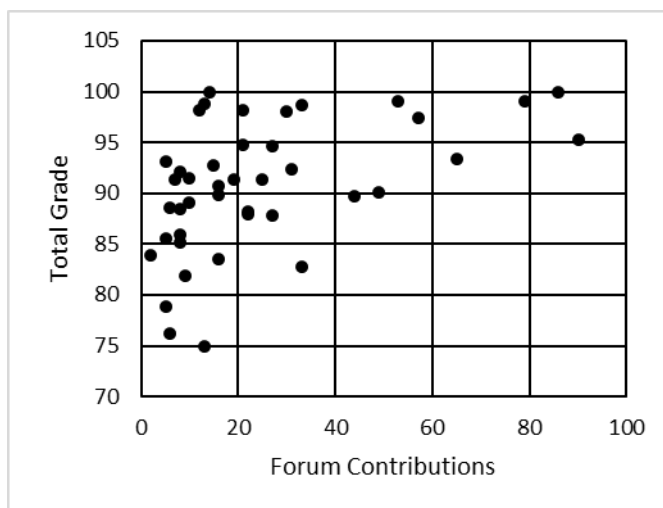

Fig. 2 Students with a high number of forum contributions tended to have higher grades

university-level, final-year project efforts, and in some cases postgraduate school level aptitude. Projects of note cover Quantum Mechanics and the Search Grover Algorithm, as well as Wavelet based MDC image compression. Since most groups surpassed required grading thresholds, the project grades do not greatly differentiate among the groups.

Weekly reports submitted by each group were ranked on the Bloom taxonomy scale. Although some reports were missing, the average Bloom taxonomy score was calculated from existing scores for each group. Evaluation of the project progress reports on the Bloom taxonomy scale found the strongest relationship with the midterm ($p=0.0098$), followed by the total grade ($p=0.0808$) and final grade ($p=0.0916$) and weakest relationship with the coupon activity ($p=0.3742$). Projects as well as the question game were mostly conducted after the midterm and both activities were a highly visible display of class material mastery that did not have as much influence on the grade as the tests. Both activities rewarded high Bloom taxonomy performance which were not as prevalent on the final test due to time limitations.

Additional Quantifiable Findings

Data was collected in online spreadsheets for coupons, online educational platform (e.g. Piazza), feedback reports, forum activities, communications, polls, as well as surveys. The quantity and timeliness of collected information could have allowed for identification of high and low student performance prior to grading events. The Piazza online forum provided an up-to-date status of student participation levels. As shown in Fig. 2, cumulative student participation on the Piazza forum over the course of the semester is related to the overall student performance in the class.

As can be seen from the Fig. 2, outlying high levels of forum activity are associated with high grade performance, in contrast to the coupon data where lower coupon count was related to low performance. Data in Table IV presents relationships between forum behavior and individual grades.

Survey on understanding the 335 concepts covered in-class revealed that the differences between students in the same group and students outside their group were statistically significant according to the anova analysis ($p=0.00081$). Every

group had a unique combination of in-class exercises to solve during the semester. When the topics covered by in-class exercises were removed from the survey the differences between group members and non-group members were statistically insignificant. Survey required students to input their level of understanding of each topic on a scale from 1 to 5. Occasionally, students had input 0, 55 or 6 and these numbers were corrected to the scale of 1 to 5. Some topics were not ranked by a student and an average level of understanding for that student was filled in automatically. One student did not rank any topics and their entire group was removed from the study. After all of the students under consideration had an assigned ranking for all of the topics, the rankings scaled to all span the same numerical range and have an average of zero for every set of student rankings. Student rankings of topic understandings were vectors whose L2 norm distance measure was used in the group vs non-group anova analysis. Thirty-nine group member distances were compared against thirty-nine randomly selected non repeating non-group distances in the anova analysis.

Conclusions

The results of the analysis imply that more frequent coupon activities would not only aid the learning process but also quickly identify groups that would have greater difficulty at a later time in the course. Since the forum data was used to identify high performance individuals and coupons identified low performance groups, it may be possible to encourage a more balanced group formation.

Both the question game and the group project were only correlated in a statistically significant way to the midterm grade and not to the final or total grade. Since the question game was not a large portion of the total grade and nearly all groups surpassed all project goals, the effort required for high achievement in these activities was not adequately accounted for in the total grade. Both of the activities took place mostly after the midterm and therefore, the effect of extra workload would mostly be seen in the final test. Since the introduction of these activities coincides with the change of grade distribution, further examination of possible causation is necessary.

Group members were indistinguishable from non-group members in a statistically significant way when midterm and final grades were considered. Statistically significant differentiation did exist in terms of how individuals self-reported their level of understanding class topics due to in-class exercises. Class topic comprehension differences between groups may explain the high levels of student satisfaction with the coupon knowledge exchange activity.

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