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EFFECTS OF FLIPPED INQUIRY-BASED APPROACH AND TRADITIONAL INSTRUCTION APPROACH TOWARDS STUDENT ACADEMIC PERFORMANCE IN GENERAL UNIVERSITY REQUIREMENT SUBJECT

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***Abstract*—This study compared student academic performance in a General University Requirement subject across two instructional approaches: traditional and flipped inquiry. A quasi-experimental design was chosen for this study with non-equivalent group posttest design. The participants consisted of a total of 197 full-time undergraduate and sub-degree students who enrolled in the General University Requirement subject "Light, man and environment". There were 99 students from class of academic year 2017/18 and 98 from class of academic year 2019/20, respectively. Results indicated that the flipped inquiry instructional approach had a significant impact on student academic performance than traditional approach. Whitney test showed that there is a difference of student academic performance between those who undertook flipped inquiry based instructional approach and the students who undertook traditional approach. A positive outlook towards this blended learning approach was received.**

***Keywords*—Flipped classroom, flipped inquiry-based learning, academic performance, engineering**

I. INTRODUCTION

In recent decades, technology enhanced learning environment provides varied ways to support teaching and learning contexts in local schools and higher education institutes. Flipped classroom model combines online learning and face-to-face active and collaborative learning give a better learning alternative for students as compared with traditional face-to-face lecture style. More specifically, the flipped classroom is a pedagogical approach that uses "a mix of diverse content via the combined technology capabilities of the Internet, higher performance computing, advanced networking, in-home electronic, and mobile communication" (1). The flipped classroom inverts traditional teaching methods so that the core information can be delivered via online learning platform (e.g. Learning Management System) prior to class (at home) and the 'assignments' move into the classroom. In the traditional lecture-based approach, "classroom time is used for the delivery of lecture materials to students, with additional class time sometimes used to engage students in basic comprehension activities, typically with scarce active learning exercises and practice problems" (2). However, the flipped approach "assists students in developing and constructing ideas of knowledge and independently" and "facilitates them to learn actively and involved continuously, both mentally and physically" (3).

In this pedagogical approach, students are able to learn basic subject knowledge and relevant theories and concepts through the online learning platform prior to class. The subject knowledge and concepts are delivered via video-recorded lectures, PowerPoint presentations, quizzes and online information outside the traditional classroom setting; therefore, students can "work through problems, advance concepts and engage in collaborative hands-on learning activities" in the scheduled class time (4). A study by Bergmann and Sams (5) revealed that the flipped instructional approach enhanced facilitator's interactions with students, as well as interactions with peers (5). By using this approach, the facilitator is able to utilize his/her class time for active learning assignments, student collaboration, and one-on-one interaction with students (6).

A meta-analysis study (7) showed that the above blended learning is an effective pedagogical approach in comparison with the traditional face-to-face approach or online learning mode. For example, a study by Alvarez-Bell (8) showed that the academic performance of students enrolled in an advance general chemistry course (86%) outperformed students enrolled in the traditional lecture section (72%). Ruddick (9)

also reported that students in the flipped section performed better than students enrolled in the traditional lecture-based 23environment in terms of course assignments, quizzes and final exam (10-14). Similarly, studies have showed enhancement of student performance in pharmaceutics course, pharmacotherapy course and different health related program (15-19). Nowadays, many discipline-based faculty adopted innovative pedagogical strategies, even though most faculty have performed excellent in traditional instruction. As both the flipped learning and inquiry-based learning are the interactive and innovative instructional approaches, we proposed integration of the two to enhance student achievement and performance. According to Love (20), flipped learning approach can be combined with active learning strategies such as inquiry-based learning, problem-based learning and collaborative learning. Inquiry is an active learning approach that can encourage students to construct their own knowledge through gathering information, discussing ideas, answering questions, and problems based on a logical test of facts and observations (21)and reflecting on the newly attained knowledge (22). A study by Thongkoo et al. (23) showed that "integrating knowledge management and inquiry-based approach into a flipped classroom can improve students' programming skills and code comprehension and help them learn more effectively with better learning achievements" (p. 304).

In short, the purpose of this study is to explore the effectiveness of the two instructional approaches (i.e. traditional instructional approach and flipped inquiry-based approach) within the context of science education. More specifically, this study presents findings of the impact of the aforementioned instructional approaches on the academic performance of the students. The following hypothesis was tested. Hypothesis: There is no difference between the academic performance of the students undertaking the traditional approach and the performance of the students undertaking the flipped inquiry-based approach.

II. METHOD

Participants

A quasi-experimental method with non-equivalent group post-test was adopted for this study to compare student performance in two different classroom settings: traditional versus flipped inquiry-based. The participants consisted of a total of 197 full-time undergraduate and sub-degree students enrolled in the General University Requirement subject "Light, man and environment" (subject code: BSE1D02) offered by the Department of Building Services Engineering of The Hong Kong Polytechnic University. There were 99 students from class of academic year AY2017/18 and 98 from class of academic year AY2019/20, respectively. This General University Requirement subject was redesigned based on the above proposed flipped inquiry-based learning.

Procedure

The traditional and flipped inquiry-based courses were operated in both AY2017/18 and AY2019/20 respectively, and were taught by the same subject lecturer. In the traditional based course, the subject lecturer utilized the common practice to lecture on relevant concepts by using PowerPoint presentations during face-to-face class teaching. In addition, students were required to have completed pre-class materials, such as assigned reading, instructor-prepared relevant video(s), PowerPoint slides and online quizzes in the scheduled period. The flipped inquiry based learning approach was adopted in the selected lectures of the subject. The concept of Bloom Taxonomy was also applied to the flipped classroom to enhance student learning at understanding level before they got into the specific contents, whereas student learning would be deepened at application/synthesis level by adopting collaborative learning, which enabled them to have more hands-on experience in class time (24-25). Students were assigned series of out-of-class online platform activities prior to the lecture. They were required to watch videos and/or complete quizzes covering five major themes - human vision and interaction of light with matter, light and health daylight and artificial light sources, photometric characteristics of light sources, as well as light and colour, prior to the class.

The purpose of the activities aimed to up skill students' understanding of relevant subject concepts and theories prior to class sessions and facilitate students to reflect their learning at understanding level (26). In classroom setting, students were engaged in the guided inquiry-based learning activities through working in pairs/groups. In these classroom activities, the subject lecturer reviewed the key concepts of the subject contents with students to up skill their subject knowledge, as well as "how these could expand and create their intellectual capacity beyond disciplinary domains" (26). The subject lecturer would also provide scaffolding to students if students encountered difficulties. The above activities, which included a variety of themes – 1) ghost on stage trick – reflection, 2) coin under glass cup trick – refraction, 3) use of lighting measurement equipment, 4) color mixing, 5) crossword puzzle on light and health, 6) equinoxes and solstices, 7) photometric characteristics of light sources, 8) simulation software, 9) role of lighting in theatre and cinematography, and 10) stereoscopy and stroboscopic effect, not only aimed to trigger students' curiosity in terms of specific knowledge and skills, but also developed their higher order thinking skills in the subject. The effect of flipped inquiry-based learning towards student academic performance was evaluated from their quizzes, case study report, oral presentation, and examination by the end of semester, which were the major assessment items of the subject. For the present study, the aforementioned assessment items were served for comparison with which to measure student academic performance.

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III. RESULTS

Data collection and analyses

The academic performance of the 197 undergraduate students, which 99 students undertaken traditional learning and 98 students undertaken flipped inquiry based learning, was measured by different assessment items (i.e. quizzes, presentation, report and final exam). There were two phases of data analysis in this study. In the first phrase, descriptive statistics were used to provide quantitative summaries of each assessment by instructional method (See Table 1 and 2). In the second phrase, Mann-Whitney test (See Table 3), which is a nonparametric test, was used to determine any significant differences between study variables. In the third phase, descriptive statistics was performed in order to understand students' perceived learning experience in the flipped inquiry based classroom.

As shown in Table 1, the mean score of Quiz 1 for the traditional instruction section was 78% as compared with 82% for the flipped inquiry-based approach section. Similarly, the mean score of the Quiz 2 for the traditional instruction was 71% compared with 78% for the flipped inquiry-based approach. The mean score for the report showed that students in the flipped inquiry-based classes performed slightly better (71%) than those in the traditional instruction class (66%). The mean score for final examination showed that students in the flipped inquiry-based approach performed better (71%) than those in traditional instruction (62%).

Table 1: Students' percentage scores on subject assessment

Course	**BSE1D02**		
Instruction		Traditional	Flipped inquiry
Assessment	Quiz 1	78%	82%
	Quiz 2	71%	78%
	Presentation	71%	70%
	Report	66%	71%
	Exam	62%	71%

Table 2 provides a summary of student performance on final grade in traditional instruction section versus flipped inquiry-based approach section. In the traditional instruction section, 18% of the student earned A grade, 63% earned B grade, 17% earned C grade; 2% earned D grade or below. Compared with the flipped inquiry-based approach section, 45% of the students earned A grade, 42% earned B grade, 6% earned C grade; and 5% earned D grade or below.

Table 2: Students' academic performance

Course	**BSE1D02**			
Final Grade	**Traditional**		**Flipped inquiry**	
	n = 99	**%**	**n = 98**	**%**
A	18	18	45	45
B	63	63	42	42
C	17	17	6	6
D	1	1	4	4
Below D	1	1	1	1

To determine the existence of normal distribution of the dependent variables, Kolmogorov-Smirnova test was performed. Results showed that the data for learning achievement of student undertaking flipped inquiry based learning and student undertaking conventional learning were not normally distributed.

According to the above findings and the non-normality of data, Mann-Whitney test was performed to decide if there are statistically significance differences between the traditional instruction section and the flipped inquiry-based instruction section on the performance of the students. Results in Table 3 showed that the flipped inquiry group was statistically significantly higher than the traditional group including Quiz 1 ($U = 3756$, $p = .006$), Quiz 2 ($U = 2845$, $p = .000$), and Examination ($U = 3570$, $p = .001$). The flipped inquiry group has the highest mean rank as well. It means that there was a difference of academic performance between student undertaking traditional instructional approach and student undertaking flipped inquiry-based approach.

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Table 3
Comparison of traditional instruction and flipped inquiry-based instruction

Assessment	Instruction	N	Mean Rank	Sum of Ranks	Z-Score	P-Value
Quiz 1	Traditional	99	87.94	8706.00	-2.756	.006**
	Flipped inquiry	98	110.17	10797.00		
Quiz 2	Traditional	99	78.74	7795.50	-5.032	.000***
	Flipped inquiry	98	119.46	11707.50		
PowerPoint Presentation	Traditional	99	102.78	10175.00	-1.025	.305
	Flipped inquiry	98	95.18	9328.00		
Report	Traditional	99	93.93	9299.50	-1.303	.193
	Flipped inquiry	98	104.12	10203.50		
Exam	Traditional	99	86.06	8520.00	-3.258	.001**
	Flipped inquiry	98	112.07	10983.00		

Note *p < .05, **p < .01, ***p < .001.

In order to understand how students perceived their own learning experience on flipped inquiry-based classroom, pre-and-post surveys were utilized to assess their perceived learning experience on flipped inquiry-based learning classroom using five-point Likert scales, with response options ranging from 'strongly agree' to 'strongly disagree'. The survey instrument in this study was based on the validated questionnaire used by McNaught et al.(27). This in-class survey was conducted by the research staff in the semester of AY2019/20.

Descriptive statistics was used to analyse students' perceived learning experience in the flipped inquiry based classroom. As shown in Table 4, the findings indicated that the majority of students in flipped inquiry-based format either "strongly agreed", or "agreed" the approach. The approach can enhance their generic competencies including creative thinking (92%), problem solving (85%), and communication skills (relationship between teachers and students) (92%), self-management learning (92%) and cooperative learning (76.9%). When being asked to rate how they perceive the flipped learning approach, the majority of students responded that "teaching staff used a variety of teaching methods" (92.3%) and "tried hard to help them understand the course materials" (100%). "They were given the chance to participate in classes" (100%), and found the explanations provided by the teaching staff useful" (92.3%), including sufficient feedback on the activities and assignments were received so as to ensure they learnt from the work to do (92.3%). Majority of them have a positive outlook towards this pedagogical approach.

Table 4. Perception of the flipped inquiry-based learning of the students of BSE1D02 (Pre-test, n=65) (Post-test, n=13)

Selected items	Average % of students chose 4 (agree) and 5 (strongly agree)	
	Pre-survey	Post-survey
Creative thinking		
• I have been challenged to come up with new ideas	81.5	92.3 (↑10.8)
Self-managed learning		
• I feel that I can take responsibility for my own learning	83.1	92.3 (↑9.2)
Problem solving		
• I have improved my ability to use knowledge to solve	84.4	84.6 (↑0.2)

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Selected items	**Average % of students chose 4 (agree) and 5 (strongly agree)**	
problems in my field of study		
Communication skills		
• I have developed my ability to communicate effectively with others	73.9	91.7 (↑17.8)
Active learning		
• Our teaching staff use a variety of teaching methods	89.3	92.3 (↑3)
• Students are given the chance to participate in classes	86.2	100 (↑13.8)
Teaching for understanding		
• The teaching staff try hard to help us understand the course material	84.6	100 (↑15.4)
• The course design helps students understand the course content	84.6	92.3 (↑7.7)
Feedback to assist learning		
• When I have difficulty with learning materials, I find the explanations provided by the teaching staff useful	81.5	92.3 (↑10.8)
• There is sufficient feedback on activities and assignments to ensure that we learn from the work we do	80	92.3 (↑12.3)
Relationship between teachers and students		
• The communication between teaching staff and students is good	73.8	100 (↑26.2)
• I find teaching staff helpful when asked questions	81.6	92.3 (↑10.7)
Cooperative learning		
• I have found that discussing course material with other students outside classes has helped me to reach a better understanding of the material	75.3	76.9 (↑1.6)

IV. DISCUSSION & CONCLUSION

Flipped classroom is an active learning approach which combines online learning tools and active learning activities in the class in order to increase student engagement and enhance their performance in the course. This active learning approach focuses on both online learning tasks and also collaborative activities rather than traditional based courses in which students were passive learners in the classroom. Though active inquiry based-approach is one of the initiatives that should be promoted in undergraduate courses, there is insufficient evidence of its effectiveness on student academic performance in the engineering courses. In view of this, we conducted flipped classroom learning combined with inquiry based-learning comparing with the traditional-based instruction on students from various disciplinary programmes.

Table 3 shows a statistically significant difference in students' scores of Quiz 1, Quiz 2 and Examination after the intervention of flipped inquiry-based instructional approach,

rejecting the hypothesis. Findings of this study reveals that with the inclusion of online learning materials and inquiry-based learning activities, and its incorporation in the field of lighting science, this pedagogical approach are useful in practice. The results appear to be consistent with study conducted by Alvaez-Bell (8), Ruddick (9), Strayer (28), in which students were well-performed in the active learning section than those were performed in the traditional-based instructional section. Also, a study by Gillispie (29) showed that medical students in the active learning action outperformed than those in the tradition-based instructional section. A research conducted by Andreychik and Martinez (2) revealed that students in an active learning section of the psychology performed better than those performed in a traditional classroom on quizzes.

The present study successfully shows how the flipped inquiry-based instructional approach utilized in the blended learning context could influence student academic performance in a General University Requirement subject. Based on the results from the pre-and-post survey of students' perceived learning experience in the flipped inquiry-based classroom, students in the post-survey of the flipped inquiry course section provided positive feedback on their basic skillsets if we look into the finding of Table 4. All in all, the use of blended learning in teaching has been for many years and generic competencies have been viewed as essential skillsets. The aforementioned blended learning approach provides students with the opportunity to experience different blended instructional approaches, teamwork, and in-class collaborative learning activities. This flipped inquiry-based instructional approach will provide an insight for educators and teaching professionals in terms of the ways of designs, improvements and modifications of the flipped inquiry-based learning in different educational contexts.

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