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Examining the Effect of Flipped Instruction on Students' Learning Approaches in a STEM Learning Context

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This study aimed to better understand the effect that the flipped method of instruction has on students' learning approaches using interactive math lecture videos in a second-year vector calculus course. Three hypotheses were tested to determine if students' perceptions of their level of active engagement, the number of interactive lecture videos they watched, and the frequency of questions they attempted were significant predictors of a deep approach (DA) to learning. Using a 12-item, three-factor Active Engagement Student Perception Survey (AESPS) Instrument and a 20-item, two-factor version of the Study Process Questionnaire (R-SPQ-2F), a statistically significant correlation was found for all three hypotheses.

Introduction

Different Approaches to Flipped Learning in STEM Education

The "flipped" model of instruction is a pedagogical approach that typically takes the traditional lecture, a one-way information dissemination model, outside of the classroom, while activities previously completed outside of class are moved into the classroom (Cortright, Collins, & DiCarlo, 2005). The flipped model of instruction has been applied to different fields within the educational context, with the objective of increasing learner engagement and interaction by changing students' learning styles from passive learning to active learning (Keengwe, 2014; Love, Hodge, Grandgenett, & Swift, 2014).

Over the years, the flipped learning method of instruction has increasingly been applied to science, technology, engineering, and mathematics (STEM) disciplines, with an emphasis on engaging students in higher-order thinking through a flexible, student-centered learning environment. However, STEM classes typically are large, lecture-based, instructor-centered settings that employ a didactic model of teaching. Learning is viewed as the transmission of facts that learners passively receive. Moreover, the prevalence of flipped learning in STEM education necessitates the application of various instructional technologies into the learning context, by means of which learners are able to engage in problem-based learning activities with the use of digital tools (Chong, Wong, Leung, & Ting, 2019; Ting, Lam, & Shroff, 2019). As such, the flipped learning approach has garnered significant attention through the development and application of new instructional technologies (Özpinar, Yenmez, & Gökçe, 2016).

Flipped Learning in Large University Mathematics Classes

Although mathematics is a required course for most science majors, poor student performance has been associated with the lack of a basic conceptual understanding of mathematics and of how students can apply what they have learned to real-world cases. Moreover, as a result of weak mathematics skills, students in a traditional lecture class fail to grasp and apply key mathematical concepts and methods to problem solving. By embedding a flipped learning approach into the classroom context, students are able to engage and interact with their peers, discuss conceptual problems, and develop mathematical reasoning and understanding in a group setting. A study conducted by McGivney-Burelle and Xue (2013) revealed that students in a flipped calculus classroom attained higher grades compared to students in a traditional lecture calculus class, thereby indicating an increased mastery of concepts as well as conceptual understanding, analytical reasoning, and problem solving skills. Hence, prior research has demonstrated that a flipped learning instructional approach increases student performance and achievements in mathematics courses (Clark, 2015; Lai & Hwang, 2016).

Integrating Video-Based Learning With the Flipped Learning Method

Research on video-based learning has increased over the past decade due to new pedagogical practices and approaches to learning, such as the flipped learning and peer assessment methods (Karaca & Ocak, 2017; Santiago Jr., Guo, Eng, Kasley, & Phillips, 2017). Typically, interactive videos viewed outside of class provide learners control over the instructional content and pace by allowing them to engage the material and, subsequently, perform the required actions or make relevant choices. Technology allows the instructor to insert questions into the video comprising a variety of question types for students to answer as they view the video, while simultaneously allowing the instructor to automatically score students' responses. Moreover, students are able to review specific video segments at their own pace.

Effects of the Flipped Classroom Method on Students' Learning Approaches

Prior research studies suggest that the flipped classroom method facilitates deep learning and optimizes learner engagement (Danker, 2015; Le Roux & Nagel, 2018). Learner-centered approaches often yield deep learning outcomes, improved conceptual understanding, and higher achievement in problem-solving activities. Learners typically have their own individual learning approaches that allow them to modify their learning strategies to suit different learning behaviors in particular contexts. Biggs (1987) has identified three distinct elements of learning approaches: (1) the deep approach to learning, which centers on an intrinsic motivation to learn and engagement with a specific area of knowledge; (2) the surface learning approach, which is centered on passive, rote memorization and the acquisition of sufficient knowledge to complete the task; and (3) the achievement learning approach, which focuses on performance strategies with added emphasis on the need for achievement. Moreover, each approach comprises of the following two elements: (1) learning motives and (2) learning strategies to further delineate the learners' learning behaviors: deep motive, deep strategy, surface motive, surface strategy, achievement motive, and achievement strategy (see Table 1).

Although research studies have yielded important new findings on the flipped model of instruction in large tertiary classes, the focus has been on in-class approaches, such as peer instruction, collaborative learning, and problem-based pedagogy. Although these studies demonstrated an increase in learner achievement using a flipped learning approach, few

Table 1
Learning Approaches With Corresponding Subscales and Description (Biggs, 1987)

Scale	*Subscale*	*Description*
Deep Approach	Deep Motive	Learners' intrinsic interests in learning or evoking satisfaction and appeal through engagement of the tasks or activities (i.e., the degree to which the task or activity engages the attention of the learner)
	Deep Strategy	Meaningful strategies that maximize learning (i.e., integrating knowledge with evidence-based practice, case-based reasoning, drawing inferences, relating facts to past experiences, etc.)
Surface Approach	Surface Motive	Characterized by extrinsically motivated behavior in which the primary aim of the learner is to meet the minimal academic requirements for assessment by exerting the least effort
	Surface Strategy	Characterized by rote learning of material, memorization of facts and content-based knowledge (i.e., recalling and reproducing facts, content memorization and repetitive practices, etc.)
Achievement Approach	Achievement Motive	Characterized by an intrinsic desire and innate need to produce desired outcomes, attaining a high standard of success, and mastering complex tasks and challenges
	Achievement Strategy	Characterized by purposeful actions and effort to achieve personal learning goals and master determined competencies

studies were directly related to a mathematics context. Furthermore, only a limited number of these studies have attempted to investigate the impact and effect of flipped learning in large mathematics classes via the use of such instructional technologies. The relevance of this study lies in investigating whether careful and deliberate pedagogical planning and design around technology-enriched learning contexts for flipped instruction can enhance students' deep learning strategies and higher-order cognitive skills, including improved learning, engagement, and achievement.

Research Objective and Hypotheses

The objective of this study is to examine the effect that flipped instruction has on students' learning approaches using interactive math videos in a second-year mathematics course. Consistent with the literature discussed above, this study proposed to test the following hypotheses:

> H_1: Students' perceptions of their level of active engagement using interactive math videos is a significant predictor of a deep approach (DA) to learning.
>
> H_2: The number of interactive videos watched and a deep approach (DA) to learning are positively correlated.
>
> H_3: The frequency of questions attempted in the interactive videos and a deep approach (DA) to learning are positively correlated.

Research Method

Research Setting and Activity

A purposive sampling methodology was considered methodologically appropriate for this type of exploratory research. The subject pool comprised a total of 91 (N = 91) undergraduate students from the faculty of Engineering enrolled in a second-year "Mathematics II" course offered at The Hong Kong Polytechnic University. The 13-week course included two hours of lecture and one hour of tutorial per week. The selection of this course for the study was determined by two criteria. First, the course provided a rich opportunity for embedding a flipped learning method of instruction into a classroom mathematics courses. Second, a flipped learning method of instruction in the form of interactive videos was specifically structured into the design and organization of the course.

Technology

HP5 (HTML5 package), an open-source online authoring tool for creating rich interactive e-learning content such as quiz-embedded interactive videos, was used in this study. This software provides for varied self-contained HTML5 interactive content and a wide range of customizable options that can be used to enhance student interaction and engagement with the course material. Moreover, the quiz-embedded video feeds allow the instructor to add multiple-choice, fill-in-the-blank, short-answer, and various other interactive formats to the videos. Finally, the authoring tool, besides extending the capabilities of the quizzes in a more interactive way, also allows for performance tracking and instant feedback of students by testing their understanding of fundamental mathematical concepts and applications. Screen captures from the HP5 interactive videos on the topic of solving non-homogeneous partial differential equations with links to drag-and-drop and multiple-choice question formats are shown in Figures 1 and 2. The first interactive link (see Figure 1) queries students on the topic of linear ordinary differential equations for which they solve the equations for the time variable function after separation of variables, and the second interactive link (see Figure 2) presents a multiple-choice question with reference to the eigenfunction of expansion in the space variable.

Instructional Method

Unlike conventional video recordings, interactive videos allow students to take control of the learning process by checking their knowledge with multiple-choice, fill-in-the-blank, and short-answer types of interactions with immediate feedback. Given that the course learning outcomes and content were *a priori* defined by the instructor, a combination of three 14-minute interactive video lectures on the method of eigenfunction expansion and substitution were tailor-made for this purpose. The interactive components were designed using HP5 and comprised multiple-choice, true-false, and short-answer questions.

The Instruments

Two instruments were used in this study to assess the effect of flipped classroom instruction on students' learning approaches. The data were collected using a self-completed questionnaire based on two instruments, yielding 91 usable samples. The first instrument, the Active Engagement Student Perception Survey (AESPS), was developed to assess students' perceptions of the flipped classroom model using interactive videos. The

Figure 1
HP5 Video Screen Captures Showing Interactive Content Such as Drag-and-Drop Format

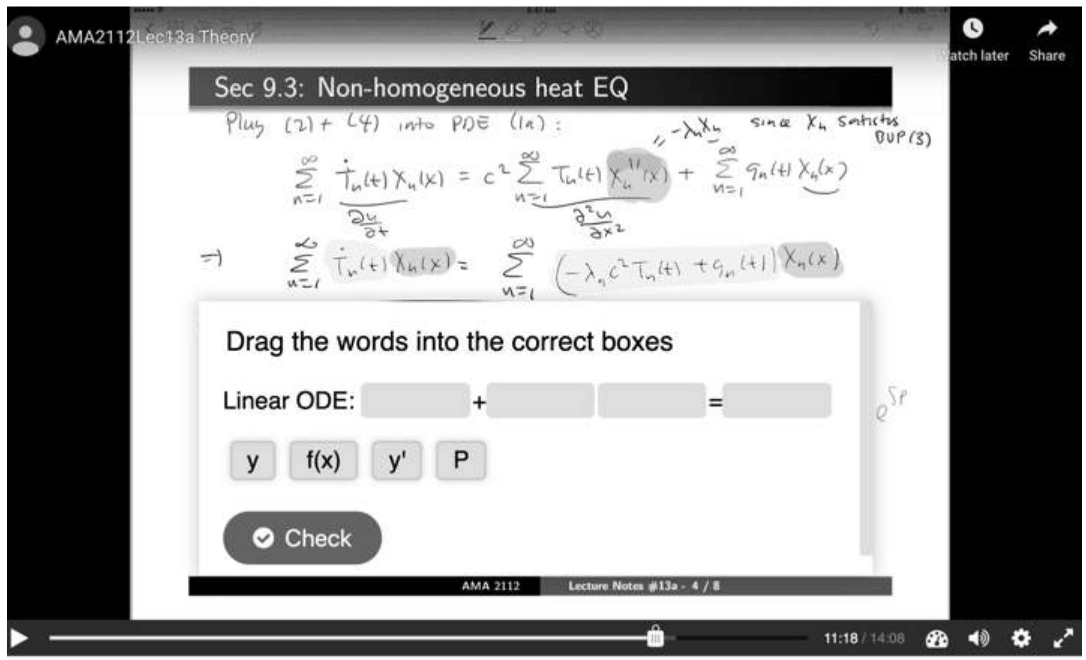
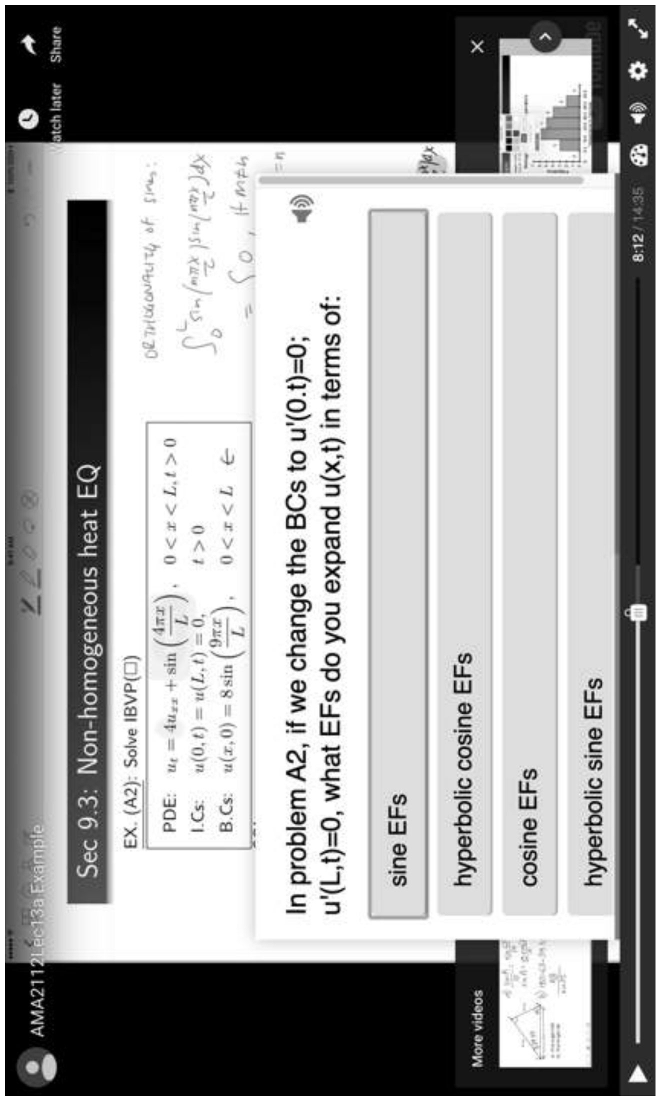


Figure 2
HP5 Video Screen Captures Showing Interactive Content Such as Multiple-Choice Question Format



9-item questionnaire (see Table 2) measures the following three constructs of students' perceptions on the flipped classroom teaching format and the use of interactive videos: Learning Context (LC), Interactive Engagement (IE), and Affective Expression (AE). Learning Context (LC) refers to the degree to which the learning situation facilitates the learning process using the flipped classroom approach. Interactive Engagement (IE) refers to the degree to which the activities in the flipped classroom approach encourage learners to engage through an open exchange of ideas and interactions. Affective Expression (AE) refers to the degree to which learners appropriate their motivational orientations and dispositions toward the flipped classroom approach. Each construct included three question items, and each item was developed using a 5-point Likert-type scale, with values ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

Results of the Cronbach's alpha coefficients were .84 for the Learning Context (LC) scale, .89 for the Interactive Engagement (IE) scale, and .82 for the Affective Expression (AE) scale. These measures that the scales were not only reliable, but also valid measures for the constructs under study. To guarantee validation and reliability, the survey instrument was developed using a process of conceptual construct validation and reliability (Moore & Benbasat, 1991).

The second instrument, the Study Process Questionnaire (SPQ), developed by Biggs (1987), was utilized specifically to determine students' approaches to learning. Moreover, the SPQ, which has been extensively utilized in research studies to examine learning behaviors in a higher education context, measures two main aspects associated with learning: a deep learning approach and a surface learning approach. Numerous studies have used various forms of the instrument in different educational contexts (Fryer, Ginns, Walker, & Nakao, 2012; Sharma, Stewart, Wilson, & Gokalp, 2013). In this study, we used the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) developed by Biggs, Kember, and Leung (2001). The modified version comprised 20 items characterized by two main scales of learning approaches, Deep Approach (DA) and Surface Approach (SA), with four sub-scales: Deep Motive (DM), Deep Strategy (DS), Surface Motive (SM), and Surface Strategy (SS) (see Table 3). Each subscale comprised five items, and a 5-point Likert scale was used to score the responses on each item, with values ranging from 1 (*never or only rarely true for me*) to 5 (*always or almost always true for me*).

The Main Empirical Study

For this study a non-probability, purposive sampling technique was

Table 2
Scale and Items of the Active Engagement Student Perception Survey (AESPS)

Scale	*Item*
Learning Context (LC)	Q1. The flipped classroom teaching style gave me more flexibility in learning the course content.
	Q4. I prefer the flipped classroom teaching style because it gave me more time to practice problem solving than the traditional lecturing style.
	Q7. I prefer the use of interactive videos.
Interactive Engagement (IE)	Q2. The use of interactive videos enabled me to collaborate with other students.
	Q5. I prefer the flipped classroom teaching style because it gave me more opportunities to communicate with other students than the traditional lecturing style.
	Q8. The interactive videos helped me to express my ideas or and opinions in class.
Affective Expression (AE)	Q3. I liked watching the lecture materials on video.
	Q6. I prefer the new lecturing style.
	Q9. I was more motivated to learn how to solve problems in the flipped classroom than in a traditional classroom.

Table 3

Scale and Items of the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F)

Scale	*Subscale*		*Item*
Deep Approach (DA)	Deep Motive (DM)	Q1.	I find that at times studying gives me a feeling of deep personal satisfaction.
		Q5.	I feel that virtually any topic can be highly interesting once I get into it.
		Q9.	I find that studying academic topics can at times be as exciting as a good novel or movie.
		Q13.	I work hard at my studies because I find the material interesting.
		Q17.	I attend most classes with questions in mind that I want answered.
	Deep Strategy (DS)	Q2.	I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied.
		Q6.	I find most new topics interesting and often spend extra time trying to obtain more information about them.
		Q10.	I test myself on important topics until I understand them completely.
		Q14.	I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.
		Q18.	I make a point of looking at most of the suggested readings that go with the lectures.

Table 3 (*continued*)
Scale and Items of the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F)

Scale	*Subscale*		*Item*
Surface Approach (SA)	Surface Motive (SM)	Q3.	My aim is to pass the course while doing as little work as possible.
		Q7.	I do not find my course very interesting, so I keep my work to the minimum.
		Q11.	I find I can get by in most assessments by memorizing key sections rather than trying to understand them.
		Q15.	I find it is not helpful to study topics in depth. It confuses me and wastes time, when all you need is a passing acquaintance with topics.
		Q19.	I see no point in learning material which is not likely to be in the examination.
	Surface Strategy (SS)	Q4.	I only study seriously what is given out in class or in the course outlines.
		Q8.	I learn some things by rote, going over and over them until I know them by heart even if I do not understand them.
		Q12.	I generally restrict my study to what is specifically set, as I think it is unnecessary to do anything extra.
		Q16.	I believe that lecturers should not expect students to spend significant amounts of time studying material everyone knows for which they will not be examined.
		Q20.	I find the best way to pass examinations is to try to remember answers to likely questions.

employed to select a sample size of 91 ($N = 91$) respondents. Moreover, a purposive sampling method is typically employed when the sample selected is readily available in the particular time frame of the study and when the experimental design includes random assignment to the treatment groups. A power test was performed to determine the sample size requirements. With a sample size of 91, a significance level of 0.05, and a test power of 0.95, the study had a power of 0.852 to yield a statistically significant result (Cohen, 1977). Hence, students taking the course (Mathematics II) represented a sample size adequate for statistical testing and analysis (Cochran & William, 1977).

From weeks 1-12, 91 students participated in the traditional classroom lecture format facilitated by the instructor. In week 13 the same students participated in the flipped learning approach using interactive video lectures, facilitated by the same instructor but with the difference being the teaching method using the flipped learning approach supported by interactive video technology (see Table 4). This study utilized a one-group before-after quasi-experimental design (Cook, Campbell, & Day, 1979); this design was employed for the following reasons. First, while it would be ideal to use a conventional experimental design and carry out random assignment to treatment and control groups, the lack of availability of two classes of students taking the same course necessitated a one-group before-after quasi-experimental design for both practical and ethical reasons. Second, ideally, if the flipped learning approach could be implemented around the middle of the term, it would allow a longer exposure for students to experience this new approach. That being said, the instructor participating in the study was keen to ensure that the materials would be covered using the current approach. Given the voluntary nature of the study, study, permission for a 13-week before-after intervention design using a flipped learning approach was granted. Moreover, while it is acknowledged there could be a novelty effect from using a flipped learning approach for one week, it would also be difficult to ascertain the wear out effect should a longer period be used. Hence, for the purpose of this exploratory study, the existence of such a novelty effect is accepted as a limitation.

At the end of the flipped learning intervention in week 13, the Active Engagement Student Perception Survey (AESPS) and the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) were administered to students to complete. The two instruments served an important role in assessing the effect that flipped instruction had on students' learning approaches (that is, the deep learning approach and the surface learning approach).

Table 4
Type of Activity, Sample Size, and Duration

Type of Activity	*Sample Size*	*Duration of Exercise*	*Facilitator*
Traditional instructor-led lecture	91	Weeks 1-12	Instructor
Flipped learning approach using interactive video lectures	91	Week 13	Instructor

Results and Analyses

Statistical Analyses Performed

Frequency distributions were calculated for all participants in the study. Table 5 shows the number of interactive videos watched in relation to the gender of the participants (81 males and 10 females). Before testing the relationship coefficients of each of the three hypotheses, we tested a number of correlations using data from the study. We tested the relationship between the number of interactive videos watched and the frequency of questions attempted on the interactive videos. Using a Chi-Square test ($p < 0.001$), we found the number of interactive videos students watched and the frequency of questions they attempted on the interactive videos were positively associated. We found that those students who regularly attempted the interactive questions had watched all three videos (see Table 6).

Next, we tested the relationship between the number of interactive videos watched and students' willingness to express ideas or opinions using the interactive videos. Using a Chi-Square test ($p < 0.001$), we found that the number of interactive videos watched and students' willingness to express ideas or opinions using the interactive videos were positively correlated. Hence, the group of students who watched the three interactive videos appeared to be more willing to express their ideas or opinions voluntarily (see Table 7).

Furthermore, we tested the relationship between the number of interactive videos watched and the total time students spent on the subject matter of the course compared to their other courses. Using a Chi-Square

Table 5
Viewing of Videos by Students

		Total
How many interactive videos did you watch out of the total of 3?	0	18
	1	27
	2	9
	3	37
Total		91

test (p <0.005), we found that the number of interactive videos watched and the duration of time the students spent on the subject matter of the course compared to other courses were positively related. The students who did not watch any interactive videos spent less time on this course than on their other courses (see Table 8).

Finally, we performed a t test to examine the relationship between the number of interactive videos watched and their choices for Q4, Q5, Q6, and Q7 of the Active Engagement Student Perception Survey (AESPS). The results, illustrated in Table 9, show that only preference toward the usage of interactive videos (Q7) and the number of videos viewed were found to be significantly related (p = .018).

Hypotheses Testing

In this section, we test each of the hypotheses presented in the previous section using multiple linear regression analysis. To test each of the hypotheses, Pearson's correlation was performed from the AESPS and R-SPQ-2F scores. Statistical significance was set at p <0.05 for all hypothesis tests, while partial support was acknowledged at significance levels between 0.05 and 0.10.

H_1: Students' perceptions of their level of active engagement using interactive math videos is a significant predictor of a deep approach (DA) to learning.

For hypothesis 1, a correlational analysis was performed between the self-reported levels of active engagement with the interactive lecture videos and learning approach. Using Pearson's correlation, we found that overall, students' perceptions of their level of active engagement was positively (**p <0.05; *p <0.10) related to a deep approach (DA) to

Table 6
Results of Chi-Square Test (*$p < 0.001$)

		How often did you attempt the questions in the interactive videos when you watched them?				
		Never	**Some of the Time**	**Most of the Time**	**All the Time**	**Total**
How many interactive videos did you watch out of the total of 3?	0	14 (77.8%)	3 (16.7%)	1 (5.6%)	0 (0.0%)	18
	1	4 (14.8%)	20 (74.1%)	3 (11.1%)	0 (0.0%)	27
	2	1 (11.1%)	6 (66.7%)	2 (22.2%)	0 (0.0%)	9
	3	1 (2.7%)	13 (35.1%)	12 (32.4%)	11 (29.7%)	37
Total		20 (22.0%)	42 (46.2%)	1 (19.8%)	11 (12.1%)	91

Table 7
Results of Chi-Square Test (*p <0.001)

		The interactive videos helped me to express my ideas or opinions.			
		No	**Yes, Picked by the Instructor**	**Yes, Picked Voluntarily**	**Total**
How many interactive videos did you watch out of the total of 3?	0	12 (85.7%)	1 (7.1%)	1 (7.1%)	14
	1	15 (57.6%)	6 (23.1%)	5 (19.2%)	26 (30.6%)
	2	6 (75%)	2 (25%)	0 (0.0%)	8 (9.4%)
	3	11 (29.7%)	7 (18.9%)	19 (51.3%)	37 (3.5%)
Total		44 (51.8%)	16 (18.8%)	25 (29.4%)	85 (100.0%)

Table 8
Results of Chi-Square Test (*p <0.005)

		How much time did you spend on the subject matter of this course compared to other courses?			
		Less Than Other Courses	**As Much as Other Courses**	**More Than Other Courses**	**Total**
How many interactive videos did you watch out of the total of 3?	0	6 (40%)	4 (26.7%)	5 (33.3%)	15
	1	3 (11.1%)	12 (44.4%)	12 (44.4%)	27
	2	2 (22.2%)	0 (0.0%)	7 (77.7%)	9
	3	1 (2.7%)	18 (48.6%)	18 (48.6%)	37
Total		12 (13.6%)	34 (38.6%)	42 (47.7%)	88

Table 9
***t* Test Results (**p* <0.5)**

One-Sample Statistics (Test Value = 0.5)

	N	**Mean**	*SD*	**Std. Error Mean**	t	df	Sig. (2-tailed)
Q4. I prefer the flipped classroom teaching style because it gave me more time to practice problem solving than the traditional lecturing style.	88	.56	.500	.053	1.067	87	.289
Q5. I prefer the flipped classroom teaching style because it gave me more opportunities to communicate with other students than the traditional lecturing style.	88	.55	.501	.053	.851	87	.397
Q6. I prefer the new lecturing style.	88	.52	.502	.054	.424	87	.672
Q7. I prefer the use of interactive videos.	88	.63	.487	.052	2.408	87	**.018***

learning (see Table 10). Moreover, we also found a positive relationship between students' perceptions of their level of active engagement and a deep motive (DM) and deep strategy (DS) approach to learning.

H_2: The number of interactive videos watched and a deep approach (DA) to learning are positively correlated.

For hypothesis 2, a correlational analysis was performed between the number of interactive videos watched and learning approach. Using Pearson's correlation, we found a statistically significant correlation ($^{**}p < 0.05$; $^{*}p < 0.10$) between the number of interactive videos watched and a deep approach (DA) to learning. Moreover, we also found a statistically significant correlation between the number of interactive videos watched and a deep motive (DM) and deep strategy (DS) approach to learning (see Table 11).

H_3: The frequency of questions attempted in the interactive videos and a deep approach (DA) to learning are positively correlated.

For hypothesis 3, a correlational analysis was performed between the frequency of questions attempted in the interactive videos and learning approach. Using Pearson's correlation, we found a statistically significant correlation ($^{**}p < 0.05$; $^{*}p < 0.10$) between the frequency of questions attempted and a deep approach (DA) to learning. Moreover, we also found a statistically significant correlation between the frequency of questions attempted in the interactive videos and a deep motive (DM) and deep strategy (DS) approach to learning (see Table 12).

Discussion, Limitations and Future Directions

This study employed a correlational design to test each of the hypotheses developed. For hypothesis 1, a correlational analysis was conducted between the self-reported levels of active engagement and learning approaches using interactive lecture videos. For hypothesis 2, a correlational analysis was performed to examine the relationship between the number of interactive videos watched and learning approach. For hypothesis 3, a correlational analysis was carried out to examine the frequency of questions attempted in the interactive videos and learning approach. To summarize, all three hypotheses were supported by the data to varying degrees and at statistically significant levels.

With reference to hypothesis 1, the data indicated that students' perceptions of their level of active engagement was positively related ($^{**}p < 0.05$; $^{*}p < 0.10$) to a deep approach (DA) to learning. A positive relation-

Table 10
Pearson's Correlation Results (p <0.05; *p <0.10)**

Scale	*Items*	*Deep Approach (DA)*	*Deep Motive (DM)*	*Deep Strategy (DS)*	*Surface Approach (SA)*	*Surface Motive (SM)*	*Surface Strategy (SS)*
Learning Context (LC)	Q1. The flipped classroom teaching style gave me more flexibility in learning the course content.	.126*	.181*	.064	-.024	-.065	.025
	Q4. I prefer the flipped classroom teaching style because it gave me more time to practice problem solving than the traditional lecturing style.	.166*	.173*	.150*	-0.14	-.023	-.003
	Q7. I prefer the use of interactive videos.	.124*	.173*	.067	-.041	-088	.015

Table 10 (*continued*)
Pearson's Correlation Results (p <0.05; *p <0.10)**

Scale	*Items*	*Deep Approach (DA)*	*Deep Motive (DM)*	*Deep Strategy (DS)*	*Surface Approach (SA)*	*Surface Motive (SM)*	*Surface Strategy (SS)*
Interactive Engagement (IE)	Q2. The use of interactive videos enabled me to collaborate with other students.	.190*	.176*	.194*	-.101	-.162	-.026
	Q5. I prefer the flipped classroom teaching style because it gave me more opportunities to communicate with other students than the traditional lecturing style.	.029*	.067*	-.012*	.089	.058	.117
	Q8. The interactive videos helped me to express my ideas or opinions in class.	.394**	.415**	.351**	-.229	-.234	-.207
Affective Expression (AE)	Q3. I liked watching the lecture materials on video.	.204**	.209**	.189*	.017	-.046	.087
	Q6. I prefer the new lecturing style.	.183*	.208**	.148*	-073	-.077	-0.64
	Q9. I was more motivated to learn how to solve problems in the flipped classroom than in a traditional classroom.	.267**	.321**	.197*	-.133	-.101	-.160

Table 11
Pearson's Correlation Results (p <0.05; *p <0.10)**

Items	*Deep Approach*	*Deep Motive*	*Deep Strategy*	*Surface Approach*	*Surface Motive*	*Surface Strategy*
How many interactive videos did you watch?	.405**	.392**	.398**	-.146	-.161	-.117

Table 12
Pearson's Correlation Results (p <0.05; *p <0.10)**

Items	*Deep Approach*	*Deep Motive*	*Deep Strategy*	*Surface Approach*	*Surface Motive*	*Surface Strategy*
How often did you attempt the questions in the interactive videos when you watched them?	.382**	.367**	.377**	-.187	-.216	-.140

ship was also found between students' perceptions of their level of active engagement and a deep motive (DM) and deep strategy approach (DS) to learning at the 0.10 and 0.05 levels of significance, respectively. This indicates that a flipped classroom approach using interactive lecture videos is more engaging than the traditional classroom and consistent with a deep approach to learning. This also validates the fact that the learning context (that is, the degree to which the learning situation facilitates the learning process using the flipped classroom approach), the degree of engagement (that is, the degree to which the activities in the flipped classroom approach encourage learners to engage through an open exchange of ideas and interactions), and the degree of affective expression (that is, the degree to which learners appropriate their motivational orientations and dispositions toward the flipped classroom approach) each encourage and support a deep approach to learning. Moreover, this result may indicate a higher student preference toward the use of interactive videos, a willingness to express ideas or opinions, and the perception that the flipped classroom approach is more engaging and offers more opportunities to communicate with each other.

With reference to hypothesis 2, the data indicated a statistically significant correlation ($^{**}p < 0.05$; $^{*}p < 0.10$) between the number of interactive videos watched and a deep approach (DA) to learning. A positive relationship was also found between the number of interactive videos watched and a deep motive (DM) and deep strategy (DS) approach to learning at the 0.10 and 0.05 levels of significance, respectively. Finally, with reference to hypothesis 3, the data indicated a statistically significant correlation between the frequency of questions attempted in the interactive videos and a deep motive (DM) and deep strategy (DS) approach to learning at the 0.10 and 0.05 levels of significance, respectively.

As noted above, a correlational design was used in this study to test each of the hypotheses. Because a correlational design was used, one limitation specific to this study is the inability to determine causality between variables (Howell, 1997). Hence, a limitation pertaining to this study is the lack of a causal model that explores, for example, mediating variables or causal pathways between factors. Also, as mentioned above, an important limitation is the use of a one-group before-after quasi-experimental design as opposed to a design with a treatment and control group comparison and the use of a flipped learning approach in the 13th week, which can be acknowledged as a practical limitation of this study.

Another study limitation is that the data collected are self-reported measures that represent subjects' perceptions. This poses a potential for response bias, which may subsequently influence the findings and interpretation of results. A final limitation of this study is that the generalizability of the findings is limited due to the relatively small sample size and the exploratory nature of the study. Thus, because the data were collected from local Hong Kong students, caution needs to be exercised when generalizing the results to other cultures, contexts, and populations.

Finally, future studies could examine whether students' perceptions of their level of active engagement when using interactive videos is a significant predictor of their level of academic performance. Future research could include studies on the correlation between the flipped learning method using interactive videos and student success as measured by final course grades. Other avenues for future research could include qualitative studies that explore students' learning approaches and assess whether students' engagement and motivation significantly increase after using a flipped learning method with interactive videos when compared to a traditional classroom. Finally, differing cultural perceptions toward the open exchange of ideas and interactions between Asian versus Western students could be examined.

Conclusions

This study is a significant first step toward examining the effect of flipped classroom instruction using interactive videos on students' learning approaches. The findings provide sufficient preliminary data to support the assertion that the students generally perceived the flipped learning method as beneficial to their learning and understanding of mathematical concepts. The significance of this study is three-fold: First, the study uses two instruments, one that we developed and a second established instrument, to provide quantitative assessments with statistical significance. This provides a basis to establish testing protocols for this type of study and benchmark examples for future such research studies. Second, while previous studies have tended to focus on Western student populations/contexts, this study provides empirical data in the context of Asia, using Hong Kong as an example. Finally, the results presented here are valuable and significant in assisting both researchers and educators to better capture the complex and multifaceted nature of the flipped learning method, while concurrently serving as a catalyst for future studies on flipped classroom instruction and approaches.

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