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Redesigning flipped classrooms: a learning model and its effects on student perceptions

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Abstract
To maximize learners' performance promotion in flipped classroom, this research redesigns a flipped classroom with four integrated practices: speed response questions, teacher face-to-face counselling, independent practices and team projects. Using questionnaire ($N = 66$) and interview ($N = 20$) data, the model is tested in two undergraduate introductory computer science courses in China, where students are typically reticent to engage in active learning in class. Data from a bipolar scale revealed that the majority of students regarded the new model as more student-centred. Using a learning capability matrix, this research deeply explored the benefits by learning dimension. The interviews provided details on the students' positive attitudes to the model and one area of concern. This research may be helpful for the scholars who are redesigning their flipped classrooms or developing new in-class activities.

Keywords Flipped classroom · Learning model · Learning capability matrix (LCM) · Student-centred learning · Student perception

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Introduction

Little has changed in the way that education is structured and delivered, and in-class lectures have continued to prevail in most classrooms for much of the last century (McLaughlin et al. 2014). However, the pedagogical model of flipped classrooms is now growing and used in many contexts (Khan 2012; Lage et al. 2000). A flipped classroom (also known as reverse or inverse classroom) is a form of blended and student-centred learning. The essence of the flipped classroom is moving the 'delivery' of material outside of formal class time (by extensive notes, video-recorded lectures and other appropriate means) and using formal class time for students to undertake collaborative and interactive activities relevant to that material (Butt 2014). Thus, students can actively engage in personalized knowledge construction through extensive interactions with peers and teachers (Kong 2014; Missildine et al. 2013). In the flipped classroom, the educators post pre-recorded lectures and readings online or provide access to other online leaning resources for students to learn on their own (Alvarez 2012; Moravec et al. 2010). Face-to-face class time is then dedicated to practice assignments, targeted remedial help or activities designed to promote higher thinking skills and abilities such as problem solving, discussions, debates and cooperation (Bergmann et al. 2011; Davies et al. 2013; Foertsch et al. 2002; Fulton 2012; Hughes 2012; Lage et al. 2000; Talbert 2012; Zappe et al. 2009). Students already have a basic understanding of course content before attending the classes, forming a basis for in class activities (McLaughlin et al. 2014). With more class time freed up, teachers in the flipped classrooms are able to make meaningful contact with students for observation, guidance, comment and assistance (Flumerfelt and Green 2013; Fulton 2012). Flipped classrooms make it possible to create a learning environment that is more student-centred than teacher-centred (Kim et al. 2014). However, some research points out weaknesses in flipped classrooms, e.g. it is time-consuming for teachers and sometimes is learner inappropriate (Mason et al. 2013). Further, given the newness and diversity of approaches within flipped classrooms, it is likely that variations in the particular classroom activities have led to the different mixed results. Thus, detailed investigations into the components of flipped classroom model are of great importance.

There are a number of documented benefits of flipped classrooms (Davies et al. 2013; Foertsch et al. 2002; Fulton 2012; Gannod et al. 2008; Herreid and Schiller 2013; Mason et al. 2013). Learners benefit from the outside-of-class events because they can allocate their time and pace their online learning to match their individual levels of comprehension. Teachers, in turn, are able to dedicate more in-class time to monitoring student performance and providing adaptive and instant feedback to an individual or group of students (Fulton 2012; Herreid and Schiller 2013; Hughes 2012). However, despite over 15 years of flipped classroom implementation, there are few design principles especially relative to the great diversity of implementing disciplinary contexts (Kim et al. 2014).

Researchers have developed many flipped classroom models, such as the flipped mastery model (Bergmann and Sams 2012), the flipped classroom model (Gerstein 2012) and the FLIPPED model (Chen et al. 2014). Few studies have examined components of these models, and they are primarily qualitative analyses (Bergmann and Sams 2012; Bergmann et al. 2011; McLaughlin et al. 2014) or only describing general characteristics of the flipped classroom (Bergmann et al. 2011). More investigation is required, especially from the perspectives of learning outcomes and learners' satisfaction.

With regard to learning outcomes, flipped classroom has been argued to enhance learners' cooperation, innovation and task orientation (Strayer 2012), learners' comprehensive abilities such as information literacy and critical thinking skills (Kong 2014) and overall learning outcomes (Missildine et al. 2013). Moreover, flipped classrooms have been found to improve student performance on traditional quizzes and exam problems (Mason et al. 2013), whereas others have found no significant difference in learning outcomes between flipped classrooms and traditional classrooms (Davies et al. 2013; Strayer 2012). This variation in outcomes raises the question of whether different kinds of learning outcomes result from different kinds of learning activities in a flipped classroom. In addition, gender differences in flipped classrooms attracts concerns because some studies found that female students had better learning performance, learning experience and examination scores than male students in the flipped classrooms (Bergmann and Sams 2012; González-Gómez et al. 2012; Gross et al. 2015).

With respect to learner perception, researchers agree that most students hold a positive view towards flipped classrooms and prefer flipped classrooms to traditional classrooms (Bates and Galloway 2012; Bishop and Verleger 2013; Butt 2014). Student satisfaction (Martínez-Caro and Campuzano-Bolarín 2011), motivation and cognitive load (Abeysekera and Dawson 2015) are all enhanced. Nevertheless, some researchers claim that learners are less satisfied with flipped classrooms (Jaster 2013; Strayer 2012). This variation in outcomes again suggests that variations in details of flipped classrooms may be important.

Overall, there is no consensus on how to assess learning performance in flipped classrooms, and it is unexplored how different learning activities in flipped classrooms influence learning outcomes and learners' satisfaction. Consequently, this study tests several different types of flipped classroom activities, with the goals of (a) developing measures to examine different benefits of flipped activities and (b) exploring the ways in which benefits vary by learning dimension. This approach will provide a rationale for designers in the future to select groups of activities to maximize overall learning performance.

The rest of this paper is organized as follows. "Tested flipped activities" section describes the learning model, which involves a range of flipped activities. "Methods" section presents the research methods, including the course context, the participants, implementation details of the model and three assessment measures. In "Results" section, we evaluate the model's effects on student perceptions based on three measures. "Conclusions and future directions" section summarizes this study and provides future research directions.

Tested flipped activities

A redesigned flipped classroom

Information technology plays a vital role in the transition from traditional teaching to flipped classroom teaching, but not every element needs to involve technology. To assess student knowledge, motivate active participation and address areas of weakness, this research developed a model of flipped instruction within four main stages: pre-class activities, interactions in the classroom (or in-class activities), post-class activities and evaluation of learning by the teacher, as depicted in Fig. 1.

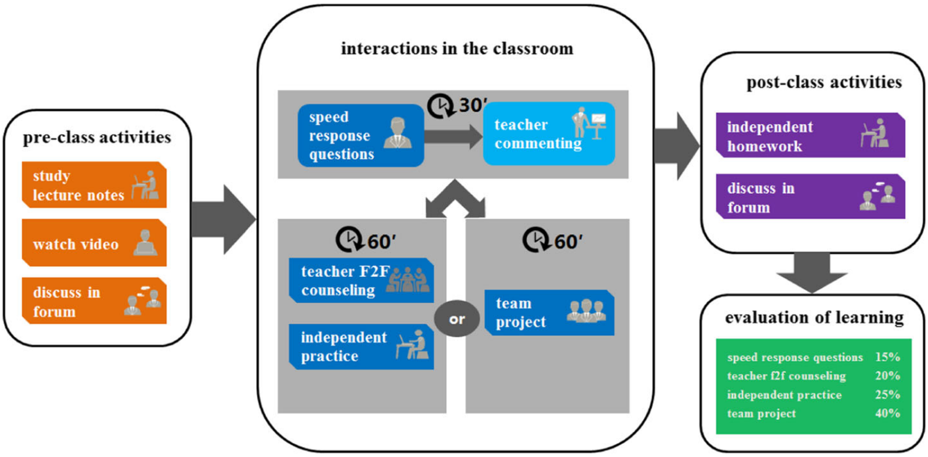

Fig. 1 The learning activities across the four stages of learning in and out of class

As is commonly the case, only a few students participated in the discussion forum at pre-class or post-class stages. Therefore, this research concentrates on two pre-class activities, *study lecture notes* (SLN) and *watch video* (WV), and the four types of in-class activities. In addition, since teacher commenting is closely connected to *speed response questions*, this research regards the two activities as one.

Four activities of the learning model

Interactive activities in class are carefully selected based on the concept of student-centred teaching (Kember 1997; O'Neill and McMahon 2005). There are four critical in-class activities in the learning model (QCPP): *speed response questions* (SRQ), *teacher F2F counselling* (TFC), *independent practice* (IP), and *team projects* (TP). Even though some students may communicate with each other in SRQ or IP activities, these two are more like personal activities. Since TFC was focused on the project work, both TFC and TP belong to group activities.

Activity 1: speed response questions SRQ is used as a warm-up activity to help teachers learn how well students previewed the lecture content, as well as providing an additional incentive to preview the lecture content. In this part, teachers show questions and corresponding point values using PowerPoint slides. Students work on each question on their own and then raise their hands when they have the answer. The teacher selects students in order of hand raising. Correct answers count as points towards the final course grade. If a wrong answer is offered, the teacher will select the next student. The teacher will give the right answer (or a model solution) if there are no volunteers any more or many students appear to be following the wrong path.

Asking questions in class has been used to trigger thinking for a long time (Aschner 1961), but the literature on flipped classrooms has placed little emphasis on it. Furthermore, although student response systems equipped with electronic handheld devices (or clickers) are now becoming more widely used in classroom (Fies and Marshall 2006; Lantz 2010), this research implements a more traditional mode of having students' raising hands. The reasons includes the following: (a) The majority of questions are constructed response, not multiple choice, to enable tests of deeper thinking and application rather than only memorization and (b) the active atmosphere is stronger when student responses are speeded and selected based on order, and current response systems are not compatible with this use case.

Activity 2: teacher F2F counselling This research offers four ways for teachers to answer student questions in this flipped classroom: (a) online discussion during self-study pre-class, (b) teachers answering in-class questions that are frequently asked online, (c) one-on-one response to questions in-class and (d) online response to questions post-class. Most of the time, these methods ensure at most short delays in responses to questions that occur over the course of learning. However, to improve students' learning in the difficult team projects, this research design a TFC activity. Team leaders first collect questions in their team pre-class or in-class. The teacher then has face-to-face discussion with team members about those questions. To minimize interference on other students in the classroom, the TFC activities are conducted in a corner of the classroom.

The TFC is like a team meeting, which is different from the teacher counselling techniques discussed in the literature. For example, in the work of Lage et al. (2000), if a student had not understood something in an assigned reading or video, a short lecture was given. However, the lecture was not for a specific team, but rather for all students in the classroom.

Activity 3: independent practice IP is completed by students personally either in-class or post-class. In the tested courses, these involve basic programming tasks. This research includes IP into the flipped classrooms rather than implementing them as is traditionally done in homework so that students may ask the teacher, teaching assistant and classmates for help when they have difficulties. They can work on the problems together and get a solution as soon as possible. TFC and IP are conducted simultaneously in this flipped classroom model, i.e. while one team is having TFC with the teacher, the rest of the class are practicing independently, which maximizes student learning time (i.e. avoids having students doing no work while waiting for a teacher to answer project questions).

Many studies have documented the advantages of cooperative learning (Demetry 2010), and the goal is to include it to enhance students' capabilities in independent thinking and working. Since, in the design, IP is conducted in parallel with TFC, it provides students opportunities to discuss and communicate with classmates in classroom, but the IP activity does not seem a waste of time because TFC can be done if all practice activities are completed.

Activity 4: team projects Teachers assign multiple team-based computer programming projects to be completed in class. Compared with IP, TP is more time-consuming per completed task, but also invokes different achievement goals. Because of different levels of proficiency across students, the time for teams to finish the project may vary substantially. Team that cannot finish a project in-class have to find time after class. TP often involves division of responsibility and cooperation, which may improve students' integrated capacity.

Many course redesigns focus on incorporating more project-based learning opportunities (Tucker 2012). Demetry (2010) indicated that students are far more apt to partaking in collaborative team-based learning in class when lectures are moved prior to class time. Thus, this research embraces TP as a major activity in the QCPP model.

Methods

Course context

Following 2 years of various course improvements, in the fall semester of 2015, this research introduced flipped classrooms in two courses: *C Programming* and *Object Oriented Programming in Java* (hereinafter called '*OOP in Java*'). In these two courses, besides traditional textbooks, screencast and lecture notes were also provided to students before the whole course. Since resources and many videos already exist, the instructor of C Programming chose a set of well-developed videos (https://www.youku.com/playlist_show/id_5649640.html) while the instructor of OOP in Java had students use resources from a popular MOOC course (https://www.coursera.org/course/pkujava) for Chinese learners. The videos for the two courses expound the lecture content clearly.

C Programming is open to freshmen in their fall semester. This course lasts for 10 weeks and meets twice a week with 110 min each time (two 50-min periods with a 10-min break). The objective of this course is to help students master basic grammar and programming skills of the C programming language and skilfully write simple programs with C through theoretical study and practice on computers. This course is also aimed to equip students with good general programming skills, which will lay a solid foundation for further study of specialized courses related to computer information processing technology, and especially software development in the field of information system and information resource management.

OOP in Java is open to sophomores in their fall semester. This course lasts for 12 weeks and meets twice a week with 110 min each time (time distribution is same as in C Programming course). This course intends to help students develop a better understanding of the basics of the Java programming language. This course also trains students in how to apply the concept of OOP design to accurately analyse problems and design programs skilfully. Furthermore, through several graded homework projects, this course gives students ample training in how to make full use of integrated development environments (i.e. NetBeans) which have gained popularity in the IT field to improve students' problem-solving ability. In addition, it can pave the way for the further study and practice of information management.

Participants

Some studies (Xie 2009; Cheng 2000) involve Chinese university students, many of which can be reticent to interact in class because they "respected the elder and senior by looking up to teachers as authority figures and not challenging or interrupting them with questions" (Xie 2009; Peng 2007). The QCPP model was iteratively developed in this context to encourage more active participation in this context.

The study involved two courses varying strategically in student demographics by gender and by age to improve the generalizability of the research. C Programming is open to 31 freshmen each fall coming from two majors: Electronic Commerce and Information Management and System. In addition, OOP in Java is open to 35 sophomores each fall in the same two majors. Demographic information of participants in the two courses is shown in Table 1. The courses ranged from balanced by gender to male dominated, as is often the range in STEM courses in China and around the world. Sometimes, first-year students have special challenges with engagement and participation, as part of the transition from high school. But more intermediate students can also show lack of engagement. There was a teacher and a teaching assistant (graduate student) for each course. The teachers had participated in education reform and had experience in organizing and administering flipped classrooms in the prior 3 years.

This research randomly selected ten freshmen and ten sophomores to be interviewed (approximately 30% of the total participants in each class).

Implementation details of QCPP model

This research set the time distributions and point values for the four activities, as follows. Of course, teachers can customize their own settings when implementing this model.

SRQ Each warm-up consists of approximately 20 questions. The point values of questions range from 1 to 3, depending on their difficulty. Across the course, a student needs to correctly answer some questions to earn full marks (15 points), but can also earn an additional five bonus marks for additional correct answers. No additional points above five are awarded to allow for more even participation across students. It usually takes 30 min to administer SRQ and teachers' brief comments on some of the more challenging questions.

TFC Each team has ten TFC opportunities across the course to produce full credit of 20 points, which account for 20% of the course grade. Extra TFCs are encouraged by the teacher, but it can be requested only when the teacher is not counselling another team that has not yet completed their ten TFCs. The time teacher spends on TFC in each class may vary and depends on students' requests.

IP This part usually lasts for 60 min (see Fig. 1) since students may spend the second 50-min period plus 10 min of the first period. There are eight independent practice assignments for C Programming to produce full credit of 24 points, taking up 24% of the course grade; there are 11 independent practice assignments for OOP in Java to produce full credit of 25 points, accounting for 25% of the course grade.

TP There are four team projects in the flipped classroom model for C Programming, accounting for 40% of the course grade, and there are four team projects in OOP in Java account for 56% of the course grade.

Table 1 Participants' demographics in each course

Demographics		C Programming ($N = 31$)	OOP in Java ($N = 35$)
Gender	Male	51%	64%
	Female	49%	36%
Age	Above 22	3%	9%
	21	0%	45%
	20	12%	43%
	19	85%	3%

Measures

In order to study the effect of this QCPP model, at the end of each course, this study asked students to complete a questionnaire survey, which was composed of two major parts: (a) an overall assessment of student centredness of the flipped classroom and (b) an assessment of the relative contribution of each activity type to various dimensions of learning. Although surveys are subject to various biases, students are best positioned to judge whether activities tended to focus on their needs (i.e. student centredness). Surveys provide some access to relative contributions and insights into aspects that are difficult to measure using object performance tasks. All students who participated in the courses took the survey, and all the survey forms were collected in class. After the courses were completed, interviews were conducted with a subset of the students in each course.

Bipolar scale of student centredness This research utilized a bipolar student centredness scale developed by Kim et al. (2014), which ranged from teacher-centred to student-centred, to assess how consistently student-centred teaching was implemented in the implemented flipped classroom model (see Appendix A). The overall reliability for the bipolar score is adequate, with a Cronbach alpha = 0.72. The scale includes seven pairs of statements, with statements on the left reflecting a teacher-centric model (i.e. a class that is highly structured, with learning directed entirely by the teacher) and statements on the right reflecting a student-centric model (i.e. a class that is less structured, responsive and open-ended). Students made judgments using a five-point scale with 5 reflecting student-centred and 1 representing teacher-centred. A mean was computed across all seven items.

Learning capability matrix Researchers have argued that the effects of flipped classrooms mainly lie in developing capabilities of expertise and skills, critical thinking, cooperation, creativity, self-control, self-efficacy, time management and lifelong learning (Bishop and Verleger 2013). Bishop (2013) employed a curriculum evaluation scale to measure the learning outcome of flipped classroom. Based on the research mentioned above and the objectives of these two computer courses, we developed a learning capability matrix (LCM) scale to measure the relative contributions of activities to three learning domains based upon 15 observation indices, as shown in Table 2.

Interview protocol To understand students' perceived benefits of the different activities in the QCPP model better, this research conducted a one-to-one interview with the students using semi-structured questions. Each interview lasted approximately 20 min. Teachers were not present during the interview to improve response honesty. Researchers interviewed participants individually with specific questions, and participants responded orally. The interviews were audio-recorded, and written transcripts were created to facilitate analysis. The questions in the interview were divided into two parts: perception of the whole flipped classroom and assessment of the specific learning activities. The examples of questions are shown as follows:

- How do you evaluate the effect of *teacher's F2F counselling*?
- What improvement could be made to *speed response questions*?
- Which activity is your favourite one among the four QCPP activities and why?
- Which activity do you dislike the most among the four QCPP activities and why?

Table 2 Indices of relative contribution to learning domains in the learning capability matrix assessment

Learning domain	Observation index
Expertise and skills	Mastery of course content
	Mastery of course skills
	Ability to analyse problems
	Problem-solving ability
Transferrable capability	Communicative and expressive ability
	Critical thinking ability
	System thinking ability
	Teamwork ability
	Leadership
	Creativity
	Autonomous learning ability
	Self-management ability
	Time management ability
Learning consciousness	Competitive spirit
	Interests in learning

Results

Bipolar-based students' perception of student-centred classroom

This research first examined the means and standard errors in student ratings for the student- vs teacher-centred survey from two perspectives: course differences (C Programming vs OOP in Java) and gender differences (see Fig. 2). All four groups (C Programming, OOP in Java, male and female) found the learning environment to be student-centred. The four means were not significantly different from each other. Every group got a mean that was significantly higher than the neutral value of 3: In all cases, students felt that the flipped classroom was more student-centred than teacher-centred. The difference by gender was very small and not significant, in contrast to findings obtained with other flipped classroom models (Bergmann and Sams 2012; González-Gómez et al. 2012; Gross et al. 2015). Although the flipped classrooms were generally regarded as student-centred, it was not perfect since there existed a large gap between the neutral value 3 and the maximal value 5. In order to improve the model, the characteristics of the particular flipped activities must be examined, as follows.

In addition, to understand the students' perceptual assessment on student-centred flipped classroom in a more detailed way, this research summarized the means of students' assessment

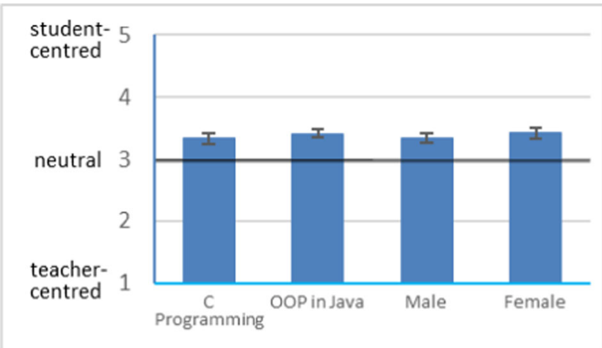

Fig. 2 Means of student assessment of teacher-centred vs student-centred

on each of the seven pairs of statements (see Fig. 3; additional means by course and gender are provided in Appendix B). The means are shown in the middle section of Fig. 3, along with their standard errors. They are presented in descending order by mean value. Overall, students perceived a strong emphasis on reflection, experiential learning and teacher facilitation, but weaker effects on the shift from correctness/task completion to evidence-based, conceptual understandings. It may be that other kinds of activities need to be added to address those components (pairs of statements) better.

LCM-based perceived contribution of learning activities to learning domains

To identify areas for improvement, this research analysed the influences of the six core learning activities on the 15 learning capabilities. The promotion of capacities was rated using a Likert scale, with values from 1 (very insignificant) to 5 (very significant). This research used the mean across items in each learning domain, with the higher the mean, the greater perceived contribution to each learning domain. Figure 4 shows the means of each learning domain across the six learning activities (see Appendix C for details).

Both main effects and interactions of the two independent variables (type of activity and learning capability) were analysed using a 2 × 2 repeated measure ANOVAs. The main effect of activity was significant $F(5, 325) = 33.00$, $p < 0.001$; the main effect of capability was significant $F(2, 130) = 8.26$, $p < 0.001$; and the interaction of activity by capability was significant $F(10, 650) = 11.17$, $p < 0.001$. Because of the significant interaction of activity with learning capability, this research conducted follow-up paired *t* test analyses on the activity means shown in Fig. 4. Then, the research observed the following patterns.

1. The means for the six activities are all far above one. Thus, students, on average, perceived some contribution to learning for all six activities to all three learning domains, although there may be some overall demand characteristic influencing the mean ratings.
2. Overall, compared to the three in-class activities (TFC, IP and TP), the two pre-class activities (SLN and WV) were perceived as less effective in improving learning performance (ps < 0.02).
3. Among the in-class activities, two activities (IP and TP) were perceived as more important for learning than the other two (SRQ and TFC) (ps < 0.001). The instructors might be unhappy to learn of this result because they spent much more time on SRQ and TFC than on IP and TP. Thus, the effectiveness of interaction between students and instructors in SRQ and TFC should be re-examined. However, there was a strong perceived contribution of SRQ to *learning consciousness* and of TFC to *expertise and skills* and *learning sonsciousness*.

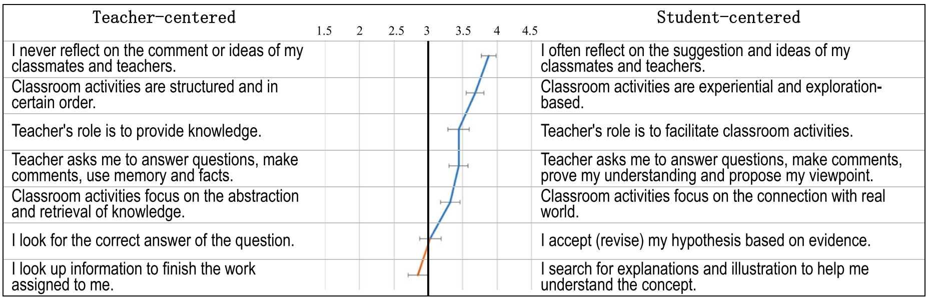

Fig. 3 Students' assessment on the teacher- vs student-centred flipped classroom

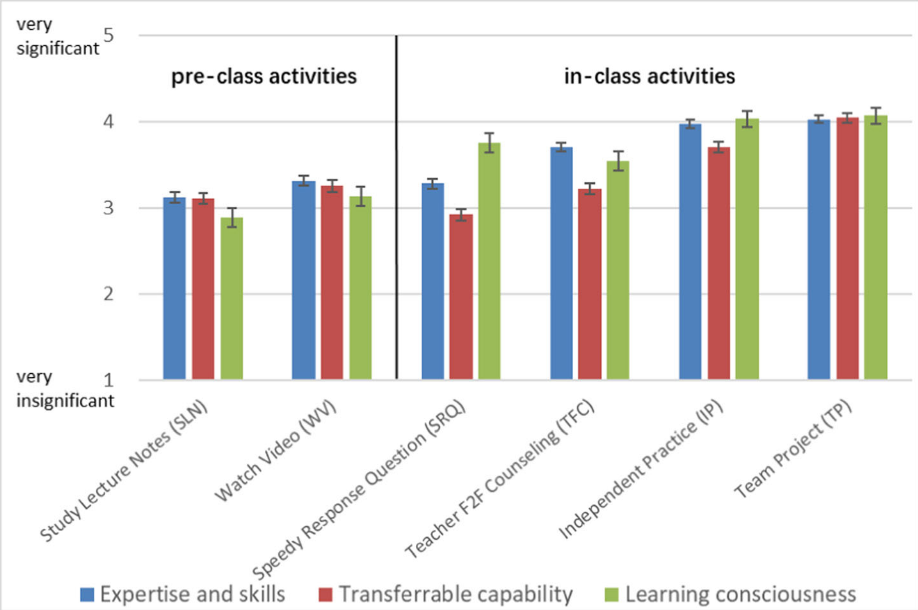

Fig. 4 Mean perceived contribution of each of the six learning activities to each learning domain

4. The means of *transferable capability* in SRQ, TFC and IP are all lower than those of expertise and skills and learning consciousness ($ps < 0.002$). It suggests that methods for improving transferable capability within a flipped class need further research.
5. Between the two pre-class activities, learning consciousness yielded a marginally lower learning performance than expertise and skills ($ps < 0.08$) and non-significant result for transferrable capability ($ps < 0.3$). It implies that there is still some room for the research on learning consciousness.

Student-centred learning is the ultimate objective of flipped classroom. This research has to reiterate some key points. The pre-class activities (SLN and WV) are the premise of flipped classroom learning. The teacher-involved activities (SRQ and TFC) are the ways for teachers to know the outcome of student learning. These four are all prerequisite for the IP and TP activities and eventually for the effective implementation of a flipped classroom.

Interview-based students' attitudes towards the QCPP model

From the interviews of 20 students, this research analysed the transcripts to determine comments associated with each of the in-class activity types. The feedback shown in Table 3 represents summaries of individual comments based on analysis of the interview transcripts. Within each of the four activities, the common positive comments (+) and common negative comments (−) made by the interviewees are shown in Table 3. In addition, the number of students making comments matching each core idea is shown in parentheses.

To characterize the general tone of the feedback, this research defined a measure, i.e. positive to negative ratio (+/– ratio), which was calculated with the sum of positive feedbacks over that of the negative feedbacks. Thus, we obtained approximate values (3:1, 3:2, 3:1 and 1:2) from activities 1

Table 3 Students' interview feedback regarding the four in-class activities in the QCPP model

Activity	Valence	Comments (number of students giving comments with similar meaning)	+/– Ratio
1. Speed response questions (SRQ)	+	The difficulty of questions is fine for us. (4) A great chance for us to get correct answer and it is easy to score. (2) Peers' performance impacts on me greatly. (3) The ambience of class is very good. (5) It makes me feel good to compete to offer the correct answer. (2)	3:1 (16:5)
	–	The number of questions is too small. (2) It is useless and it only tests responding speed. (1) I am introvert and do not like this activity. (1) Some quick response questions are too rigid. (1)	
2. Teacher F2F counselling (TFC)	+	It is specific. (3) It is a bridge to connect the teacher and students, which can enhance learning. (3) Inquiry poses some pressure on me. (2) Unexpected gains. (1) I get more chances to communicate with the teacher and peers. (1) It compels me to summarize the knowledge points. (1)	3:2 (11:7)
	–	It takes a long time to wait for my turn. (4) It can solve only a few problems and thus is relatively useless.(2) There are too many questions. Students should read the book by themselves instead of always resorting to the teacher. (1)	
3. Independent practices (IP)	+	It improves my hands-on ability. (3) It helps me apply what I have learned. (3) It checks the learning outcomes. (3) Great sense of achievement. (2) I enjoy great freedom and can fully exert my imagination. (1)	3:1 (12:4)
	–	It is a little bit too difficult.(2) The task requirements are not presented clearly enough. (1) The relevancy of two adjacent tasks is getting weaker and weaker.(1)	
4. Team projects (TP)	+	It highlights team spirit. (4) Team work makes me happy. (1) It is highly efficient. (1) It provides more perspectives.(1)	1:2 (7:13)
	–	Communication and coordination within group is not easy. (5) Someone dominates the work. (4) Two hours is too short. (2) It is too stressful. (2)	

through 4, which are presented in the last column of Table 3, followed by their exact values (16:5, 11:7, 12:4 and 7:13 accordingly) in parentheses. From the feedback and the +/– ratios in Table 3, this research observed that SRQ and IP had primarily positive feedback whereas TFC had a more 'mixed' result (around 3:2) and TP received primarily negative feedback.

1. As for the mixed TFC feedback, the crux of students' dissatisfaction may come from insufficient instructor availability, which was represented by a combination of 'teacher-

student ratio' and 'counselling qualification of teacher and teaching assistant' components. In order to assure counselling quality, we did not allow our teaching assistants (two graduate students) in these two flipped classrooms to play the role of counsellor. Thus, the actual teacher-student ratios in these two classrooms were both around 1:33. A number of negative comments from students are connected to the problem of teacher-student ratio. For example, four students had the similar complaint that "It takes a long time to wait for my turn", and two students had the complaint that "It can solve only a few problems and thus is relatively useless" (see Table 3). If we had more teachers (or sufficiently trained TAs) in the flipped classrooms, the complaint in the first example would be eliminated and that in the second example might be alleviated. The counselling qualification issue will be discussed further in the "Study limitations" section.

2. As for the disappointing TP results, two reasons are suggested. Firstly, the complaints about time and stress mainly result from the difficulty of the teamwork tasks. For example, students complained that "2 h is too short" and "It is too stressful". Secondly, the training on team communications should receive more attention, including in-class and out-of-class communication, to maximize TP's contribution to learning in flipped classroom. For example, some students claimed that "Communication and coordination within group is not easy" and "Someone dominates the work".
3. Even though IP gets a satisfactory performance, the task design and its difficulty level should be concerned because some students prompted that "It is a little bit too difficult", "The task requirements are not presented clearly enough" and "The relevancy of two adjacent tasks is getting weaker and weaker".
4. The fact that SRQ has the highest +/– ratio might result from the fact that the students are more motivated by SRQ than by other activities. For example, five students admitted that "The ambience of class is very good", and three students said "Peers' performance impacts on me greatly".

Study limitations

This study systematically examined a specific QCPP learning model for structuring the classroom activities of two computer-programming courses taught using a flipped model. It discusses the impact of this model on student perceptions of learning. However, some limitations exist with this study.

Firstly, the data focused on students' perceptions rather than on objective measures of student learning because of the desire to tease apart relative contributions of each activity within the larger model. Among the three learning domains in this study, learning consciousness is inherently about perception, but this research admit that transferable skills dimension is likely best measured using objective measures, despite the great challenges associated with doing so. Secondly, we did not explore the issue of 'counselling qualification of teaching assistants'. If the graduate students (teaching assistants in most of flipped classrooms) had sufficient experience in counselling, the results of student satisfaction might be improved because they could effectively play the role of instructor and thereby change the problems associated with a high student-teacher ratio. A well-designed training program and detailed implementation plan would be needed to support a role for graduate students. Thirdly, this research mainly concentrated on the four in-class activities in QCPP model. Some out-of-class activities, such as SLN, WV and discuss in forum, have not been sufficiently studied in this paper. Theoretically, these out-of-class activities should play important roles to support in-class activities. Last, because of the domain-general nature of the activities in the QCPP model, it should theoretically be easy to apply this model in other courses rather than computer-programming courses, but this research has not verified the success of the model in other courses.

Conclusions and future directions

Based on research in introductory and intermediate courses, this paper investigated a new mode for flipped instruction. The new flipped classroom model divided the learning process into six learning activities—SLN, WV, SRQ, TFC, IP and TP. The whole learning procedure of the flipped classroom can be classified into three learning parts: pre-class self-study, student-centred flipped classroom interaction and post-class review. Future work on flipped classrooms could benefit from explicit attention to each of these three learning parts.

To verify the benefits of the proposed QCPP model, this research developed and applied three measures. This research applied a bipolar scale developed by Kim et al. (2014) and found that the majority of students regarded the QCPP as a more student-centred model along most dimensions of student vs teacher centredness. In addition, this research found that the difference between male and female was not significant. This research proposed a LCM approach to evaluate the perceived contribution of learning activities to learning capabilities. This research found that the in-class activities were perceived more effective than the out-of-class activities as a whole. In addition, this research implemented an interview and developed a measure of +/– ratio, by which this research found that, among the four activities in QCPP model, SRQ and IP had primarily positive feedback, TFC had mixed result and TP received primarily negative feedback.

This research gains several insights from these findings. First, insufficient instructor availability affects students' satisfaction in implementing the QCPP model, which could be solved by improving teacher-student ratio and assuring the counselling qualifications of teaching assistants. Second, some measurement tools such as the LCM proposed in this study can be applied to measure both the individual classroom activity and overall learning outcomes of flipped classrooms. The LCM can be tailored to study other activities (in-class or out-of-class) and by examining more student capabilities. Researchers can make a handbook of learning activities for use in flipped classrooms to give further guidance to instructors. The handbook may cover the application procedure of learning activities, assessment form of learning performance and students' interview records. Instructors can use this handbook to assess different combination of learning activities, examine whether the activities are in correspondence with course objectives and examine whether the combination of different learning activities can lead to learning performance improvement. Last, the post-course interview is very valuable. For example, the interview in this study helped us to find that we owe more efforts to the management of the TP activity.

This study is based on two flipped classrooms in a Chinese university. However, it has several implications for flipped environments in other cultural contexts. (1) Broadly speaking, the redesigned flipped classroom (three learning parts, six learning activities) model could be utilized in other cultural contexts as structural guide for functions/strategies that could be adapted. (2) SRQ is designed to motivate Chinese students to join in the 'game' of speed response question. Since Asian students in a number of countries have similar reticence to participate in class (Cheng 2000), SRQ might become a good solution in other Asian universities. Further participation is often a problem in introductory courses in all countries, so SRQ might be useful to even more useful to students in those countries where participation is less counter-normative. (3) Similarly, TFC may be most important and most challenging to implement in Asian country universities because of early K-12 experiences with face-to-face communication between student and teacher. (4) IP and TP is a pair of practice activities that are not mutually exclusive but rather supportive of one another. Therefore, practitioners in flipped classrooms can adjust the workload (or time consumption) of each activity according to their culture context or students' competency levels. That is to say, if their students need more skill in doing independent working, IP could be emphasized; otherwise, if their students should enhance team-working capabilities, TP could be given more importance.

Being under development, flipped classroom needs consistent design, efforts and research. This study could be improved in the future from four aspects: (a) The research of the interactions between teachers and students outside class will be enhanced. (b) This research is set in two basic computer science courses, so future research needs to explore the difference of flipped classroom learning activities in different fields and subjects. (c) Since the in-class activity SRQ is highly acclaimed by students, a systematic research using objective outcome measures is now needed. (d) More importantly, since flipped classroom is playing an increasingly important role in the upcoming social learning era, from the findings of this study, an in-depth qualitative research project will be interesting and appealing.

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Appendix A

Table 4 Bipolar scale by Kim et al. (2014)

		Choice ↓	
Q1	I look for the correct answer of the question.	○○○○○	I accept (revise) my hypothesis based on evidence.
Q2	I never reflect on the comment or ideas of my classmates and teachers.	○○○○○	I often reflect on the suggestion and ideas of my classmates and teachers.
Q3	I look up information to finish the work assigned to me.	○○○○○	I search for explanations and illustration to help me understand the concept.
Q4	Teacher's role is to provide knowledge.	○○○○○	Teacher's role is to facilitate classroom activities.
Q5	Teacher asks me to answer questions, make comments, use memory and facts.	○○○○○	Teacher asks me to answer questions, make comments, prove my understanding and propose my viewpoint.
Q6	Classroom activities are structured and in certain order.	○○○○○	Classroom activities are experiential and exploration-based.
Q7	Classroom activities focus on the abstraction and retrieval of knowledge.	○○○○○	Classroom activities focus on the connection with real world.

Appendix B

Table 5 Bipolar data analysis of questionnaire

	C (mean ± SD)	Java (mean ± SD)	*t* test	Male (mean ± SD)	Female (mean ± SD)	*t* test	Average
Q2	3.87 ± 0.96	3.89 ± 0.83	0.89	3.74 ± 0.89	4.07 ± 0.86	0.14	3.88 ± 0.11
Q6	3.74 ± 1.00	3.63 ± 1.11	0.42	3.37 ± 1.05	4.11 ± 0.92	0.00	3.68 ± 0.13
Q4	3.52 ± 1.21	3.37 ± 1.31	0.59	3.26 ± 1.33	3.68 ± 1.12	0.10	3.44 ± 0.15
Q5	3.45 ± 1.31	3.43 ± 1.01	0.52	3.42 ± 1.06	3.46 ± 1.29	0.72	3.44 ± 0.14
Q7	2.97 ± 1.20	3.63 ± 1.09	0.07	3.71 ± 1.01	2.79 ± 1.20	0.00	3.32 ± 0.15
Q1	2.71 ± 1.24	3.31 ± 1.21	0.03	3.08 ± 1.24	2.96 ± 1.29	0.52	3.03 ± 0.15
Q3	3.06 ± 1.12	2.66 ± 1.21	0.23	2.82 ± 1.23	2.89 ± 1.13	0.74	2.85 ± 0.15

Confidence intervals are 95%. Q1 through Q7 are the labels of statement pairs in Appendix A

Appendix C

Table 6 Mean ± SD values of 15 abilities by six learning activities

ID	Capability	Study lecture notes	Watch video	Speed response questions	Teacher F2F counselling	Independent practices	Team projects
Expertise and skills							
A1	Mastery of course content	3.68 ± 1.22	3.73 ± 1.30	3.26 ± 1.13	3.83 ± 1.03	4.11 ± 0.99	3.79 ± 0.95
A2	Mastery of course skills	3.45 ± 1.20	3.55 ± 1.24	3.15 ± 1.19	3.58 ± 1.07	4.11 ± 0.96	4.00 ± 1.02
A3	Ability to analyse problems	3.09 ± 1.27	3.26 ± 1.24	3.21 ± 1.22	3.55 ± 1.10	4.15 ± 1.06	4.11 ± 0.95
A4	Problem-solving ability	3.05 ± 1.16	3.30 ± 1.23	3.27 ± 1.23	3.76 ± 1.16	4.18 ± 0.91	4.17 ± 0.92
Transferrable capability							
A5	Communicative and expressive ability	2.56 ± 1.33	2.79 ± 1.32	3.64 ± 1.12	3.94 ± 0.96	3.44 ± 1.19	4.06 ± 0.94
A6	Critical thinking ability	2.92 ± 1.28	3.11 ± 1.28	3.23 ± 1.23	3.70 ± 1.12	3.80 ± 0.90	3.89 ± 1.05
A7	Systemic thinking ability	3.08 ± 1.28	3.47 ± 1.22	3.21 ± 1.18	3.59 ± 1.16	4.02 ± 1.06	4.18 ± 0.94
A8	Teamwork ability	2.65 ± 1.28	2.55 ± 1.25	2.74 ± 1.29	3.21 ± 1.32	3.15 ± 1.26	4.44 ± 0.95
A9	Leadership	2.38 ± 1.15	2.47 ± 1.22	2.62 ± 1.30	2.79 ± 1.35	3.05 ± 1.25	4.18 ± 0.99
A10	Creativity	2.59 ± 1.29	2.73 ± 1.27	2.95 ± 1.26	3.30 ± 1.29	3.76 ± 1.08	3.97 ± 1.04
A11	Autonomous learning ability	3.70 ± 1.16	3.86 ± 1.05	3.11 ± 1.20	3.53 ± 1.18	4.14 ± 1.01	3.94 ± 1.05
Learning consciousness							
A12	Self-management ability	3.68 ± 1.17	3.86 ± 1.07	3.03 ± 1.15	3.32 ± 1.17	4.03 ± 1.10	3.94 ± 1.02
A13	Time management ability	3.67 ± 1.19	4.06 ± 1.07	3.06 ± 1.29	3.18 ± 1.20	4.09 ± 1.08	3.80 ± 1.23
A14	Competitive spirit	2.68 ± 1.35	2.94 ± 1.33	3.92 ± 1.17	3.36 ± 1.34	3.92 ± 1.17	4.00 ± 1.08
A15	Interests in learning	3.09 ± 1.27	3.33 ± 1.15	3.58 ± 1.31	3.73 ± 1.13	4.14 ± 0.99	4.14 ± 0.99

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