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A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course

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ABSTRACT

The flipped classroom is a well-recognized learning mode that enables effective practice and interactions among teachers and students in the class by switching the in-class instructional time and out-of-class practicing time. However, owing to their lack of self-regulated competence, most students might fail to browse and comprehend the instructional materials out of class by themselves. In this paper, a self-regulated flipped classroom approach is proposed to help students schedule their out-of-class time to effectively read and comprehend the learning content before class, such that they are capable of interacting with their peers and teachers in class for in-depth discussions. In order to evaluate the effectiveness of the proposed approach, a quasi-experimental design was employed in an elementary school Mathematics course. The experimental group students learned with the self-regulated flipped classroom approach, while the control group students learned with the conventional flipped classroom approach. The study was conducted using a quantitative approach. The instruments used were a performance test, and questionnaires of self-efficacy and self-regulation. The experimental results indicated that the post-test score of the experimental group was significantly higher than that of the control group. It was also found that the higher self-regulation students showed significantly different learning achievements when learning with different approaches, while there was no significant difference between lower self-regulation students with the different learning approaches. Moreover, the experimental group showed significantly higher self-efficacy than the control group. In addition, the learning log analysis results further showed that, conforming to the objective of the self-regulated strategy, the students would determine the goals for the next learning phase based on their current performance. To sum up, the findings of this study indicate that integrating the self-regulated strategy into flipped learning can improve students' self-efficacy as well as their strategies of planning and using study time, and hence they can learn effectively and have better learning achievements.

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1. Introduction

Scholars have emphasized the importance of conducting student-centered learning activities in school settings (Agbatogun, 2014; Piirto, 2011). In student-centered learning activities, fostering students' active learning and solving their individual learning problems have been identified as the keys to improving their learning performance (Chang, Hsiao, & Barufaldi, 2006; Kamarainen et al., 2013). Among various learning modes, flipped classrooms are considered as an effective mode for engaging students in active learning as well as in meaningful peer-to-peer and peer-to-teacher interactions during the in-class learning process (Forsey, Low, & Glance, 2013; Pluta, Richards, & Mutnick, 2013; Teo, Tan, Yan, Teo, & Yeo, 2014). Moreover, Bergmann and Sams (2012) indicated that flipped classrooms enable teachers to take individual students' needs into account as well as to facilitate more interactions among peers and teachers in the classroom.

The learning context of flipped classrooms consists of two kinds of activities: computer-assisted out-of-class personal instruction and interactive in-class group learning activities (Bishop & Verleger, 2013). That is, students obtain learning content before class, and then spend time in class deepening their understanding of the content (Baker, 2000; Lage, Platt, & Treglia, 2000). This learning mode emphasizes self-paced learning, and supports students in solving problems through the guidance (Rahman, Aris, Mohamed, & Zaid, 2014).

However, scholars have pointed out the challenges of conducting the flipped classroom approach, such as the preparation of instructional videos with effective learning guidance (Rahman et al., 2015; Schultz, Duffield, Rasmussen, & Wageman, 2014). Without proper guidance or assistance, most students might show low self-regulated behaviors and little responsibility during the learning process (McLaughlin et al., 2013; Sun, Wu, & Lee, 2016). For example, in the out-of-class learning activities, students may fail to schedule their time to watch the videos and comprehend the learning content owing to their lack of self-regulation. In this circumstance, they are likely to fail to effectively learn in the following in-class activities (Mason, Shuman, & Cook, 2013).

Therefore, to enhance the effectiveness of the flipped classroom, it is important to provide students with a self-regulating mechanism. In this study, a self-regulated flipped classroom approach is proposed. A learning system has been implemented based on the proposed approach to enable students to determine the learning goals, engage in learning based on their own plans, monitor and evaluate their own learning performance, and make reflections accordingly. Moreover, an experiment was conducted to evaluate the performance of the approach in terms of improving students' learning achievement, self-efficacy, and self-regulation.

2. Literature review

2.1. The flipped classroom

In recent years, the educational paradigm has shifted from teacher instruction mode to student-centered learning. Based on this kind of innovation, more technologies have been integrated into the educational scene, and multiple learning modes have provided students with various ways of learning (Li et al., 2014). Among the various learning modes, the "flipped classroom" is regarded as a potential and extraordinary learning method that engages students in applying their learning knowledge and conducting higher order thinking, rather than receiving direct teaching instruction (Davies, Dean, & Ball, 2013; Flumerfelt & Green, 2013).

The term "flipped classroom" represents the learning approach that exchanges the time used to deliver basic knowledge in class and the out-of-class time for applying the knowledge or doing homework (Bergmann & Sams, 2012); that is, teachers are able to engage students in more learning activities for applying the knowledge they have learned through practicing, doing projects, discussion, and solving problems in class (Missildine, Fountain, Summers, & Gosselin, 2013), as shown in Fig. 1. The

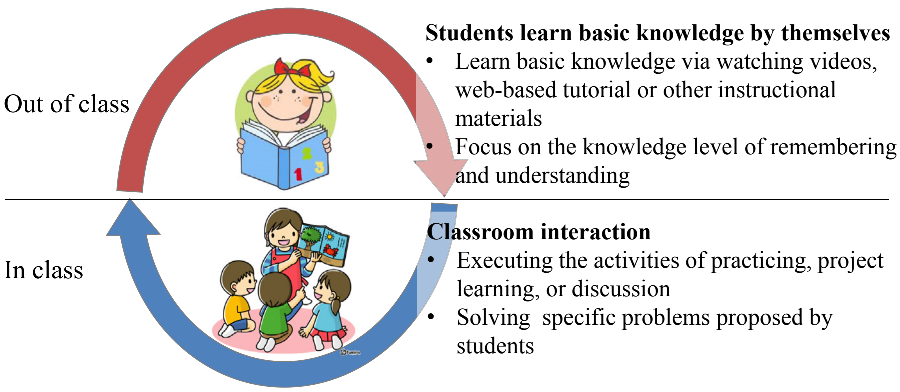

Fig. 1. The learning mode of the flipped classroom.

materials for out-of-class learning, which could be instructional videos, web-based tutorials or other forms of courseware, are mainly related to the knowledge levels of remembering and understanding (Baker, 2000; Mason et al., 2013; Rahman et al., 2014).

In the flipped classroom, students are able to take control of their own learning pace, and be responsible for their own learning process. On the other hand, class time is freed up so that teachers can develop meaningful activities to stimulate the students to engage in higher order thinking (Kim, Kim, Khera, & Getman, 2014). To sum up, there are four advantages that the flipped classroom can provide: active learning, cultivating students' learning attitudes, favorable use of class time, and putting emphasis on students' learning status and solving students' personal problems (Bergmann & Sams, 2012; Gaughan, 2014). Scholars have further indicated that, to successfully adopt flipped learning, teachers must have strong teaching beliefs and put a great deal of effort into guiding students to understand the real meaning of the learning content (Bergmann & Sams, 2012; Hwang, Lai, & Wang, 2015).

Another important element of the flipped classroom is learner presence, which represents students' performance of their self-efficacy and self-regulation (Bloom, Kurian, Chua, Goh, & Lien, 2013). Several researchers have indicated that students' learner presence intention is associated with their learning performance and the strategies they use (Kim et al., 2014; Shea & Bidjerano, 2012). For example, in the out-of-class learning mode, there is plenty of information on the Internet, some of which can encourage students to learn, while some might influence students' concentration. In this situation, how students utilize the resources and what strategies they apply in learning are important (Rahimi, van den Berg, & Veen, 2015; Rosario et al., 2015). If students exhibit better self-regulation, they might effectively explore and learn the learning materials without being affected by other unrelated content (Liu, Lan, & Ho, 2014). Conversely, students with lower self-regulation might learn little before class, which could affect their performance in the in-class learning. Worst of all, they may be unable to engage at all in the class activities (Margolis & McCabe, 2003; Rahman et al., 2015). That is to say, students' out-of-class learning performance plays an important role when students and teachers conduct their in-class activities (Mason et al., 2013). Hence, how students perform their self-regulation is regarded as a critical issue in students' flipped learning performance (McLaughlin et al., 2013), and a mechanism for encouraging students to be self-regulated in learning is essential when conducting flipped learning activities (Sun et al., 2016).

2.2. Self-regulated learning strategy

Self-regulated learning is considered as a potential learning process that enhances students' motivation to learn and to reflect on their learning process, and thus contributes to the resolution of their learning (Michalsky & Schechter, 2013; Siadaty et al., 2012). With self-regulated learning, students can deeply comprehend complex topics during their learning (Jacobson & Archodidou, 2000; Jarvela et al., 2015; Labuhn, Bogeholz, & Hasselhorn, 2008). In the meantime, their behaviors and attitudes consistent with self-regulated learning also contribute to their self-confidence (Artino & Jones, 2012; Stefanou, Lord, Prince, & Chen, 2014).

Zimmerman (2002) revealed the three self-regulated learning processes of the forethought phase, the performance phase, and the self-reflection phase. In the forethought phase, shown in Fig. 2, students should analyze the learning tasks and set specific learning goals and strategies to achieve these goals. The second phase, performance, means that students implement their learning based on their learning strategies and try their best to achieve their learning goals. During these processes, students could be aware of their performance with regard to certain learning goals, and monitor the appropriate learning strategies for achieving their goals. The last phase indicates how students evaluate the correlations between their learning results and their learning strategies in order to determine the effectiveness of the learning strategies.

Owing to advancements in technology, self-regulated learning strategies are no longer restricted to the interactions between individuals' psychological views and their learning; such interactions have been extended to include the use of some technological tools (DiBenedetto & Bembenutty, 2013; Mellado et al., 2014). For instance, Tabuenca, Kalz, Drachsler, and Specht (2015) conducted a self-regulated learning activity using mobile technology, and found that the approach improved the students' time management behaviors during the learning process.

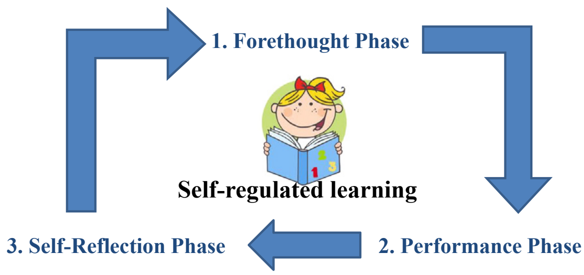

Fig. 2. The process of self-regulation.

According to the reviews, the flipped classroom learning mode has reversed the direct teaching of traditional courses, and focuses instead on leading students to apply knowledge as well as to achieve higher order thinking learning objectives (Flumerfelt & Green, 2013; Li et al., 2014). Researchers have further demonstrated that students need to be self-regulated during their flipped learning so as to control their learning process and monitor their learning performance (Mason et al., 2013).

Therefore, in this study, a self-regulated flipped classroom approach was proposed for engaging students in being self-regulated in their learning. Moreover, several research questions were investigated to evaluate the effectiveness of the proposed approach:

(1) Can the self-regulated flipped classroom approach improve the students' learning achievements in comparison with the conventional flipped classroom?
(2) Can the self-regulated flipped classroom approach improve the students' self-efficacy in comparison with the conventional flipped classroom?
(3) Can the self-regulated flipped classroom approach improve the students' self-regulation in comparison with the conventional flipped classroom?
(4) What is the relationship between students' goal setting and their self-evaluation performance?

3. A self-regulated flipped classroom approach

To encourage students to be self-learners, a self-regulated learning system was developed for supporting the flipped classroom learning activities. The system consists of an out-of-class learning system, a self-regulated monitoring system, a teacher management system, and a database, as shown in Fig. 3. The out-of-class learning system consists of the e-books and some quizzes provided by the teachers; the students read those learning materials and took the quizzes before starting the in-class activities. The self-regulated monitoring system is a platform on which the students can set their learning goals and evaluate their learning performance before and after their courses. The teacher management system allows teachers to upload e-books for students and to give students comments and feedback based on their learning process. Finally, the database not only records the students' learning logs and their profiles, but also provides them with diagnoses based on the teacher's criteria of self-regulation and on the students' learning logs from the out-of-class learning and the self-regulated monitoring system.

Fig. 4 shows the learning procedure of the students' self-regulated flipped classroom learning process. At the beginning of the learning course, the teacher introduces the syllabus of the learning unit, and then explains the learning mode of self-regulation and the flipped classroom. Once the students understand the learning mode, they are asked to set their learning goals based on their prior experience of Mathematics courses. Only after they finish setting their goals are they allowed to learn in the out-of-class learning system. In this system, they can read the e-books and take quizzes wherever they are, and their learning logs and performance will be recorded in the database. The teacher can check the students' learning logs and performance and then conduct some discussion based on any misunderstandings or high-error-rate questions in

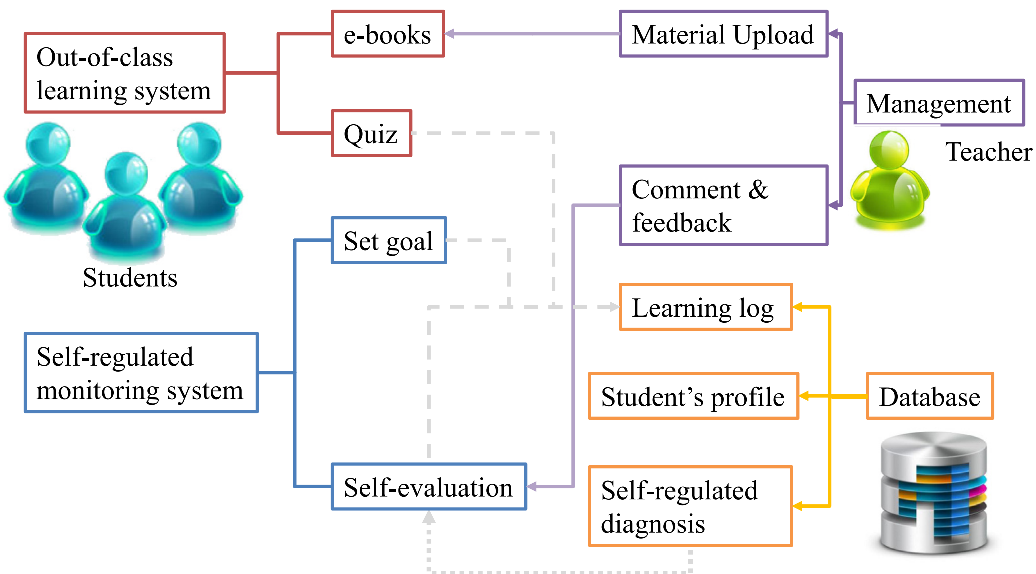

Fig. 3. Structure of the self-regulated flipped classroom environment.

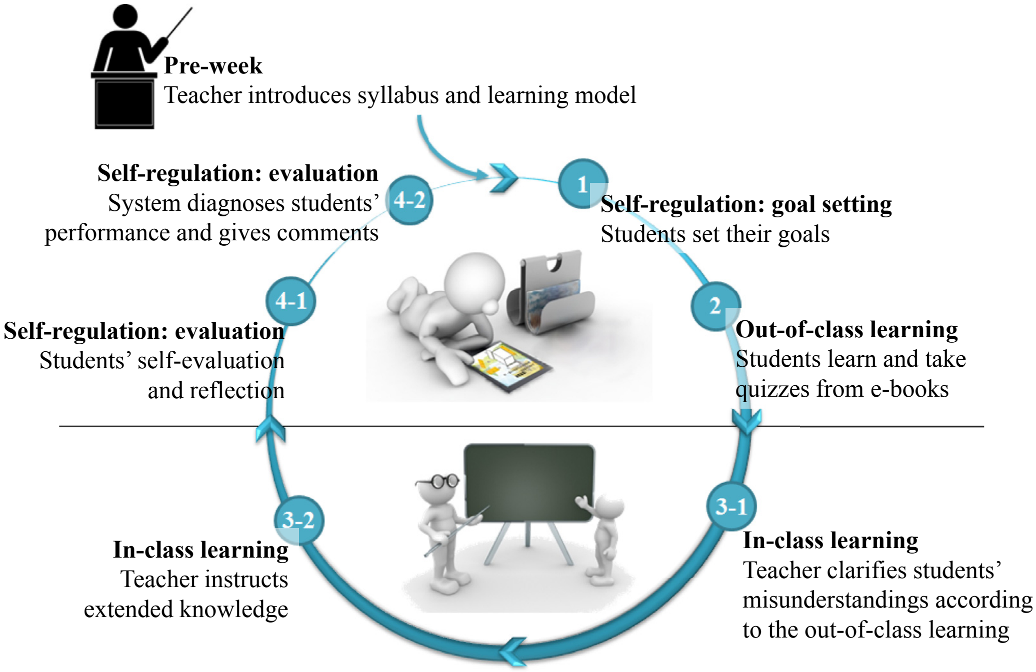

Fig. 4. Learning flow of the self-regulated flipped classroom approach.

class. Also, some extended knowledge instruction or interactive learning activities are conducted in the in-class activities. After the students experience both the out-of-class and the in-class learning activities, they are guided to perform self-evaluation in the self-regulated monitoring system. As soon as the students send their personal evaluation, the database provides them with some diagnosis according to their learning performance for them to adjust their self-regulation.

Fig. 5 shows the goal setting interface in each unit. There are four learning goals students should set (i.e., What score do I wish to get? How much time do I think I will spend? Where do I plan to learn? What strategies do I plan to use?). As soon as the students set these goals, the database records the data for the diagnosis in the evaluation step.

After the students finish setting their goals, they are allowed to read the e-books before their in-class activities. Fig. 6 shows the interface of the e-books, some descriptions and the videos of the learning knowledge which are provided for the students to learn.

Fig. 7 shows that the students not only read the e-books out of class, but also need to take some quizzes before the class. There are various quiz mechanisms provided in the e-books including multiple choice, matching, dragging, and fill-in-the-blank questions. The quiz is able to examine students' performance of self-learning and preparedness of the basic content for the in-class learning (Rahman et al., 2015). The system records the time the students spent reading the e-books as well as their answers to the quizzes in the database. Therefore, the students can track their individual performance and verify the answers to any of the quiz questions they failed to answer correctly. On the other hand, the teacher can check the students'

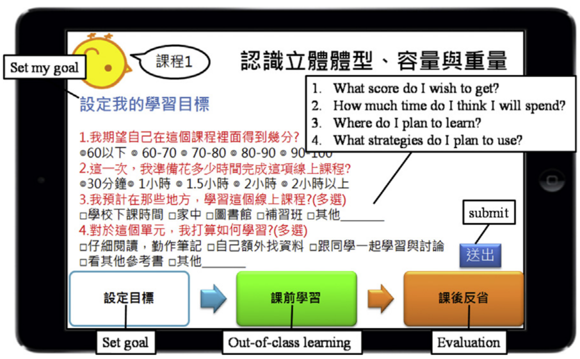

Fig. 5. Interface of the first step, goal setting.

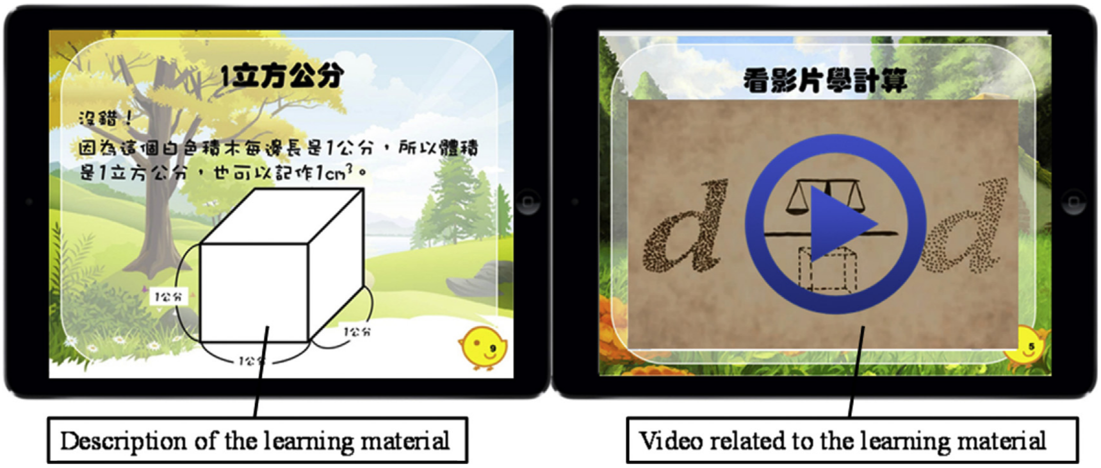

Fig. 6. Interface of the e-books, knowledge description and video watching.

learning logs and performance in the database, and adjust the in-class activities based on the students' performance before class.

After the students finish the out-of-class learning, they engage in the in-class learning activities in which the teacher conducts some discussion related to the students' out-of-class learning status and extended instruction. After they finish each unit, they are asked to perform self-evaluation. Fig. 8 shows the evaluation interface. There are three questions the students are asked: What score do I think I can get? Where did I actually study the e-books? What strategies did I actually use? After the students finish their evaluation, they need to submit their results and read their teachers' comments corresponding to the learning unit.

Fig. 7. The quiz mechanisms in the e-books.

Fig. 8. Interface of the last step, evaluation.

The teacher's comments are based on the goals the students set, the score the students actually got, the recording from the system, and the criteria set by the teachers, as shown in Table 1. In the goal setting step, the system automatically records the data as soon as the students set up the score they expect to get (SES) and the time they expect to spend on the out-of-class learning (SET). During the time the students are learning with the out-of-class learning system, the system records the time they spend on the e-books (SRT) and the score they get on the quiz (SRS). Moreover, in the evaluation step, the students evaluate their learning performance (SVS). The data mentioned above are the factors of the self-regulated diagnosis.

The results of the self-regulated diagnosis are shown in Table 2. The system calculates those abovementioned data and compares the values with the formula, calculating the suitable learning diagnosis for each student. The diagnosis consists of two scales: the performance of time management and the performance of self-evaluation. For instance, if the student's evaluation of his/her learning score was lower than the expected score, but his/her quiz score recorded by the system was also higher than the lowest limitation set by the teacher, the achievement rate of the student's performance evaluation is 75%, and the system's comment is: "You did a great job on the quiz, but it seems that you didn't feel confident about your learning performance; try to find out the problems or talk to the teacher."

Fig. 9 shows the interface of the diagnosis provided by the self-regulated diagnosis system. After the students submit their self-evaluation corresponding to their learning units, the system instantly compares some recorded data and gives the individual diagnosis to each student. Finally, the students make their self-reflection after they read the comments, and prepare the next goal setting for the following learning unit.

4. Method

4.1. Participants

The participants were two classes of fourth graders of an elementary school. One class was the experimental group and the other was the control group. The experimental group, including 20 students, learned with the self-regulated flipped classroom approach. On the other hand, the control group with 24 students learned with the conventional flipped classroom approach. That is, the students in both groups engaged in the same learning activity.

4.2. Instruments

The measuring tools of this study included the pre-test, post-test, and the questionnaires of self-efficacy and self-regulation.

Table 1
The variables employed for self-regulated diagnosis.

Recorded steps	Variable	Description	Data source
Goal setting	SES	The score of the out-of-class quiz students expected to get	Students set it by themselves
	SET	The out-of-class learning time students expected to spend	Students set it by themselves
System recorded	SRT	The out-of-class learning time students actually spend	System records
	SRS	The score of the out-of-class quiz students actually get	System records
Self-evaluation	SVS	The performance of the out-of-class learning students think they can get	Students evaluate it by themselves
Teacher's criteria	TES	The score of the out-of-class quiz teachers think students should get	Teachers set the lowest limitation of the out-of-class score
	TET	The out-of-class learning time teachers think students should spend	Teachers set the range of the learning time

Table 2
The results and comments of the self-regulated diagnosis.

Scales	Formula	Achievement rate	System's comment
Time management	If SET-SRT $\geq$ 0, and TET-SRT $\geq$ 0	100%	You perfectly controlled the learning time, and finished your learning in the time the teacher expected.
	If SET-SRT $\geq$ 0, and TET-SRT<0	50%	You correctly controlled the learning time you expected, but the learning time exceeded the teacher's expectation. Please try to improve your learning efficiency.
	If SET-SRT<0, and TET-SRT $\geq$ 0	75%	You perfectly controlled the learning time according to the teacher's expectation, but it seems that the learning time you expected was quite different from the learning time you spent; please adjust your expectation in order to match your abilities.
	If SET-SRT<0, and TET-SRT<0	25%	Your learning time is much slower than the teacher's and your expectation. Please try to improve your learning efficiency and find out what caused you to learn so slowly.
Self-evaluation	If SES-SVS>0, and TES-SRS $\leq$ 0	75%	You did a great job on the quiz, but it seems that you didn't feel confident about your learning performance; try to find out the problems or talk to the teacher.
	If SES-SVS>0, and TES-SRS>0	25%	It seems that you didn't feel confident about this learning and your performance was poor. Please study the e-books again and ask the teacher about the concepts you can't figure out.
	If SES-SVS $\leq$ 0, and TES-SRS $\leq$ 0	100%	You did a great job on the quiz, and you felt confident about your performance. Keep going!
	If SES-SVS $\leq$ 0, and TES-SRS>0	50%	It seems that you felt confident about your learning, but you didn't do well on the quiz. Please read the e-books again and figure out your misconceptions.

The pre-test and post-test were developed by three experienced teachers. The pre-test aimed to evaluate the students' prior knowledge of the mathematics course in the "Area and perimeter" unit. It consisted of five multiple-choice items (10%), 2 matching items (16%), 17 fill-in-the-blank items (34%), and 10 question-and-answer items (40%), with a perfect score of 100. The post-test consisted of ten multiple-choice items (50%), five matching items (25%) and five question-and-answer items (25%) to assess the students' competence in identifying and calculating various complex volumes. The perfect score of the post-test was 100. In addition, two experienced mathematics teachers were invited to ensure the pre-test and post-test were sufficient to evaluate the students' learning achievements of the selected units. The Pearson's correlation between the two tests was 0.029, indicating a low correlation between the tests. Moreover, the Kuder–Richardson Formula 20 (KR-20) of the post-test was 0.58, indicating an acceptable internal consistency (Cortina, 1993).

The questionnaire of self-efficacy was modified from the measurement developed by Wang and Hwang (2012). It consisted of eight items (e.g., "I believe that I can understand the most difficult part of this course") with a five-point Likert rating scale. The Cronbach's alpha value of the questionnaire was 0.92.

The questionnaire of self-regulation was modified from the measurement developed by Barnard, Lan, To, Paton, and Lai (2009). It consists of 24 items with a five-point Likert rating scheme, including 5 items for "Goal setting", 4 for " Environment structuring", 4 for "Task strategies", 3 for "Time management", 4 for "Help seeking", and 4 for "Self-evaluation." The total Cronbach's alpha value of the questionnaire was 0.92, and the Cronbach's alpha values of the six dimensions were 0.95, 0.92, 0.93, 0.87, 0.96, and 0.94, respectively.

4.3. *Experimental procedure*

The learning procedure is shown in Fig. 10. In the first week, the students from both groups (n = 44) took the pre-test and completed the pre-questionnaire which consisted of items related to self-efficacy and self-regulation. Following that, the

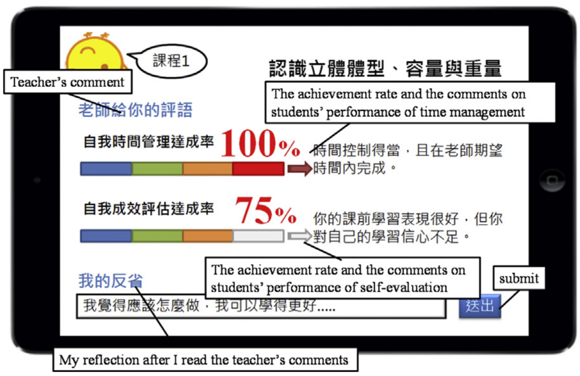

Fig. 9. The interface of diagnosis provided by the system.

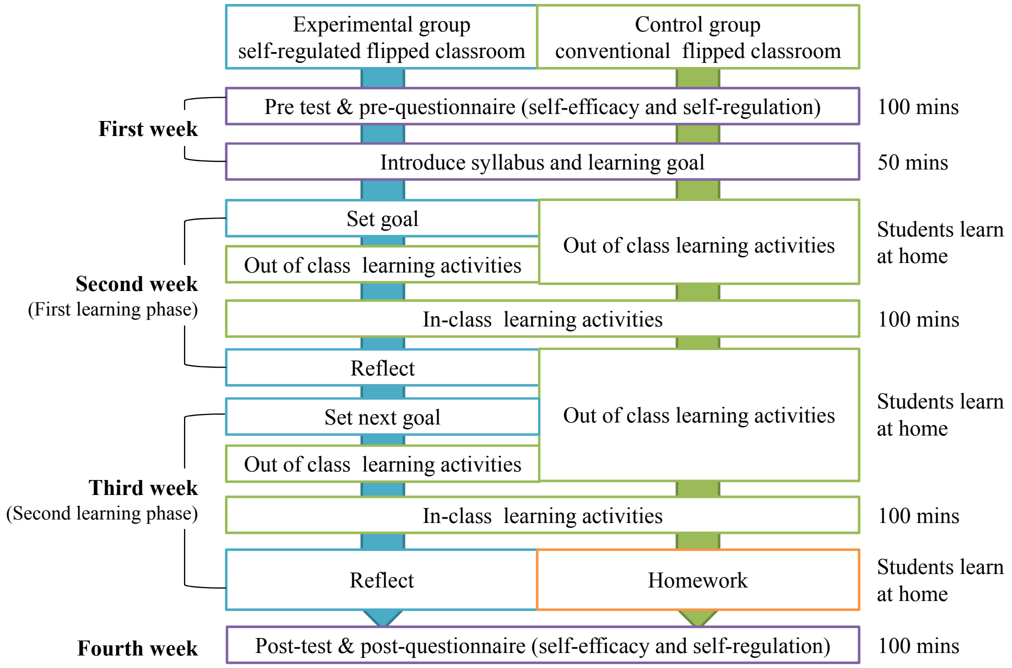

Fig. 10. Diagram of the experiment design.

teacher introduced the syllabus and the learning goal to the students in both classes. In the second and third weeks (i.e., the first and second learning phases), the students studied units one and two, respectively. In each week, there were one out-of-class activity and one in-class activity. Before the out-of-class learning activities, the students in the experimental group were asked to set their own learning goals. During the out-of-class learning activities, both groups of students read the e-books with instructional videos and completed a learning sheet. Then, they engaged in the in-class learning activities, including group discussions and solving problems raised by the teacher. After finishing the in-class learning activities, both groups of students received feedback from the teacher. In addition, the experimental group students ($n = 20$) were asked to do self-evaluation and reflection in the self-regulated monitoring system as well as set their next learning goal.

The only difference between the two groups was the self-regulated learning mode. The students in the experimental group learned with the self-regulated flipped classroom approach. On the other hand, the control group learned with the conventional flipped classroom learning approach. In the fourth week, all of the students took the post-test and post-questionnaires of self-efficacy and self-regulation.

5. Results

The IBM SPSS was employed to examine the performances of the two groups, including their pre-tests, post-tests, and pre- and post-questionnaires (i.e., self-regulation and self-efficacy). Moreover, the Shapiro-Wilk test was employed to examine the normality of the data. The value of this test was 0.96, $p = 0.11$, indicating that the sample of this study had normal distribution.

5.1. Analysis of learning achievement

The one-way analysis of covariance (ANCOVA) was employed to evaluate students' learning achievement in the experimental group and the control group. The Levene's test of determining homogeneity of variance was not violated ($F = 3.11$, $p > 0.05$), indicating that the assumption is tenable and that ANCOVA can be used to interpret the relationships between the students' prior knowledge and their learning achievement in the post-test. Table 3 shows the results of the learning

Table 3
The one-way ANCOVA result of the post-test scores of the two groups.

Group	N	Mean	SD	Adjusted mean	Adjusted SD	*F*
Experimental group	20	90.20	9.69	90.65	1.90	16.23^{***}
Control group	24	80.50	7.16	80.12	1.73	

$^{***}p<.001$.

achievement according to the post-tests of the two groups. The adjusted means and standard error were 90.20 and 9.69 for the experimental group, and 80.50 and 7.16 for the control group. It was found that the post-test scores of the two groups were significantly different (F (1, 41) = 16.23, $p < 0.001$). The post-test score of the experimental group was significantly higher than that of the control group. This implies that the self-regulated flipped classroom approach benefited the students more than the conventional flipped classroom approach.

To further understand the effects of the self-regulated flipped classroom approach on the learning achievements of the students with different self-regulation levels, the students were classified into high and low self-regulation groups based on their self-regulation ratings on the pre-questionnaire. The students in the top 50% were regarded as high self-regulation, while the others were low self-regulation. The independent variables were the two learning approaches and two levels (i.e., higher and lower) of self-regulation, while the dependent variable is the students' learning achievement. The Levene's test was not violated ($F = 0.68$, $p > 0.05$), suggesting that a common regression coefficient was appropriate for the two-way ANCOVA.

Table 4 shows the two-way ANCOVA results. It was found that significant effects were observed for the learning approaches (F (1, 39) = 10.53, $p < 0.01$), and the interaction between the learning approaches and self-regulation (F (1, 39) = 4.38, $p < 0.05$) on the students' learning achievements. Furthermore, the effect size (η^2) of learning approach was 0.21, indicating a small to medium effect size, while the effect size of the interaction between learning approaches and self-regulation levels was 0.10, representing a small effect size (Cohen, 1988).

A simple main-effect analysis was further employed to explore the effects of the self-regulation levels on the learning achievements of the students who learned with different flipped classroom approaches, as shown in Table 5. It was found that the students with different self-regulation levels in the experimental group showed significantly different learning achievements (F (1, 39) = 5.81, $p < 0.05$, $\eta^2 = 0.13$). On the other hand, there was no significant difference between the students in the control group who engaged in different levels of self-regulation (F (1, 39) = 0.19, $p > 0.05$, $\eta^2 = 0.01$). These results indicate that the engagement of students' self-regulation levels played an important role in learning when learning with the self-regulated flipped classroom approach.

Table 6 shows the simple main-effect analysis results of the effects of the learning approaches on the learning achievements of the students with different self-regulation levels. It was found that the higher self-regulation students showed significantly different learning achievements when learning with different approaches (F(1, 39) = 15.82, $p < 0.001$, $\eta^2 = 0.29$), while there was no significant difference between lower self-regulation students with different learning approaches (F (1,

Table 4
The two way ANCOVA result of the learning achievement.

Variables	*SS*	*df*	MS	*F*	η^2
Pre-test	70.93	1	70.93	1.12	0.28
Learning approaches	668.00	1	668.00	10.53^{**}	0.21
Self-regulation	146.48	1	146.48	2.31	0.06
Learning approaches * Self-regulation	277.64	1	277.64	4.38^{*}	0.10
Error	2474.12	39	63.44		

**p<0.01, *p<0.05.

Table 5
Simple main-effect analysis results of self-regulated levels on students' learning achievement.

Variables		*SS*	*df*	MS	*F*	η^2
Self-regulated flipped classroom (experimental group)	Between groups	368.25	1	368.25	5.81^{*}	0.13
	Within groups	2474.12	39	63.44		
	Total	2842.37	40			
Flipped classroom (control group)	Between groups	11.88	1	11.88	0.19	0.01
	Within groups	2474.12	39	63.44		
	Total	2486	40			

*p<.05.

Table 6
Simple main-effect analysis results of the self-regulated approach on students' learning achievement.

Variables		*SS*	*df*	MS	*F*	η^2
Lower self-regulation	Between groups	44.79	1	44.79	0.71	0.02
	Within groups	2474.12	39	63.44		
	Total	2518.91	40			
Higher self-regulation	Between groups	1003.75	1	1003.75	15.82^{***}	0.29
	Within groups	2474.12	39	63.44		
	Total	3477.87	40			

***p<.001.

39) = 0.71, $p > 0.05$, $\eta^2 = 0.02$). According to the results, it is implied that the self-regulated flipped classroom approach could benefit the students who engaged in higher self-regulation more than those with lower self-regulation.

Fig. 11 shows the interaction between the different flipped classroom approaches and the self-regulation levels on the students' learning achievements. It was clear that the students who learned with the self-regulated flipped classroom approach performed significantly better than those who learned with the conventional flipped classroom approach. Moreover, the students who engaged in higher self-regulation showed significantly higher achievement than those with lower self-regulation while learning with the self-regulated flipped classroom.

5.2. Analysis of self-efficacy

The Levene's test of determining homogeneity of regression was not violated ($F = 2.10$, $p > 0.05$), showing a common regression coefficient for one-way ANCOVA. Table 7 shows the results of self-efficacy for the two groups. According to the ANCOVA result, it was found that the self-efficacy performance of the experimental group was significantly higher than that of the control group ($F(1, 41) = 11.78$, $p < 0.01$, $\eta^2 = 0.22$). The adjusted means of the values were 4.74 in the experimental group and 3.73 in the control group. The standard errors of the two groups were 0.16 and 0.15, respectively. This result implies that the self-regulated flipped classroom approach can more significantly improve students' self-efficacy than the conventional flipped classroom.

5.3. Analysis of self-regulation

The assumption of homogeneity of regression also indicated a common regression for one-way ANCOVA ($F = 1.85$, $p > 0.05$). Table 8 shows the result of the students' self-regulation in the two groups. The result of the ANCOVA showed a significantly positive effect on students' self-regulation in the experimental group ($F(1, 41) = 20.59$, $p < 0.001$, $\eta^2 = 0.33$). The adjusted means of the two groups were 4.33 and 3.53, while the standard errors were 0.13 and 0.12. This result implies that the self-regulated flipped classroom approach can more significantly stimulate the students' self-efficacy than the conventional flipped classroom.

To further investigate the students' awareness of their self-regulation in each aspect, the independent t-test was employed to explore the students' awareness of "goal setting", "environment structuring", "task strategies", "time management", "help seeking", and "self-evaluation." The t-test results showed that there was no significant difference between the self-regulation

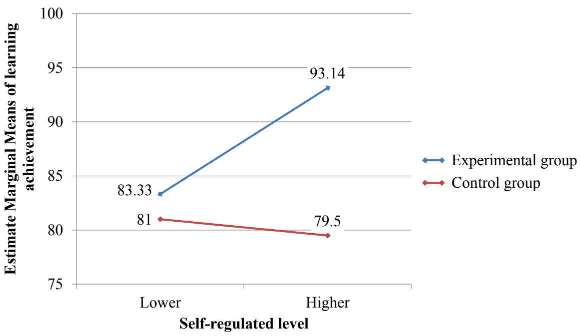

Fig. 11. Interaction between self-regulation levels and learning approaches.

Table 7
The one-way ANCOVA of the students' self-efficacy.

Group	N	Mean	SD	Adjusted mean	Adjusted SD	F	η^2
Experimental group	20	4.46	0.57	4.74	0.16	11.78**	0.22
Control group	24	3.74	0.82	3.73	0.15		

**$p<0.01$.

Table 8
The one-way ANCOVA of students' performance of self-regulation.

Group	N	Mean	SD	Adjusted mean	Adjusted SD	F	η^2
Experimental group	20	4.33	0.65	4.33	0.13	20.59***	0.33
Control group	24	3.54	0.49	3.53	0.12		

***$p<.001$.

ratings for each dimension of the pre-questionnaire for the two groups ($t = -0.69$–1.46, $p > 0.05$), indicating that the two groups of students had equivalent awareness of their self-regulation before entering the flipped classrooms.

This study further compared the six self-regulation dimensions in the post-questionnaire, namely goal setting, environment structuring, task strategies, time management, help seeking, and self-evaluation, as shown in Table 9. It was found that the experimental group students obtained a significantly higher score for the awareness of goal setting (n = 20, M = 3.98, SD = 0.64) than the control group students (n = 24, M = 3.39, SD = 0.64), t = 3.02, p = 0.004, Cohen's d = 0.92. The experimental group students obtained a significantly higher score for the awareness of task strategies (n = 20, M = 4.06, SD = 0.60) than the control group students (n = 24, M = 3.35, SD = 0.55), t = 4.09, p = 0.000, Cohen's d = 1.23. For the awareness of time management, the experimental group students (n = 20, M = 3.88, SD = 0.69) also performed better than the control group students (n = 24, M = 3.36, SD = 0.61), t = 2.67, p = 0.011, Cohen's d = 0.79. On the other hand, the experimental group students (n = 20, M = 4.16, SD = 0.53) also obtained significantly higher scores than the control group students (n = 24, M = 3.47, SD = 0.44) in the dimension of help-seeking, t = 4.71, p = 0.000, Cohen's d = 1.42. Finally, in the dimension of self-evaluation, the experimental group students (n = 20, M = 3.94, SD = 0.69) also performed better than the control group students (n = 24, M = 3.26, SD = 0.60), t = 3.47, p = 0.001, Cohen's d = 1.05. Furthermore, Cohen (1988) indicated that a Cohen's d value greater than 0.05 represents a medium effect size, while a Cohen's d value greater than 0.80 represents a large effect size; this result, therefore, indicated a rather good effect size.

5.4. Analysis of learning logs

In order to understand the students' actual performance and awareness in the self-regulated flipped classroom approach, the students' learning logs from the out-of-class learning systems and self-regulated monitoring system were investigated. After excluding the incomplete data, a total of 11 students' self-evaluation scores were obtained. Table 10 shows the average scores and average times according to the experimental students' learning logs. According to the statistics, it was found that the students expected to score 82.27 on average in the first learning phase (SES 1) compared with 81.82 in the second learning phase (SES2). Furthermore, the system records showed that the students scored 80.18 and 89.76 on average in the first (SRS1) and the second (SRS2) out-of-learning periods, respectively. Moreover, the students evaluated that they could get 82.27 and 80.90 in the first (SVS1) and the second (SVS2) learning phases, respectively, after they finished the individual phases.

On the other hand, the students considered that they would spend 27.27 and 25.91 min on average in the out-of-learning periods of the first (SET1) and second (SET2) phases, while the system records reported that they actually spent 15.27 and 22.18 min on average (SRT1 and SRT2).

Table 9
The independent t-test result for the students' awareness of self-regulation in each dimension.

Dimension	Group	N	Mean	SD	t	d
Goal setting	Experimental group	20	3.98	0.64	3.02^{**}	0.92
	Control group	24	3.39	0.64		
Environment structuring	Experimental group	20	3.98	0.64	1.41	0.45
	Control group	24	3.70	0.61		
Task strategies	Experimental group	20	4.06	0.60	4.09^{***}	1.23
	Control group	24	3.35	0.55		
Time management	Experimental group	20	3.88	0.69	2.67^{*}	0.79
	Control group	24	3.36	0.61		
Help seeking	Experimental group	20	4.16	0.53	4.71^{***}	1.42
	Control group	24	3.47	0.44		
Self-evaluation	Experimental group	20	3.94	0.69	3.47^{**}	1.05
	Control group	24	3.26	0.60		

*p<.05, **p<.01, ***p<0.001.

Table 10
The description of the students' learning logs in the experimental group.

Dimension	Variable	N	M	SD
Goal setting (overall learning scores)	SES1	11	82.27	6.47
	SES2	11	81.82	7.83
System recorded (actual out-of-class learning scores)	SRS1	11	80.18	11.88
	SRS2	11	89.76	11.02
Self-evaluation (overall learning scores)	SVS1	11	82.27	6.47
	SVS2	11	80.90	8.01
Goal setting (expected out-of-class learning times)	SET1	11	27.27	14.72
	SET2	11	25.91	15.14
System recorded (actual out-of-class learning times)	SRT1	11	15.27	6.65
	SRT2	11	22.18	14.57

Employing the Pearson's correlation coefficient analysis, the learning logs of the students in the experimental group are further discussed, as shown in Table 11. For the research sample (n = 11), significantly, the students' self-evaluation score for the first learning phase (SVS1, M = 82.27, SD = 6.47) was positively correlated with their goal setting score for the second learning phase (SES2, M = 81.82, SD = 7.83), $r = 0.71$, $p < 0.01$. The students' self-evaluation score for the second learning phase (SVS2, M = 80.90 SD = 8.01) was positively correlated with their goal setting score for the second learning phase (SES2, M = 81.82, SD = 7.83), $r = 0.92$, $p < 0.001$). Moreover, their self-evaluation score in the second period (SVS2, n = 11, M = 80.90, SD = 8.01) was positively correlated with their self-evaluation score in the first learning phase (SVS1, M = 82.27, SD = 6.57), $r = 0.53$, $p < 0.05$). This indicates that the students might refer to their previous performance for setting new learning goals and for evaluating their current performance.

In addition, the expected learning time set by the students in the second learning phase (SET2, n = 11, M = 25.91, SD = 15.14) was highly correlated with that set in the first learning phase (SET1, n = 11, M = 27.27, SD = 14.72), $r = 0.65$, $p < 0.01$. It was also found that the students' expected learning time for the first learning phase (SET1, n = 11, M = 27.27, SD = 14.72) was negatively correlated with their expected score in the same phase (SES1, n = 11, M = 27.27, SD = 14.72), $r = -0.56$, $p < 0.05$. This implies that when the students planned the expected learning time for the next phase, their learning time in the previous phase was taken into account. Moreover, at the beginning of the learning activity (i.e., the first learning phase), the students expected to spend less time and get a higher score, while in the later learning phase, their plan better met their actual needs.

6. Discussion and conclusions

Recently, the implementation of flipped classrooms has been increasingly discussed. Some practical research has revealed the advantages of flipped classrooms, and proved that this learning mode can benefit students' learning. However, several researchers have proposed the importance of proper learning guidance and learners' presence in the context of flipped classrooms. In order to assist students in experiencing active learning and self-regulated learning in this learning mode, in this study, a self-regulated flipped classroom approach was developed for assisting students' out-of-class learning and improving the quality of the in-class interaction with peers and teachers. An experiment was conducted in an elementary school to evaluate the proposed learning approach. The experimental group learned with the self-regulated flipped classroom approach, while the control group conducted the conventional flipped classroom approach. The experimental results showed that the proposed approach significantly benefited the students' learning achievement, self-efficacy, and self-regulation.

These findings provide evidence that self-regulated learning strategies can benefit students in terms of the deliberate construction of knowledge and the use of effective learning strategies (McNamara, 2011). This kind of learning strategy applied in the flipped classroom provides a strong learning mechanism by which students can monitor their personal learning process and evaluate the most appropriate learning strategies for them. This result also conforms to the theory proposed by Zimmerman, Bonner, and Kovach (1996) that the integration of self-regulated learning into courses can improve students' learning achievements. Moreover, this study allowed the students to experience active learning and receive personalized feedback based on their learning status, which improved their self-efficacy (Bandura, 1997).

According to the two way ANCOVA results, there was an interesting finding that the self-regulated learning strategy strongly benefited the higher self-regulated students in the experimental group. It was concluded that the students who were used to higher self-regulation had already understood the strategy of planning and using study time and learning effectively by themselves (Eilam & Reiter, 2014; Stoeger, Fleischmann, & Obergriesser, 2015; Uzuntiryaki-Kondakci & Capa-Aydin, 2013). Therefore, those students can be stimulated easily when learning in the scenario of self-regulation. In this situation, those teachers who plan to conduct in-class activities could take more care of the lower self-regulated students. In the meantime, the overall performance of self-regulation in the experimental group was significantly better than that of the students in the control group. It is concluded that regardless of whether students engage in higher or lower self-regulation, they can improve their awareness of self-regulation when learning with the self-regulated flipped classroom approach.

Table 11
The correlation of the students' learning logs.

	SES1	SES2	SRS1	SRS2	SVS1	SVS2	SET1	SET2	SRT1	SRT2
SES1	1									
SES2	−0.18	1								
SRS1	0.26	−0.24	1							
SRS2	−0.03	−0.28	0.45	1						
SVS1	−0.31	0.71**	−0.45	−0.34	1					
SVS2	−0.03	0.92***	−0.24	−0.27	0.53*	1				
SET1	−0.56*	0.05	−0.35	−0.17	0.35	0.15	1			
SET2	−0.37	−0.04	−0.28	−0.38	−0.04	−0.06	0.65**	1		
SRT1	0.09	−0.30	0.33	0.01	−0.22	−0.18	−0.01	0.21	1	
SRT2	0.22	0.01	−0.14	−0.02	−0.38	−0.01	0.02	−0.29	−0.15	1

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

Moreover, the students who learned with the self-regulated flipped classroom approach showed higher performance in goal setting, task strategies, time management, help seeking, and self-regulation. This implies that the monitoring and diagnosis mechanism in the proposed approach engaged the experimental group students in empowering their self-observation, ascertaining the learning strategies they applied, and being personally aware of their effective learning (Ferreira, Simao, & da Silva, 2015). These results also conformed to the correlation results of students' learning logs which proved that their self-evaluation scores were associated with their following goal setting and performance evaluation. While no significant difference was found in the dimension of environment structuring, it makes sense that both groups of students learned with similar approaches (i.e., out-of-class e-book learning and in-class discussion) and learned in the same places (i.e., in class or at home).

In sum, the major contribution of this study is to evidence that integrating the self-regulated strategy into flipped learning can improve students' self-efficacy as well as their strategies of planning and using study time, thus further improving their learning achievements. This also implies that students' learning performances in flipped classrooms might not be as good as expected without self-regulated support. On the other hand, the limitations of the present study need to be noted. As the sample size of the experiment was not large, it might be imprecise to infer the findings to other cases. In addition, owing to the limitation of the measuring tools, the analysis results might contain some bias.

Consequently, several follow-up studies can be considered, such as the application of proper learning strategies in flipped classrooms and the investigation of the relevant issues with large sample size and long-term experiments. In the future, we plan to investigate the effects of self-regulation in a long-term flipped classroom in an elementary school social studies course, and to discuss the actual behaviors and learning performance of the students learning with different flipped classroom approaches.

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