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The effects of the regulated learning-supported flipped classroom on student performance

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Abstract

Flipped classrooms have been growing in popularity in higher education for their potential to promote students' active engagement in learning. Ironically, the key to the success of flipped classrooms is the agency of students to actively participate in learning. The flipped classroom approach requires students' responsibility for their learning and a high level of self-regulation in completing individual and collaborative learning tasks. However, many college students tend to be more comfortable with a traditional, passive form of lecture-based course and are not yet prepared for an active form of learning. In this study, we developed a regulated learning-supported flipped classroom framework grounded in self-regulation and social regulation research. The purpose of this study was to investigate the impact of the regulated learning-supported flipped classroom on student engagement and performance. Our results showed that the flipped classroom with regulation guidance had a significant influence on students' use of higher-order cognitive skills. The implications of this study are further discussed based on the findings.

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Introduction

In recent years, flipped classrooms have become popular in higher education for their potential to promote students' active learning (O'Flaherty & Phillips, 2015). In a flipped classroom, in-class time is dedicated more to active forms of learning such as group discussion and collaborative problem solving while a passive form of learning such as listening to lectures is completed individually at home (Bishop & Verleger, 2013). Prior to in-class sessions, instructors provide pre-recorded lectures online and individual students watch the lectures and acquire essential knowledge for the class. Students then spend in-class time engaging in interactive, higher-order group activities. This model thus allows students to actively engage in richer learning activities and enables instructors to interact frequently with individual students and monitor their performance in class (Bergmann & Sams, 2012).

In flipped classrooms, students' ability to regulate learning must play a significant role for the intended learning to occur (Sletten, 2017; Sun et al., 2018). During the pre-class phase in flipped learning, since the pre-class exposure to learning materials is a key element for successful learning in class, students must devote time to independently study the pre-recorded lectures and gain foundational knowledge (Herreid & Schiller, 2013; Kim et al., 2014; Lee et al., 2016). In addition to regulating individual and independent learning at home, students need to proactively participate in collaborative activities, negotiate with others, and develop shared knowledge during the in-class phase while they are coordinating and monitoring group work (Chan, 2012; Hsu, 2018; Lee, 2017).

Unfortunately, many college students do not seem to have adequate levels of regulated learning skills. Past research has shown that students in flipped classrooms demonstrated poor self-regulated learning behaviors and low responsibility for their learning (Lai & Hwang, 2016; Sun et al., 2017). Students often attended class without watching the pre-recorded lectures and completing pre-class assignments and demonstrated a low level of engagement in group activities in class (Jo & Kim, 2016; Patanwala et al., 2017). Students seem to be accustomed to a passive learning environment and resistant to the new teaching approach of flipped classrooms (Herreid & Schiller, 2013; Long et al., 2017). Thus, students are not properly prepared for an active way of learning (Hao, 2016). For college students to fully benefit from flipped learning, it seems critical to develop their capability to regulate their individual and group learning.

To the best of our knowledge, there is relatively little empirical research to support college students' regulated learning in flipped classrooms. In this study, we proposed a flipped classroom design framework that incorporates regulated learning guidance in a university course. The purpose of the study is to examine the effects of the regulated learning-supported flipped classroom (RL-FC) on student learning and engagement.

Literature review

Flipped classrooms

The flipped classroom approach has been recognized as an innovative teaching method to promote student engagement, as it provides the formation of learning environments that encourage students to actively engage in the learning process (Bergmann & Sams, 2012). In the flipped classroom, students study online materials on their own before a class, and they can do so at their own speed and in their own time, which enhances students' feelings of control over the learning process (Braun et al., 2014). Given such preparation for the class, it is expected that students' engagement in in-class learning such as higher-order problem-solving activities will be enhanced, which facilitates a deep understanding of the class material (Akçayır & Akçayır, 2018). Research has reported empirical evidence for the positive impact of flipped classrooms on student engagement and learning (Fisher et al., 2018). For example, students in flipped classrooms spent more time completing assignments and preparing for exams compared to those in traditional classrooms (Burke & Fedorek, 2017). Also, students in flipped classrooms reported that they developed a better understanding of course contents and gained more knowledge, resulting in higher course grades (Chiang & Wang, 2015; Foldnes, 2016; Galway et al., 2014).

Despite the positive effects of this new learning approach, flipped classrooms have also faced several challenges, as often reported in the literature. One common issue associated with flipped classrooms is that students do not often complete the self-study before a class (Chuang et al., 2018; Filiz & Kurt, 2015; Lo et al., 2017). For example, over 70% of students in a calculus flipped classroom did not watch the pre-class instructional videos (Palmer, 2015). These students had difficulty in adapting to flipped learning and failed to engage in in-class discussions (Chen et al., 2014). Preparation before class significantly influenced participation and active engagement in in-class activities (Kim et al., 2014; Mason et al., 2013).

In addition, a few researchers have pointed out that students experience difficulty participating in and adapting to collaborative group learning (Halili et al., 2014; Kim et al., 2014). In flipped classrooms, students are expected to apply prior knowledge and construct new knowledge by working collaboratively with others. For productive collaborative learning to occur, students need to support others members' learning, and the group should be able to collectively regulate learning processes (Winne et al., 2013). However, the literature on collaborative learning has often reported on the challenges and problems students encounter in group work (Le et al., 2018). For example, students showed low commitment to group work (Pauli et al., 2007), poorly coordinated group interaction, and had few productive group discussions. (Barron, 2003). Moreover, students' lack of communication and collaboration skills hindered group functioning and collaborative knowledge construction in group work (Popov et al., 2012; Ross, 2008).

In short, despite the fact that the flipped classroom approach offers a rich learning environment where students can be involved in active learning, students must

be ready to take advantage of this new opportunity. Flipped classrooms require students to take more responsibility for constructing their knowledge and participating in group work actively using their prior knowledge. It is certainly a new way of learning for students who are accustomed to a traditional, passive method. In fact, some students reported a preference for attending lectures, as they could ask questions and receive just-in-time feedback (Mazur et al., 2015). Flipped classrooms will be even more challenging for students who are less inclined to self-regulated learning (Kalman & Blau, 2017; Keengwe et al., 2014). Thus, as Kim et al. (2014) pointed out, proper support for students' regulation of learning will be beneficial to successful flipped classroom learning.

Regulation processes involved in individual and collaborative learning

Researchers have argued that three modes of regulation processes are essential for successful learning or collaborative learning, namely (1) self-regulation, (2) shared regulation, and (3) co-regulation (Järvelä et al., 2016). First of all, *self-regulation* is what has been considered for decades as a critical skill for any learning (Zimmerman & Martinez-Pons, 1986). Traditionally, self-regulated learning refers to learners' *proactive* use of cognitive, metacognitive, and motivational strategies in the learning process in order to achieve effective learning and performance (Pintrich, 2000; Zimmerman & Schunk, 2011). For example, self-regulated learners plan their learning, implement the plan with effective learning strategies, and use metacognitive strategies to monitor and evaluate their progress and learning outcomes (Zimmerman & Martinez-Pons, 1986). Also, self-regulated learners usually sustain a high motivation to learn combined with clear learning goals and a strong belief in their ability as a learner (Pintrich, 2000). In the context of collaborative learning in particular, self-regulated learning refers to *individual* students' metacognitive control over their cognitive, behavioral, and motivational processes in learning through iterative processes of planning, monitoring, evaluation, and adaptation (Hadwin et al., 2018).

According to Zimmerman (2002), the self-regulated learning process involves three cyclical phases: the forethought phase before learning, the performance phase during learning, and the self-reflection phase after learning. In the forethought phase, self-regulated learners set specific learning goals and adopt strategies to attain those goals. Through goal-setting, students identify specific learning outcomes they want to reach (Zimmerman, 1999). Goal setting provides criteria for monitoring students' progress in learning and facilitates the use of cognitive and metacognitive learning strategies (Pintrich & De Groot, 1990; Schunk, 2000). Moreover, student-initiated learning goals are usually connected to their personal interests, which can help students persist in learning. In the performance phase, students execute the strategies selected during the forethought phase and monitor their performance and progress. For example, students can self-record their use of time to track the time they spend studying. Another common monitoring strategy is self-questioning: Students can ask themselves questions about what they have learned to check if they have correctly understood it (Wong & Jones, 1982). In the last phase of self-regulated learning, the self-reflection phase, students

evaluate their learning outcomes according to the learning goals they previously established. Based on their evaluation, students modify or refine their learning strategies to improve subsequent learning (Zimmerman, 2008).

Besides the regulation of an individual's own learning (i.e., self-regulation), researchers have proposed that two other forms of regulation are critical for collaborative learning. One of these is the regulation of a group's learning, the so-called *shared regulation* (Volet, et al., 2009a, 2009b). Shared regulation involves group members taking control of the task together through shared planning, monitoring, and reflection processes to achieve a joint task (Hadwin et al., 2018). Effective shared regulation usually emerges from the group interactions involved in goal setting, co-construction of knowledge, and monitoring and overcoming challenges (Järvelä & Hadwin, 2013).

Collaborative learning also includes a co-regulation process (Järvelä & Hadwin, 2013). Co-regulation is broadly understood as the dynamic metacognitive processes that take place among two or more collaborators to support the emergence of self-regulation and the shared regulation of learning (Hadwin et al., 2018). It involves the interaction of students indirectly offering cognitive, metacognitive, or motivational assistance to each other, which facilitates strategic individual and group monitoring, evaluation, or adaptation of their learning processes (Hadwin et al., 2011; Järvelä & Hadwin, 2013). For example, students can engage in co-regulation processes when they ask questions of each other (Volet, et al., 2009a, 2009b). Question-asking requires students to provide explanations of content knowledge. By answering the questions, students engage in knowledge building, and especially high-level questioning that can promote a deep-level engagement with content.

There have been a number of empirical studies that reported the impact of these regulation processes on student learning in the flipped classroom. For example, the level of students' use of metacognitive learning strategies had a significant relationship with their pre-class preparation as well as their final grades (Shibukawa & Taguchi, 2019; Sletten, 2017). When students were prompted to use self-regulated learning strategies such as goal setting and self-evaluation in a flipped learning environment, they indeed demonstrated greater self-regulation and higher performance than those who had a flipped classroom without self-regulation prompts (Lai & Hwang, 2016). Sun et al. (2018) also reported a similar finding that self-regulated students demonstrated higher achievement scores in a flipped classroom. Moreover, other researchers studied the impact of shared regulation and co-regulation in flipped classrooms. Blau and Shamir-Inbal (2017), for example, conducted qualitative analysis of students' reflections on flipped learning components and reported that the processes of group regulation (i.e., co-regulation and shared regulation) were manifested in the learning processes. The study indicated that such regulation skills were essential for students to successfully complete group work.

Research questions

This study aims to address the problem of poor regulation skills of college students in flipped classroom by developing a flipped classroom design framework that is designed to facilitate the students' regulated learning processes. Based on the

framework, we implemented a regulated learning-supported flipped classroom (RL-FC) in a university course. The purpose of the study is to examine the impact of the RL-FC on student engagement and performance. Although students' involvement in active learning is at the mercy of their willingness, our proposed model aimed to offer a structured approach to regulation support in flipped classrooms and promote students' regulated learning processes. In particular, the following three research questions are addressed in the study:

1. What is the effect of the RL-FC on student engagement in pre-class learning?
2. What is the effect of the RL-FC on individual performance?
3. What is the effect of the RL-FC on students' collaborative performance?

Design framework of regulated learning-supported flipped classroom

Our instructional design framework for the RL-FC was developed based on the theoretical models of self-regulated learning (Zimmerman, 2002, 2008; Zimmerman & Martinez-Pons, 1986) and collaborative regulation, including co-regulation and shared regulation (Salonen et al., 2005; Volet, et al., 2009a, b). In our framework, we propose three phases of RL-FC reflecting the three phases of self-regulated learning proposed by Zimmerman (2002): *planning*, *monitoring*, and *evaluation*. Within each phase, regulated learning supports are integrated at the individual and group levels. Figure 1 presents the regulated learning supports incorporated in each phase of our flipped classroom framework.

The planning phase applies to the pre-class learning phase in the typical flipped classroom model. In our RL-FC framework, three steps are designed to foster students' self-regulatory processes: (1) goal setting, (2) summary writing and quizzes, and (3) questioning and sharing ideas. First, students were asked to set up their own learning goals after watching video lectures and reviewing the learning materials. After setting their goals, students summarized what they had learned and took

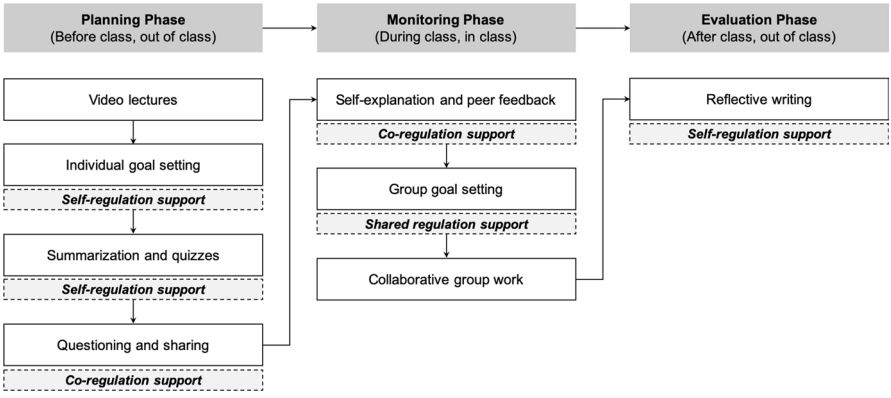

Fig. 1 Phases, learner activities, and guidance for regulated learning in the RL-FC framework

quizzes. By summarizing the learned content, students can reflect on their knowledge, and by taking quizzes, they can assess their learning. Self-evaluation of one's learning progress is an important self-regulatory skill (Zimmerman & Martinez-Pons, 1986). In the final step of the planning phase, students shared the learning goals they set, along with other ideas and questions about the content, with their peers in an online discussion forum and received comments from peers and the instructor. Interacting with others fosters the co-regulated learning process that can subsequently promote an individual's own self-regulatory process (Hadwin & Oshige, 2011). For example, students can build more meaningful goals and modify their understanding of the topic through comparing their own goals and knowledge with those of their peers.

The monitoring phase refers to the in-class learning phase of the flipped classroom model involving various types of collaborative work. Before the collaborative work, two learning activities were integrated particularly to foster students' regulatory processes: (1) self-explanation and peer feedback and (2) group goal setting. First, students engaged in a self-explanation activity in a small group. Self-explanation is not only an effective learning strategy for enhancing the understanding of content learning but also an essential self-regulatory cognitive strategy, which is a so-called 'elaboration' (Chi et al., 1994; Wolters et al., 2005). During the self-explanation activity, students described their own understanding of the important concepts learned and received feedback from peers to correct any misunderstandings. This activity was designed to promote the co-regulation of students in particular, as they could monitor and adjust their understanding through interaction with peers. It can also enhance students' understanding of the background knowledge, which would lead to the use of more high-order cognitive skills in the subsequent collaborative activity. In addition, group goal setting can help students mutually monitor their collaborative learning process, provide support for each other, and make consistent efforts to complete the joint task. That is, a group goal-setting process is expected to foster the shared regulation of a group (Järvelä & Järvenoja, 2011). After setting the group goals, students engaged in group activities such as discussion and collaborative knowledge building during the monitoring phase of RL-FC.

The last phase of RL-FC, the evaluation phase, corresponds to post-class learning. This phase was designed to foster students' self-regulation by engaging in self-reflective activities. After the class, students reflected on their collaboration process, considering the time and effort they had put in. They were also asked to evaluate their individual and group achievement according to the learning goals they had set up in the previous phases.

Methods

A quasi-experimental design was employed in this study to investigate the effects of the RL-FC on student engagement and performance. The control group was taught using a traditional flipped classroom (FC) approach whereas the treatment group featured a flipped classroom based on the RL-FC design framework.

Context and participants

This study was conducted in two classes of a career planning course at a large private university in South Korea. The same instructor taught both classes, and each of the classes was randomly assigned to either the control or treatment group. Freshmen from a wide variety of majors take this course to fulfill their general education requirements. In this course, students explored their career goals and personal characteristics, learned strategies for decision-making, researched different careers, and developed a career plan. The flipped classes were offered during the first four weeks of the 16-week course.

Out of a total of 93 freshman students enrolled in the two sections of the course, 87 students agreed to participate in the study. Forty-two students participated in the FC group, and 45 students participated in the RL-FC group. Participants represented various majors including education, political science, communications, and business. Of the 87 participants, there were 45 female students (51.7%) and 42 male students (48.3%). The average age of the participants was 19 ($SD = 0.85$).

Description of the two flipped classrooms

Two topics were covered in the flipped classroom sessions of the course: the Myers-Briggs Type Indicator (MBTI) Personality Framework and the Holland Code. In Week 1, the instructor (Author I) provided an introduction to the flipped classroom and explained the expectations for students in this type of class. The instructor emphasized, in particular, the completion of pre-class preparation activities. The two topics of the flipped classroom sessions were taught in Weeks 2 and 3. In Week 4, students in both FC and RL-FC took a quiz that assessed their understanding and application of the knowledge about the MBTI Personality Framework and the Holland Code. Figure 2 summarizes the learning procedures in the FC and RL-FC. The primary difference between the two groups was whether the guidance for regulation was provided or not in each phase of the flipped classroom.

In the pre-class learning phase, students in both the control and treatment groups watched two video lectures, each of which was approximately 20 min long. After watching the lectures, students answered multiple-choice conceptual questions (e.g., "Which one is the wrong description of the MBTI evaluation?") and posted questions related to the topic on a discussion board. Additionally, students in the RL-FC group engaged in two more activities that were designed to promote students' *self-and co*-regulation. First, RL-FC students were required to set up their personal learning goals and summarize what they had learned (see Fig. 3). Then, they were required to share their learning goals along with content-related questions on an online discussion board. Second, students received personalized feedback from the instructor and peers on their postings. Students spent approximately 40 min in the FC group and 50 min in the RL-FC group to complete the pre-class activities.

During the in-class learning phase, students in both FC and RL-FC groups participated in collaborative activities, which lasted for 100 min, in small groups

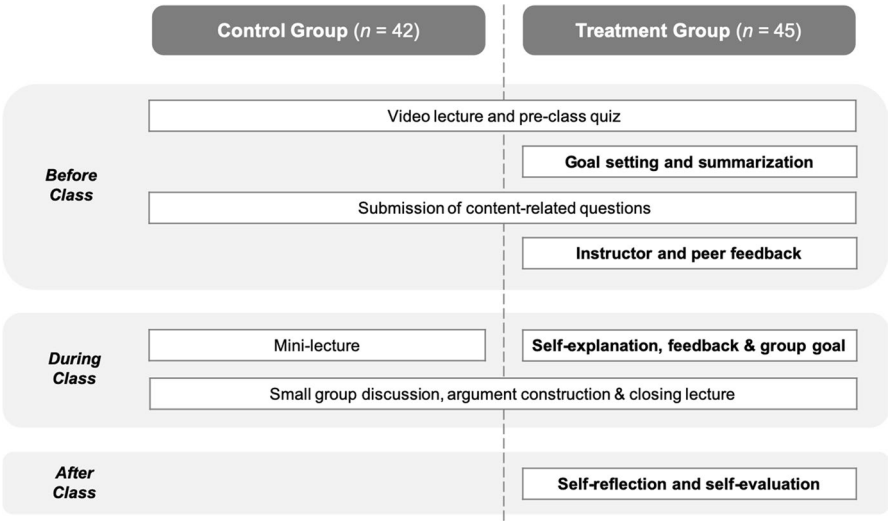

Fig. 2 Procedures in the FC and RL-FC

consisting of 3–4 students; however, the format of the class was slightly different between FC and RL-FC groups. The instructor in the FC group started the class with a 10-min lecture on the main concepts of the topic. Then, students engaged in a small group discussion in an online forum. The instructor provided a real-life case about a college student who was considering various career options, such as middle school teacher, researcher/college professor, businessman/entrepreneur, and entertainment producer. Students were asked to discuss different personality types and how well they might be suited to the listed career options. The discussion was held in an online text-based chat environment for about 30 min. After the discussion, each group was asked to develop an argument about the most suitable job for the student in the case based on his MBTI results. At the end, the instructor provided a closing mini-lecture to address students' questions about the topic.

Students in the RL-FC group, on the other hand, did not receive the instructor's mini-lecture at the beginning. Instead, students completed tasks that were designed to promote *shared* and *co*-regulation. First, students participated in a self-explanation activity in a small group. They collaboratively completed a worksheet to describe the concepts they had learned from the pre-class materials as they shared and discussed their own understanding and ideas with peers. This activity was intended to help students monitor and refine their understanding of the topic. Next, students were asked to set up group-level learning goals. Then, as in the FC group, students engaged in online text-based discussion and argument-building activities and received a mini-lecture at the end of the class.

For the RL-FC group, the post-class learning phase was implemented after the in-class sessions, which corresponds to the evaluation phase of our RL-FC framework. In this phase, students wrote a reflective journal responding to the guiding questions provided by the instructor. Students reported their group's collaboration processes

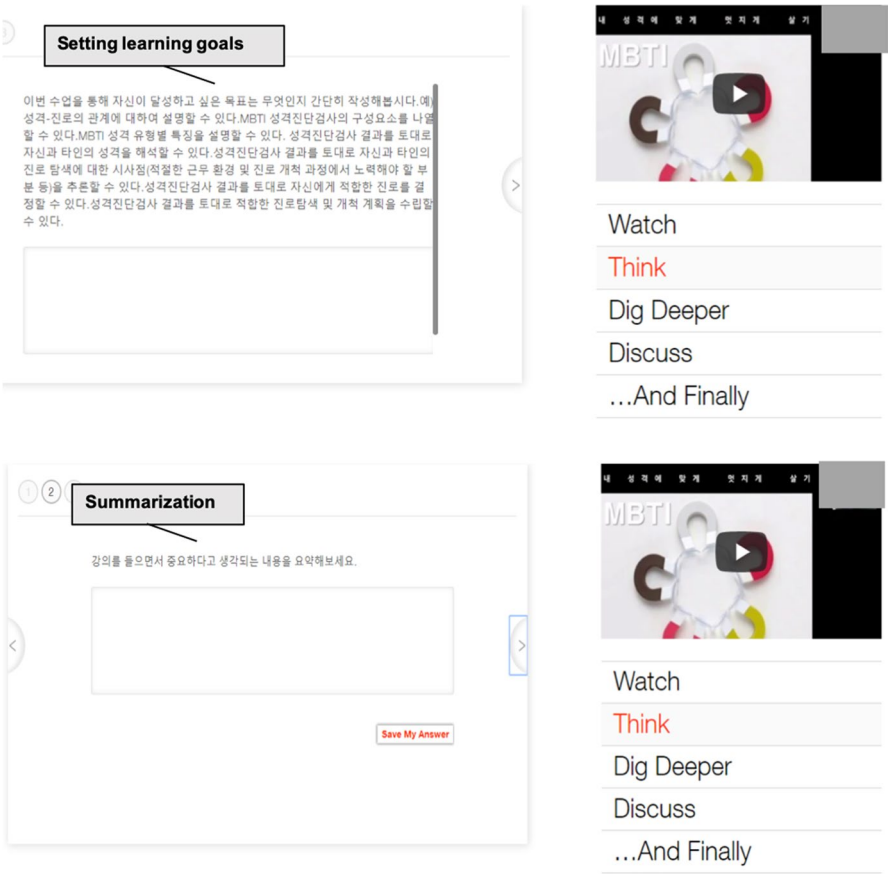

Fig. 3 Interface of learning goal setting and summarization in the planning phase of the RL-FC

and reviewed individual and group achievement according to the goals they had set up in the previous phase. Also, they were asked to provide suggestions for improving their learning.

Data collection and analysis

To begin with, we assessed students' online learning efficacy (OLE), discussion efficacy (DE), and prior knowledge of the MBTI and Holland Code during Week 1 in order to determine the equivalence of the FC and RL-FC groups before engaging in the flipped learning sessions. The OLE and DE questionnaires were developed and validated by Kim (2010) to assess students' perceived confidence to learn in online environments and to participate in group discussions. Each of the questionnaires was composed of 10 items, which students rated on a 5-point Likert scale. In this study, Cronbach's α of the OLE and DE were 0.82 and 0.77, respectively. To assess the

students' initial understanding of the MBTI and Holland Code, the instructor developed 5 multiple-choice items, and students completed them on the first day of class. Two professors of Career Education other than the course instructor independently reviewed these items to establish their content and face validity. Both professors agreed that the items matched the two domains being measured.

To measure students' engagement in the pre-class learning, we calculated the number of students who completed the preparation activities in each of the two groups. If students completed all of the preparation activities including the quiz, learning goal setting and summarization (RL-FC group only), and question sharing, we coded them as 'complete'; if they did not complete any of these preparation activities, they were coded as 'incomplete.' Then, chi-square tests were performed to examine the difference in the number of students who completed the preparation activities between the FC and RL-FC groups.

To assess students' individual performance, a brief test of conceptual understanding was administered in Week 4. The test, developed by the instructor, comprised 10 knowledge and application questions, including 6 multiple-choice items (e.g., "Which personality category in Myers-Briggs theory does the following case illustrate?") and 4 open-ended questions (e.g., "What career path would you recommend to a friend who has the MBTI personality type of ISTJ? And why?"). More sample test questions are provided in the Appendix. Students' answers to the open-ended questions were scored based on the extent to which they understood the theory and used theoretically accurate logic. Once the total scores of individual students were calculated, a t-test was used to compare scores between the FC and RL-FC groups. Without a significant association between prior knowledge and quiz scores ($p = 0.342$), prior knowledge was not included as a covariate in the analysis.

Students' collaborative performance was measured by assessing the quality of the groups' written arguments. An argument analysis framework developed by Yang et al. (2009) was adapted to evaluate the quality of group arguments. The analysis framework included three components of an argument: claim, evidence, and reasoning. A claim is defined as a conclusion that answers the original question; evidence is defined as data that supports the claim; reasoning is defined as a justification that links the claim and evidence. Based on Yang et al. (2009)'s framework, we developed a rubric that guided the scoring of how well students provided each of the three components in their arguments (see Table 1). A score of each component of an argument ranged from 1 to 5, which added up to a total argument quality score of 3 to 15.

From both FC and RL-FC groups, a total of 38 arguments were identified. Authors III and IV jointly segmented each argument into different components, and then independently evaluated a small sample (20%) of the arguments and assigned scores based on the framework. The inter-rater reliability between the two coders for the sample arguments was adequate (Cohen's $k = 0.952$). After further discussion by the two researchers to resolve disagreements in coding, Author IV coded the remaining arguments. Table 2 presents examples of argument coding and scoring. The argument quality score was calculated by adding up the scores of the three components. Mann–Whitney U tests were used to compare the argument quality scores

Table 1 Group argument analysis framework: components of an argument and descriptions of the components at different levels of quality

	Components of an argument		
	Claim	Evidence	Reasoning
5 points	Claim is specific and clear, considering alternative claims associated with the topic	Evidence is from the source material and relevant, well-integrated, and specific	Reasoning clearly links evidence to claim; clear and specific
4 points	Claim is specific and understandable to others	Evidence is from the source material, relevant and well-integrated, yet general	Reasoning adequately links claim to evidence, yet is general
3 points	Claim is understandable to others	Evidence is from the source material and relevant to the claim, but some pieces of evidence are weakly integrated	Reasoning adequately links claim to evidence, but it is not clear enough
2 points	Claim is relevant to the topic, but it is not explicitly stated	Evidence is relevant to the claim, but statements are somewhat vague and mainly drawn from personal experience	Reasoning is insufficient and relates only tangentially to the claim
1 point	Claim is not provided or irrelevant to the topic, or simply re-states the topic	Evidence is irrelevant to the claim, incorrectly used, or not provided	Reasoning is poorly provided or not provided

Table 2 Argument analysis examples

Arguments	Claim	Evidence	Reasoning
"We recommend counseling psychology or art-related jobs for the INFP type. We think the best job for this type is a middle school teacher because it involves a lot of communication with students."	3	1	1
"I think that a middle school teacher is most suitable for the INFP type. (1) 'I' is characterized by being calm, and with this characteristic, he seems to be able to lead a class well. There is a tendency to enjoy being alone for this type of person and establishing a deep relationship with a small number of people. Middle school students are still young kids, so it is expected that many of them are friendly, so they would come first even if he himself does not approach them. So I think that there should be no problem for them to get to know each other. (2) 'N' is characterized by focusing on the possibility of the future and considering changes and diversities in priority. Middle school teachers should be able to predict some degree of potential in their students and give advice, so I think the job is appropriate in this regard. Also, middle school students experience many changes physically and emotionally, and a teacher needs to care for such changes, so I think it is appropriate. (3) 'P' is characterized by openness to fit the circumstance. I think a middle school teacher is appropriate because they could take appropriate actions for students who make trouble or are free-spirited considering their circumstances. (4) 'F' is characterized by making a right decision, taking into account people's feelings. It is important to have an attitude that sympathizes with and understands the feelings of their students, since many middle school students are in puberty. Also, they are sensitive to others' emotions and feelings so that they are able to recognize the feelings of others quickly. Thus, a middle school teacher is suitable for people who have this type of characteristic. There might be many children who are reluctant to tell their parents or teachers about what's going on in their lives. This type of person would be able to notice their students' changes sensitively, understand their feelings and make them feel comfortable. So, a middle school teacher seems to be appropriate	4	3	5

between the treatment and control groups. The data sources and analysis methods aligned with the research questions are summarized in Table 3.

Results

Preliminary analyses

A series of *t*-tests was conducted to examine the equivalence between the control and treatment groups before students participated in the flipped classroom sessions. There were no significant differences in students' OLE, DE, and prior knowledge of MBTI and Holland Code between the two groups (see Table 4).

Table 3 Alignment of research questions, data sources, and analysis methods

Research questions	Data sources	Analysis methods
1. What is the effect of the RL-FC on student engagement?	Completion of the pre-class activities	Chi-square tests
2. What is the effect of the RL-FC on individual performance?	Quiz scores	*t*-tests
3. What is the effect of the RL-FC on collaborative performance?	Group arguments	Content analysis and Mann–Whitney U

Effects on student engagement

Chi-square tests indicated no significant associations between the type of flipped classroom and the completion of the preparation activities in the two flipped classroom sessions (Session 1, χ^2 (5) = 0.22, p = 0.636; Session 2, χ^2 (5) = 0.161, p = 0.688) (see Table 5).

Effects on individual performance

The results of *t*-tests showed a significant difference between the FC and RL-FC in knowledge test scores, $t(75) = -1.658$, $p < 0.05$ (see Table 6). The effect size was moderate, Cohen's $d = 0.54$.

Table 4 Equivalence between the control and treatment groups

	FC (n = 42)		RL-FC (n = 45)		*t*	*p*
	M	SD	M	SD		
OLE	4.13	0.65	3.95	0.69	1.26	> .05
DE	3.57	0.47	3.54	0.60	0.26	> .05
Prior knowledge	2.98	0.60	3.00	0.57	-0.16	> .05

Table 5 Contingency table showing the number of students who completed preparation activities in two types of flipped classrooms

	Session 1		Session 2	
	FC	RL-FC	FC	RL-FC
Preparation activity completion				
Complete	16	17	36	35
Incomplete	26	28	6	10
Total	42	45	42	45

Effects on collaborative performance

The scores of argument quality in the FC group were not significantly different from those in the RL-FC group in Session 1, $U = 23.50$, $p = 0.079$ (see Table 7). However, in Session 2, the quality of arguments in the RL-FC group was significantly higher than that of the FC group ($n = 9$, $Mdn = 8.00$), $U = 0.00$, $p = 0.000$). Table 8 presents sample arguments of the RL-FC group in Session 1 and 2.

Discussion

In this study, we developed an instructional design framework of RL-FC and examined its effects on student engagement and performance. The RL-FC framework was grounded in the research on self-regulation (Zimmerman, 2002, 2008) and co- and shared regulation (Hadwin et al., 2018; Volet, et al., 2009a, 2009b). The framework included three phases of regulated learning—planning,

Table 6 Independent samples t-test for individual performance by groups

Groups	*n*	*M*	*SD*	*t*	df	*p*
FC	38	8.74	4.45	−1.66	75	< .05
RL-FC	39	11.18	4.60			

Table 7 Mann–Whitney test for collaborative performance by groups

	FC ($n = 9$)			RL-FC ($n = 10$)			*U*	*p*
	Min	Max	Mdn	Min	Max	Mdn		
Session 1	5.00	11.00	8.00	6.00	11.00	10.00	23.50	.079
Session 2	7.00	9.00	8.00	10.00	14.00	10.00	.00	.000

Table 8 Sample arguments of the RL-FC group in session 1 and 2

	Sample group arguments
Session 1	We would recommend a psychotherapist
What kind of career would you recommend to someone with an INFP personality type?	People with an INFP personality type tend to have a strong desire to help others. Psychotherapists need to have empathy for other people's problems
Session 2	We would recommend a professor
What kind of career would you recommend to someone who is 'social" according to Holland Codes?	Although professors play various roles in their profession, one of their main jobs is to teach students. Thus, professors should be able to understand and communicate well with their students. Given that 'social' people enjoy interacting with others and helping others, this type of person is well-suited to be a professor

monitoring, and evaluating—at the individual and group levels (Zimmerman, 2002). Multiple types of guidance for self-, co-, and shared regulation in learning were provided in each phase.

We hypothesized that the students who received regulation guidance would be more engaged in learning and better at individual performance as well as collaborative group performance in the learning activities. Our results showed that students in the RL-FC group performed better in the conceptual tests and the group argumentation activities than those in the FC group. The RL-FC group generated more pieces of evidence to formulate an argument, and their reasoning was more specific, with better linkages between claims and evidence. The differences in the group argumentation were more salient in the second session. On the other hand, we did not find positive results with regard to the effects of regulation guidance on engagement in pre-class learning. The amount of students' participation in pre-class activities was not significantly different between the two groups.

The findings imply that individual students in the RL-FC group not only have acquired a better conceptual understanding of the topics but also have engaged in better collaborative processes. Despite the similar level of pre-class learning completion rates between the two groups, a higher individual performance of the RL-FC group on conceptual understanding was observed, which suggests that regulation guidance in the pre-class phase (i.e., goal setting, summarization, and questioning) may have promoted a deep level of learning for individual students. In addition, the better performance in the group argumentation activities suggests that students in the RL-FC group may have engaged in a higher level of thinking to generate sound arguments. These results are consistent with the findings reported in previous studies (Blau & Shamir-Inbal, 2017; Lai & Hwang, 2016) that students with regulation support have engaged in a greater or better use of learning strategies, which has led to higher performance.

However, we did not find evidence that the regulation guidance enhanced engagement in the pre-class activities. In our study, we only looked at the "quantity" of engagement (i.e., the number of students who completed the activities). If we had examined the "quality" of engagement or learning outcomes, we might have found some difference. Nevertheless, considering the comparatively low completion rate of the pre-class activities, especially in the first session, the finding reaffirms that fostering students' participation in pre-class activities in flipped classrooms is still challenging (Patanwala et al., 2017; Shibukawa & Taguchi, 2019). It is possible that additional forms of support may be required to sufficiently promote students' engagement in pre-class activities. As Burke and Fedorek (2017) asserted, many students are not prepared for an active form of learning, and thus, students may need to be explicitly taught how to self-regulate their learning and how to work effectively in groups. According to Sletten (2017), students' use of study strategies was indeed a significant predictor of the frequency of watching pre-class videos. During the orientation session before the start of the flipped classrooms, it would be critical for instructors to not only emphasize the importance of studying the pre-class materials but also teach effective learning strategies for succeeding in flipped classrooms. Instructors could

also ask students to specify their own study plans and strategies for completing the pre-class requirements.

In addition, support for students' perceived interest and value may play an important role in enhancing engagement in pre-class learning. According to Pintrich (2004), besides goal setting, the perceived task value and interest are two other critical elements for self-regulated learning in the planning phase. To facilitate students' perception of value and interest in learning materials, for example, instructors may articulate how the topic of learning materials is related or beneficial to students' real life. As in the recent study by Shibukawa and Taguchi (2019), the sharing of learning objectives with students for their pre-class preparation could be also beneficial. Further research is necessary to determine the factors that influence students' participation in pre-class activities.

It is worthy to note that both RL-FC and FC groups showed an increase in the number of students who completed the pre-class activities from Session 1 to Session 2. Sun (2015) suggested that multiple cycles of flipped classrooms may be needed until students get accustomed to the new format of learning. In our study, the number of students that completed the pre-class learning activities in the second session was more than twice as many as the number in the first session. After only one experience of a flipped classroom, students' engagement was dramatically improved. This may also be a potential explanation for the lack of difference in the group argumentation between the two groups in the first session. It would be interesting for future studies to look at how multiple sessions of flipped classrooms influence students' engagement and performance.

Three limitations of the study should be noted. First, the study did not take students' initial level of regulatory skills into account. In this study, students were provided with the same scaffolding in two different learning sessions regardless of their initial level of self-regulation skills. It is possible that the regulation support provided in this study was not sufficient for some students to develop sufficient regulation skills. It may have been necessary for instructors to provide more guidance to less self-regulated students. Next, because we used intact classrooms for the two experimental conditions, random assignment was not possible. Lastly, this study was conducted with only a small number of participants and the generalization of the study results should be cautiously considered. Additional studies are needed to determine whether regulation support is effective with a large number of students in different contexts.

Despite these limitations, this study showed that regulation guidance in flipped classrooms benefited and enhanced students' individual learning and group performance. The value of flipped classrooms lies in student-centeredness, which requires students' self-regulated and co-regulated learning. The findings of our study imply that students' self- and co-regulation could be supported in flipped classrooms with appropriate guidance and support. In our study, based on the RL-FC framework, we implemented a few specific types of self- and co-regulation guidance such as goal setting, feedback, and reflection throughout the three phases of flipped learning (i.e., pre-, in-, and post-class). Future research should be pursued to gain more insights into how to effectively implement regulation guidance and support regulated learning in other flipped classrooms.

Appendix

1. Which personality category in Myers-Briggs theory do the following characteristics illustrate?

- Focuses on the present - Processes information through the five senses - Attends to details

   a. Extrovert
   b. Sensing
   c. Judgement
   d. Intuition

2. Which of the following jobs are best suitable for a person with the MBTI personality type of ESFP?
   a. Researcher
   b. Accountant
   c. Teacher
   d. Engineer

3. Which Holland category is a person with the following traits most likely to fit into?

- Likes to work with objects, machines, or tools - Prefers concrete, hands-on activities rather than abstract problem-solving - Lacks analytical skills - Material-oriented, practical, functional, and predictable

   a. Artistic
   b. Enterprising
   c. Realistic
   d. Social

4. Which of the following occupations do you think would be least suited for a person with a Holland code of AS? Describe why you think so.

Designer, Electric engineer, Poet, Counselor

5. What career path would you recommend to your friend with the personality trait of ISTJ? And why?

Declarations

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