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Flipping organic chemistry course: Possibilities and challenges

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Abstract. The flipped classroom approach was applied to an introductory organic chemistry course. A total of 76 video clips (15 hours of running time) were developed and delivered to 41 sophomores (21 females and 20 males) through Youtube in addition to the university's learning management system. The students were asked to preview the lecture contents before each class by watching a pre-class video. For in-class activities, exercise problems were presented to groups of 3-5 students. An instructor and a teaching assistant guided each group to solve problems cooperatively, monitored the students' group activity and answered their questions. At the end of every chapter, the students were asked to evaluate their group work and personal preparedness for the class and also to write a short reflective journal. The muddiest point of each chapter, i.e., the topic posing the most difficulty to students' understanding, was surveyed through *Google Forms*®. The students liked watching the videos before each class and performing student-centered, in-class group activities but a few limitations were also found and reported.

1. Introduction

Since a documentary entitled "Search for future classroom" was broadcasted in March 2014, the flipped classroom has attracted a lot of attention in the Korean educational society. Teachers who are practicing and want to adopt flipped classrooms have built a teachers' network called the "future classroom network", and some regional educational offices have adopted it for the innovation of public education [1]. One year later in March 2015, four broadcasted episodes of the documentary showed various educational effects of flipped classrooms based on the experiments with more than a thousand schools. This further increased interest that has been expressed through professional development programs, local teacher networks, and research papers.

Korean students' attitude towards math and science are quite low despite their high academic achievement from international comparison studies such as TIMMS and PISA [2]. Many Korean educators attributed this to teacher-centered instruction focusing on the transfer of knowledge. Although the national curriculum aimed participatory instruction and most teachers agree that the student-centered approach is better, teachers have to spend most of their teaching time explaining knowledge. This is related to the Korean educational system, which aims almost exclusively at the university entrance exam. Within this educational environment, teachers have suffered from the discrepancy between theory and practice [3].

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In order to reinforce the student-centered environment and decrease teacher-centered instruction, various teaching strategies based on constructivism have been suggested including the flipped classroom. However, this simple way of delivering a flipped classroom with "video lectures viewed at home along with problem-solving group work completed in-class" [4] is not a completely new approach. It was begun by two high school chemistry teachers, Jonathan Bergman and Aaron Sams, who were trying to solve a problem of frequent student absences in 2007 [5]. The simple flipped classroom is described as replacing "after-lecture homework with the expectation that students study course material prior to class" [6]. As an extension to this concept, before-class study was recently reinforced with the help of online videos, such as Khan Academy which have become widely spread worldwide at all school levels.

At the university level, extensive research has been conducted [6-8] with a limited numbers of papers in the field of engineering education [9;10]. Organic chemistry has been considered the most difficult subject for students [11;12]. Attempts have been made to adopt a flipped classroom to organic chemistry courses, with positive influences on grades and attitudes being reported [7;11]. However, its application still remains limited in the field of science at the university level, and no research on the flipped classroom has been conducted in university chemistry courses in Korea. Therefore, the present study explores the effect of flipped classrooms in the Korean context.

2. Method

2.1. Subjects

A flipped organic chemistry course worth 3 credits and entitled *Organic Chemistry 1* was run with 41 sophomores (21 female and 20 male) majoring in chemistry education at a private university in South Korea.

2.2. Lecture details

Before each lecture, the students were advised to watch a lecture video through the Learning Management System (LMS). All contents were uploaded at least two to three days before. Students could watch the movies with their smartphones and desktop computers. During the class, exercise problems were provided. These problems were mainly application problems sourced from the textbook, and were supplemented with additional problems for upgrading problem-solving abilities. The students solved the problems within small groups of 4-5 members. The groups were formed according to the students' friendship. After the midterm exam, however, the small group members were changed to heterogeneous groups based on the midterm exam result.

At the end of every chapter, various types of quiz were implemented such as (a) individual quiz and group reward, (b) relay group quiz in which students solved one problem in a sheet on the wall one by one, and (c) solving together and group reward. The quiz scores were not added to final grade, but only used as a reference to check the students' understanding. As the students solved problems in groups, the lecturer interacted with the students in the lecture room. He answered students' questions, but would not give direct answers. A teaching assistant, one of the authors, also helped students as the lecturer did.

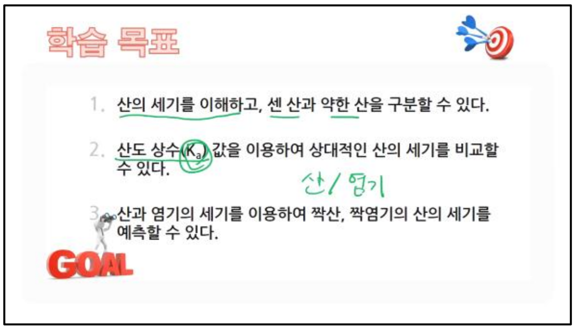
2.3. Lecture Videos

Pre-class video consisted of three main parts: introduction, concept explanation, and exercise problem and summary. Figure 1 presents some screenshots of these parts. The videos began with an introductory talk recalling the previous lecture and providing motivation to study the topic. The lecturer's face was shown in this slide to familiarize the students. Then the learning goals were presented briefly. Total time of introduction was less than a minute.

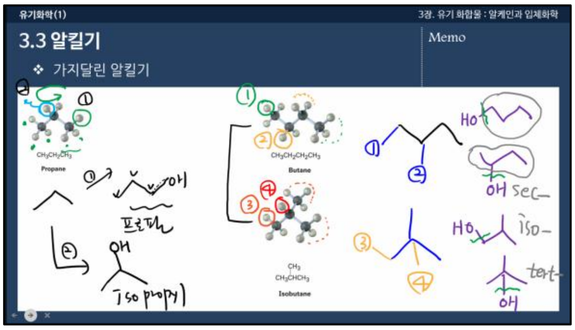
The lecture slides for concept explanation using figures and schemes were based on the textbook. The lecturer attached some memos during the explanatory talk. Sometimes, the lecturer was

shown during concept explanation. For example, in chapter 4, the lecturer demonstrated a molecular model showing the conformation of 1-substituted cyclohexane.
At the end of the lecture, the lecturer explained how to solve the exercise problem. Usually, the problem answers were not given directly in order to let the students solve the problems themselves. General directions were given for other application problems. Lastly, the learning goal was re-presented, and the main topics and concepts were summarized in terms of the goals. Problem numbers which needed to be solved were also presented for further study. According to the general rule for making pre-class videos, the lecture tried to make each clip shorter than 20 *min*. As a result, a total of 76 video clips averaging 11.9 *min* and totalling 905 *min* (15*h* 05*m*) were produced for the semester.

(a) Introduction



(b) Learning goal



(c) Explanation with screen writing

(d) Explanation with molecular model

Figure 1. Selected screenshots of the pre-class videos

2.4. Tools

The lecture contents were prepared by *Microsoft PowerPoint®* with *Office Mix*, which is a free add-in for PowerPoint available at http://mix.office.com. The lecture slides were prepared first, then *Wacom®* pen tablet was used for screen writing during the recording. The voice was recorded with movement of mouse writing together.

2.5. Survey Questionnaire

The authors developed a feedback questionnaire on the flipped learning that was administered at every chapter from chapter 3 to chapter 8. The questionnaire consisted of questions on the students' satisfaction with the pre-class lecture videos, in-class activity, self-evaluation of watching video and in-class participation with a scale from 1 to 3 (1 = dissatisfied; 2 = neither satisfied nor dissatisfied; 3 = satisfied). The muddiest point of each chapter and reflective writing on their performance were also asked. The questionnaire was delivered to students through *Google Forms®* and they answered through their smartphones.

3. Results and Discussion

3.1. Students' perception of the flipped classroom

Students' perception of the flipped classroom including satisfaction with the pre-class videos and in-class activities, and self-evaluation on their group work, preparedness, and participation were monitored during chapter 3 to 8, as shown in table 1, figure 2 and 3. Reflective journals by students were also collected and analyzed.

Table 1. Students' feedback on the flipped classroom

	Chapter 3		Chapter 4		Chapter 5		Chapter 6		Chapter 7		Chapter 8		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Satisfaction														
Pre-class video	2.68	0.47	2.79	0.41	2.65	0.54	2.72	0.45	2.66	0.48	2.64	0.55	2.69	0.48
In-class activity	2.42	0.55	2.50	0.56	2.54	0.61	2.72	0.45	2.63	0.49	2.61	0.56	2.57	0.54
Self-evaluation														
Group work	2.53	0.6	2.61	0.55	2.73	0.45	2.75	0.44	2.63	0.49	2.64	0.49	2.64	0.51
Preparedness	2.05	0.61	2.34	0.63	2.16	0.73	2.08	0.69	2.06	0.72	1.97	0.85	2.12	0.71
Participation	2.37	0.59	2.47	0.56	2.43	0.55	2.53	0.51	2.38	0.61	2.36	0.60	2.43	0.57

M=mean score; *SD*=standard deviation

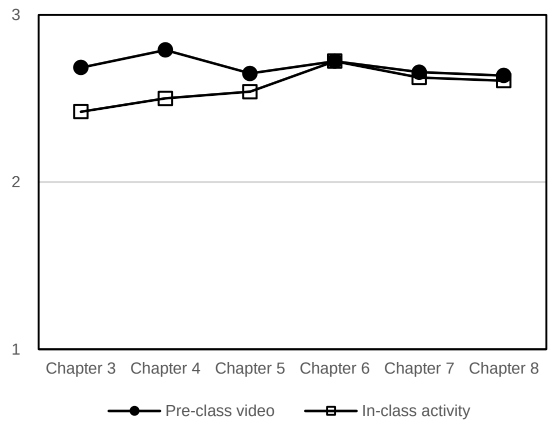


Figure 2. Students' feedback on the satisfaction with the pre-class videos and class activities

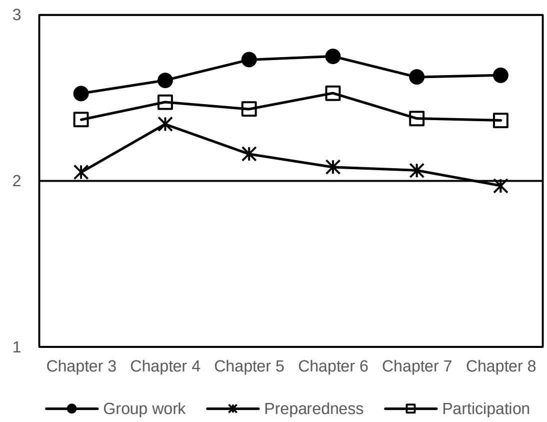


Figure 3. Students' self-evaluation of their group work, preparedness, and participation

3.1.1. Feedback on the Pre-class videos and In-class activities

The mean scores of satisfaction with the pre-class videos and in-class activities were 2.69 and 2.57, respectively, which indicated that the students were generally satisfied (figure 2). Students' positive perceptions of the pre-class videos and in-class activities were also found in their journals below. The most frequent feedback comment was the usefulness of the lecture videos. They liked the online videos since the videos could be watched freely and repeatedly at their convenience. Some students mentioned the helpfulness of using a molecular model in the video.

- *We've already reached to chapter 3, and I just felt that didn't review them well. So, I'm planning to watch the videos again. I think this is a big benefit of the flipped classroom!*
- *I love the way the professor explained the concepts with the molecular model. Well, it is not so easy to understand organic chemistry only based on 2D structure. But I could understand more with the model in the video and also with a tangible model in class.*

The satisfaction level of the in-class activities was relatively low during chapters 3 to 5 (mean score range: 2.50~2.54), but it increased from chapter 6, which implied that the students had some trouble with the flipped classroom initially, but became familiar with the new approach which demanded that they study by themselves as the course proceeded. The students' feedback on group work in their journal was also positive. Many students commented that they got help from group members to understand a concept in organic chemistry. Contrary to the lecture-centered classroom, the students could ask a question freely and obtain and offer some help from others. They also liked to solve more problems than before.

- *I concentrated more than before since I had realized the importance of watching the pre-class videos. I hated group activities before, but now I loved solving problems with group members.*
- *In chapter 3, just as in chapter 2, it was good to ask questions whenever I had something to ask without investing any additional time after the lecture. Actually the time for group presentation was decreased and the time for problem solving was increased. Although both have strengths and weaknesses, but with the way we are trying now, lectures can be speedy.*

However, there were some technical limits of the pre-class videos. One student reported a problem that the video would not play on her smartphone. A slight noise was also reported in another student's journal. Many students mentioned that the length of the video was too long to concentrate. Much attention needs to be paid to these technical issues.
A few students reported the fundamental constraint of learning in the flipped classroom. When they studied topics with the pre-class videos, sometimes they had some trouble in understanding the difficult concepts by themselves. However, they could not ask a question to the lecturer before the lecture. This problem could be solved by organizing study groups for in-class and out-class activities. Additionally, the conceptual difficulty of organic chemistry cannot be overlooked, although the key concepts can be explained briefly and questions can be asked at the beginning of each class. There were also problems in group works such as the free-rider effect. In this study, the lecturer stressed that all group members study together in cooperation, although there was no obligation or group reward. But one or two negligent students became a burden to the other group members.

- *As I watched the video, I was sorry that I could not ask a question immediately. This might be a limit of studying with a video at home.*
- *There was a certain limit of solving problems just after watching the video. So I felt the need to review concepts with the textbook after watching the video. I will study the textbook before watching the video. Unless watching video first, then study the textbook.*
- *I was upset that one of our group members fell asleep during group activities. I felt that I fell behind since I couldn't solve all the given problems due to spending some time to awaken and teach him.*

3.1.2. Self-evaluation of group work, preparedness, and participation
The students' self-evaluation of their group work and participation were positive with mean scores of 2.64 and 2.43, respectively (Figure 3). The students liked and tried their best in their group. They were satisfied with their group work which made them participate more in the group activities. The students' journals also showed their positive perception of group work.

- *It was difficult for me to identify the R, S configuration of a certain molecule and I was a little bit confused. However, I got to understand with the help of my colleagues. I loved to study together more than to do alone.*

- *Chapter 3 has many concepts and contents, but attracted me more than previous chapters. The ring flip of cyclohexane and calculating the energy from the interactions was so attractive to me that I studied pleasantly without any difficulty.*

However, the self-evaluation on their preparedness (M=2.12) was slightly lower than the other factors. Many students confessed that they did not watch the pre-class videos, and increasingly so after the midterm exam, possibly because of the increasing difficulty of the concepts after the introduction of stereochemistry and organic reactions. A heavy homework load from other lectures also reduced their available time to watch the pre-class videos. As they came to the class without watching the pre-class videos, they had difficulty in following the lecture topics. As one of the students noted, they were lazy in watching the videos since this was not obligatory. So, this issue needs to be taken into account carefully before starting a flipped classroom.

- *I came to the class without watching all the videos of chapter 4. So I couldn't follow the other member's pace, which held back the other members. However, they helped me, so I didn't give up participating. Next time, I will watch the pre-class video.*
- *It was difficult for me to follow the lectures without watching the pre-class videos at first. Watching the video in this chapter, however, made easier for me to understand the topics and concepts.*

3.2. Muddiest point of the lecture topic
The muddiest points [13], i.e., the topic that students found the most difficult to fully understand, were surveyed at the end of chapters 3 to 8. The student choices of the muddiest point are shown in Table 2. One of the most difficult topics among the muddiest points from the overall chapters for students was the oxidative cleavage of alkenes in chapter 8 (55%), followed by assigning R or S configuration in chapter 5 (54%). The muddiest point selections naturally tended to be concentrated in the later chapters. For example, in chapters 3 and 4, only one topic was selected as a muddiest point by more than 40%, compared to two to three topics in chapters 5-7. This tendency may have been influenced by the reduction in studying of the pre-class videos, and the students' decreasing preparedness.

Table 2. Major muddiest points of each chapter

Topic	Muddiest point	Percentage
Ch3. Alkanes and stereochemistry	Gauche and anti conformation	42%
Ch4. Cycloalkanes and stereochemistry	1,3-Diaxial interaction	32%
Ch5. Stereochemistry at Tetrahedral Centers	Assigning R or S configuration	54%
Ch6. Overview of organic reactions	Describing transition state	50%
Ch7. Alkenes: Structures and reactions	The Hammond postulate	53%
Ch8. Alkenes: Reactions and synthesis	Oxidative cleavage of alkenes	55%

4. Conclusion
In this study, college students' perception of the flipped classroom was investigated after this approach was adopted in an organic chemistry course for 15 weeks. The students' attitudes towards the flipped organic chemistry course were generally positive. The use of pre-class videos assisted the students in understanding the basic concepts in organic chemistry in advance, which laid a foundation for solving many problems in class. The lecture video could be watched anywhere that was convenient to the students, and watch repeatedly until they understood it fully. In class time, the students had the benefits of solving many problems, such as developing their understanding and upgrading their

problem solving ability. They also benefited in terms of their social relationships with their peers through the small group activities. The lecturer had enough time to interact with the students individually in the classroom and many students liked this personal relationship.

However, the flipped classroom approach needs to be carefully implemented to prevent any decrement in effectiveness. As watching the video before the lecture was not mandated, the students' degree of preparedness may have been lowered, which reduced the effectiveness of the in-class activities. As requested by some students, a certain range of mandatory homework for watching the videos seems to be needed. Another issue was choosing the most effective method for grouping the students among heterogeneous, homogeneous, and friendship-based. Active learning environments like think-pair-share [14] or uncritical inference test [12] can be alternative in-class activities to increase the level of student engagement.

Finally the flipped classroom is not a method for making, nor is it about the technology. Rather it is a method for organizing the class structures. Considerable time is needed to make and upload the videos before the course is commenced. Designing the in-class activities is crucial in ensuring an effective flipped classroom. There also have been some argues on the advantages and disadvantages of flipped classroom in engineering education [10]. Therefore, more trials of adopting flipped classrooms are needed in the various science and engineering fields in order to fully explore the possibilities and challenges of this new approach.

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