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The flipped classroom approach in undergraduate engineering courses: students' perceptions

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ABSTRACT: The flipped classroom approach is useful in many educational environments, including on-line, blended and face-to-face, and especially during challenging times, such as the Covid-19 pandemic. Based on constructivist learning theory [1], and social cognitive career and motivation theory [2], this study was guided by two research questions: 1) how can the flipped classroom approach activate learners' previous knowledge with the use of new materials in the form of recorded videos and other materials in a virtual engineering classroom?; and 2) how do engineering students describe their satisfaction and experience after a semester-long course based on a flipped classroom? An experimental classroom environment was created for four second-year engineering courses with the same instructor at a South Korean university. The results indicate that students enjoyed the flipped classroom approach due to student autonomy and student-to-student interactions. The study results may assist to improve and upgrade the current on-line, blended, and face-to-face courses and programmes with technologically-assisted teaching and learning tools.

Keywords: Constructivist learning, engineering education, engineering students, flipped classroom, social cognitive career and motivation theory

INTRODUCTION

Engineering courses are taught using traditional top-down teaching and learning strategies and approaches, which means students are listeners. Although some theoretical courses, such as calculus, statistics and software design, can be successfully delivered in a top-down classroom environment, many engineering courses are profession-oriented and project-based modules; engineering courses should, therefore, focus on how to combine new knowledge and materials based on previous knowledge and lived experiences of the learners in order to establish applicable and professional skills to be used in the engineering industry and practice [3].

The flipped classroom approach is useful in many on-line and distance learning classroom environments, particularly during the Covid-19 pandemic, when physical interaction between teachers and students is not possible. Being a learner-centred teaching and learning process, students are required to watch lesson videos and read textbook materials before lecture time. During lectures, students deliver lessons to their peers based on the recorded videos and the reading, and host exercises as student-teachers.

Previous studies indicated that the flipped classroom approach increases learning motivation, achievement and self-efficacy, as well as teacher-student, student-teacher, and student-student interactions, problem-solving skills and engagement [4]. Even when teachers opt to deliver the second half of the lesson after the student-teachers' session, each student may take part and share their understanding and knowledge with their peers and teachers interactively. In other words, students may gain a sense of belonging as they are not merely listeners, but an integral part of lesson delivery [5].

Recently, some scholars examined the application of flipped classroom approaches. A recent study advocated that such an approach may significantly increase the problem-solving skills of all students, regardless of their subject and academic major [6]. Another pre-test and post-test pilot study in the science classroom environment also indicated that nearly 90% of students in flipped lessons expressed satisfaction with this method of learning [7].

Although some argued that the flipped classroom approach may only work in reduced-size classes, an earlier study [8] indicated that in introductory-level or theoretical courses, the flipped classroom approach significantly increased learning outcomes and motivation in large-size classroom environments [8]. Group flipped lessons and teacher-multiple students' lessons could overcome the challenges of large enrolment numbers.

Some studies also indicated that on-line teaching and learning platforms and technologies might be employed in the flipped classroom environments. An earlier study pointed out that the Moodle teaching and learning platform may provide a forum for sharing, discussion and submission instead of the traditional paper-based examination [9]. Another study also echoed that the distance learning platform with reasonable student autonomy may increase students' performance and learning outcomes [10]. Therefore, the flipped classroom approach may be useful in current science classroom environments.

Purpose of the Study

Although many studies argue that the flipped classroom approach is useful in science classes, only a few studies are concerned about how this approach may be used in an engineering classroom environment, specifically for on-line course delivery during the Covid-19 pandemic. Based on constructivist learning theory [1], and social cognitive career and motivation theory [2], this study was guided by two research questions:

1) How can the flipped classroom approach activate learners' previous knowledge with the use of new materials in the form of recorded videos and other materials in a virtual engineering classroom?
2) How do engineering students describe their satisfaction and experience after a semester-long course based on a flipped classroom?

THEORETICAL FRAMEWORKS

Constructivist learning theory indicates that learners combine their previous experience with the current knowledge to establish new understanding, skills and knowledge [1]. The previous experiences and understanding are key in this theory as individuals, particularly adults, cannot form new ideas without the comparisons and sense-making processes from their earlier learnt and current knowledge [1]. As constructivist learning is an active, on-going and context-based process, in the current study, learners may build up new knowledge with their previous experiences, teacher and classmates' instructions, and flipped teaching and learning strategies.

Social cognitive career and motivation theory can assist in the understanding of motivations, sense-making and decision-making of individuals and groups [2]. The theory indicates that individuals can be influenced by psychological and social factors. The psychological and internal factors regard self-efficacy, academic interests, personal considerations, educational and professional achievements, and career goals. On the other hand, the social and external factors involve interests in career development, financial considerations, surrounding environments, and other individuals and social groups.

METHODOLOGY

The Current Flipped Classroom Case

In a virtual flipped classroom environment, a semester-long course was taught in two 90-minute lessons per week via the Zoom platform. Each lesson was divided into two 40-minute segments, including two 20-minute student-guided lessons. During the student-guided lessons, the student acting as teacher was expected to prepare PowerPoint presentations, introductions, main lessons, exercises, and allocate discussion time for their peers. For the exercises and discussion sections, the student-teacher could split the main Zoom session and arrange peers into breakout rooms for small group discussions and sharing. The student-teacher had the freedom to conduct the lesson in any way, as long as it met the expectation of the guided lesson and the requirements. After two student-guided lessons were completed, the teacher took over the student-guided lessons and provided appropriate knowledge, further exercises and stimulated discussion based on the student-guided lessons. For the rest of the lesson, the teacher continued with the new knowledge based on the textbook materials.

Students were given their student-guided lesson topics, guidelines, teaching and learning materials, and related information during the first lesson of their engineering courses. The student-guided lessons did not start until the third week of the semester. Therefore, students should have enough time to prepare their lessons and materials. Factors such as, language proficiency (e.g. second language), use of picture, facial expression, eye contact and dress code did not influence students' grades.

Participants

The participants were second-year engineering students from four courses at a South Korean university. The courses had the same instructor. Before the semester started, the instructor had agreed to rearrange the lesson materials according to the guidelines of this study, and to follow the flipped classroom approach and the grading rubrics, thereby assisting in collecting information for the study.

Students' consent to participate in the study was crucial, therefore, before the lesson started, all students were asked about their intentions. Those that did not wish to join this study, could switch to another session based on traditional teaching and learning with the same instructor. As a result, 120 students decided to join this study.

Data Collection

The researcher had provided all the essential guidelines and instructions to the instructor before the semester started. The instructor continued with the lessons and courses during the semester based on the flipped classroom approach. The participating students had to fill up two surveys, with the same content, after completing their mid-term and after the final examinations. The survey could not be sent to their instructor, and the instructor could not read the answers and comments from the survey in order to protect the rights of all parties. The surveys included 12 Likert scale questions and ten short-answer questions based on the theoretical framework and the research questions. The scale had five points: strongly agree (SA - 5), agree (A - 4), neither agree nor disagree (N - 3), disagree (D - 2) and strongly disagree (SD - 1). A total of 240 valid surveys (N = 240) were collected as all students answered the survey appropriately without any problems.

FINDINGS AND DISCUSSION

All students said that this was their first experience of the flipped classroom approach, and all indicated that the experience was positive. In the surveys, none of them expressed any negativity about their flipped engineering lesson or the virtual delivery mode of their course.

Table 1: Findings from the Likert scale surveys.

Survey questions	SA (5)	A (4)	N (3)	D (2)	SD (1)
1. The flipped classroom approach increases my learning motivation.	199	38	3	-	-
	82.92%	15.83%	1.25%	-	-
2. The flipped classroom approach enhances my learning during my current engineering course.	180	50	10	-	-
	75.00%	20.83%	4.17%	-	-
3. The flipped classroom approach encourages peer-to-peer interaction in the virtual classroom environment.	214	20	6	-	-
	89.17%	8.33%	2.50%	-	-
4. The flipped classroom approach encourages me to read additional materials from the textbooks.	185	50	5	-	-
	77.08%	20.83%	2.08%	-	-
5. The flipped classroom achieves the expected outcomes from the syllabus and meets my expectations.	235	5	-	-	-
	97.92%	2.08%	-	-	-
6. The engineering lessons are more interesting with the flipped classroom approach.	203	35	2	-	-
	84.58%	14.58%	0.83%	-	-
7. The flipped classroom approach activates my previous engineering knowledge to complement the new knowledge from this course.	211	27	2	-	-
	87.92%	11.25%	0.83%	-	-
8. With the flipped classroom approach, students have more autonomy in the class.	208	28	4	-	-
	86.67%	11.67%	1.67%	-	-
9. The flipped classroom approach may result in an improvement in my performance.	200	32	8	-	-
	83.33%	13.33%	3.33%	-	-
10. The flipped classroom is a better teaching approach for basic engineering courses, regardless of the delivery options.	208	24	8	-	-
	86.67%	10.00%	3.33%	-	-
11. Other engineering instructors at the university should employ the flipped classroom approach in their engineering courses.	222	16	2	-	-
	92.50%	6.67%	0.83%	-	-
12. In the future, I would prefer to have other engineering courses delivered using the flipped approach.	217	15	8	-	-
	90.42%	6.25%	3.33%	-	-

As indicated in Table 1, in regard to the application of the flipped classroom approach, most students believed that their engineering courses based on this approach significantly increased their learning motivation (98.75% SA and A).

In line with social cognitive career and motivation theory [2], the participants' academic interests were met as the current flipped classroom engineering courses allowed them to manage new knowledge. Also, as can be seen in item 9, over 90% of the participants stated that the flipped classroom approach outperformed traditional face-to-face and top-down teaching in the usual classroom environment. Further, item 5 indicates that none of the participants believed the flipped classroom approach might negatively influence the expected syllabus outcomes. These findings show that these groups of engineering students supported this approach, particularly in virtual engineering lessons.

Qualitative Sharing: Previous Knowledge Activation without Borders

Besides the data from the Likert scale surveys, all participants shared rich insights and comments about the flipped classroom approach during their engineering lessons. Two themes were identified; namely, 1) activation of the previous and basic engineering, mathematics and communication knowledge with this interactive approach; and 2) engaging learning experiences without borders.

Activation of my Previous and Basic Engineering, Mathematics, and Communication Knowledge with this Interactive Approach

All participants had positive experiences in regard to the relationship between their previous knowledge and current new materials during flipped teaching and learning in virtual classrooms during the Covid-19 pandemic. First, a group of second-year student participants indicated that the recorded videos, reading materials and mandatory preparation for the lessons significantly activated their previous knowledge of basic engineering concepts, regardless of their academic major. Engineering programmes include profession-oriented subjects that require students to have strong foundations in science, technology, engineering and mathematics (STEM) practice. In other words, engineering students should combine and apply STEM knowledge in practice. With regards to this, participants expressed how the flipped classroom approach activated their knowledge from the previous year in the current engineering classroom. Two comments were captured:

> *…the student-teacher PowerPoint teaching is very useful …I can capture my reading and teach my classmates …and my classmates can teach us too …because I have to read the books and watch the videos …I have to re-read some of my previous courses …because I do not want to teach wrong information…* (Participant #112, Survey)

> *…we took the introduction to engineering and computer engineering system during our first year …but this course required us to re-read many of our last year's books because we have to prepare the PowerPoint …I am glad that I can use my past textbooks and handouts because I know my knowledge is useful…* (Participant #69, Survey)

Besides the knowledge from their first-year experiences, many students also indicated that their knowledge and applications of mathematics are useful in the flipped classroom, particularly when explaining theories and exercises. The researcher captured two stories:

> *…engineering is all about how to handle mathematics into the engineering subject …my student-teacher session needs me to explain the calculus theory and formula in Unit 6 …I also need to think about how to host the discussion sessions and contribute some exercises for our classmates …excellent training for my mathematics and my engineering skills…* (Participant #3, Survey)

> *…I believed my engineering knowledge from my first year would be useless …but that was wrong …I am glad that my teacher allowed me to re-use the mathematics theories in this engineering course …I want to tell my classmates about my interests in mathematics and electronic engineering …I can use all my first-year and high school skills again in mathematics…* (Participant #143, Survey)

Moreover, communication and presentation skills were mentioned more than 150 times in the survey. Many indicated that the flipped classrooms, particularly those incorporating student-teaching sessions, strongly encouraged them to improve their communication and presentation skills as they had to teach their classmates and host discussion sessions with them. One student said:

> *…this is my first time hosting a lesson in front of my classmates …I do not understand how to teach …but this engineering course allowed me to do so …I hope I can have this fun course in the future …I think the Korean universities should always employ these student-teaching lessons for all subjects…* (Participant #178, Survey)

In short, almost all participants supported the flipped classroom approach that included student-teaching sessions, connected their previous experiences, engineering knowledge, mathematics abilities and allowed them to develop their communication skills when conducting their own lessons and hosting discussions in front of their classmates. Social constructivist theory states that learners' new learning is established though a combination of previous and new knowledge [1]. Almost all participants expressed their strongest agreement with their current experiences, indicating their satisfaction.

Engaging Learning Experiences without Borders

South Korea is a popular country for international education. In regard to the engineering courses included in the present study, the enrolled students came from different parts of South Korea and other countries, including China, Japan, Thailand, Mongolia, Uzbekistan, Pakistan, India, Vietnam, United States and the United Kingdom. Due to the Covid-19 pandemic, many students connected via the Internet for virtually held classrooms. The courses were taught in English and all students were encouraged to communicate in English due to their level of language proficiency. More importantly, during the classes students from all countries were engaged in the student-teaching sessions and discussions. One student shared the following comment:

> *…other of my courses …I know my classmates from Korea and foreign countries …but I cannot interact with them because we only need to listen …but in this engineering course with a student-teaching session …I have*

to teach and prepare some exercises and discussion questions for all my classmates …I learned their name, nationalities, language and cultural backgrounds… (Participant #99, Survey)

In short, this study shows that the academic interest in sharing the participants' previous knowledge and STEM subject experiences with their classmates played an important role. University is a place where students should learn interaction and communication skills together, particularly during presentations and group projects. In regard to this study, specific environments and individuals played a key role in connecting teachers and peers altogether in one virtual classroom across different countries. However, despite the different locations, the outcomes and achievements from the interactions and peer-to-peer discussions were not negatively impacted.

DISCUSSION

The flipped classroom approach is a useful strategy that may activate previous experiences and integrate them with the current knowledge through the use of recorded videos and reading materials. A recent study also advocated that audio-visual materials may significantly increase motivation and learning performance in the science classroom environment [11]. In a previous study based on surveys and qualitative sharing [12], participants indicated that the relationships between their student-teaching experiences, recorded videos and the preparation of their PowerPoint presentations merged with their previous experiences, engineering skills, mathematics abilities and community skills in their classroom environment, including the student-teaching sessions and student-hosted discussions [12][13]. Based on social constructivist theory, the researcher advocated the view that the flipped classroom approach significantly activated previous knowledge and established new grounds through the use of current materials [1].

In both surveys and qualitative data, all participants gave positive feedback about their experience of the flipped classroom approach from the semester-long engineering course conducted virtually. According to a recent study, students are usually keen to connect their previous knowledge with current exercises to establish new understanding [14]. Also, when students can share their ideas when interacting with their classmates, their self-efficacy may increase significantly. Other studies also indicated that students should be given more autonomy and self-directed learning opportunities in order to expand their proximal zone of development and attain new knowledge [15][16].

Based on social cognitive career and motivation theory [2], and the data and evidence collected from participants, it can be established that their academic interests and the connections between STEM subjects, previous knowledge, and current new knowledge in their engineering course greatly increased the participants' learning satisfaction, motivation and experiences [2]. Moreover, their environment and the individuals they interacted with also played important roles. Although virtual learning may limit some experiences and interactions, the participants agreed to use this learning mode and managed distance-based communication and sharing with their peers internationally [17]. Backed by social cognitive career and motivation theory [2] and the factors related to individual students and their environment, it can be concluded that peer-to-peer learning interaction and motivation are essential, regardless of geographic location and the current global pandemic crisis.

LIMITATIONS AND FUTURE RESEARCH DEVELOPMENT

The Covid-19 pandemic became a milestone for many colleges and universities to employ technology-based teaching and learning approaches, such as the flipped classroom approach. However, it is very likely that after the Covid-19 pandemic, many classrooms will return to face-to-face campus-based teaching. The current study focused only on the temporary on-line classroom environments due to the health crisis; however, it is important to understand both the flipped classroom environment and experiences in the traditional face-to-face classrooms. Therefore, future research studies may explore face-to-face classroom environments in terms of new methods, tools and the established research background.

Second, the current study employed the flipped classroom approach in on-line engineering classrooms. However, other type of classrooms and subjects, such as second language learning, laboratory experiments, clinical courses and internships may also employ the flipped classroom approach as a method for effective learning. Therefore, future research studies may expand the subjects and backgrounds to cover other groups of people and schools.

Third, non-native English speakers may experience difficulties and confusion as the instructional medium is not their first language. Regardless of the location and subject taught, the language barriers may limit the learning experiences and achievements in flipped classrooms, on-line classrooms and various classroom environments during the Covid-19 pandemic. Future studies may take these ideas as opportunities to expand the current situations, and investigate issues and problems.

CONTRIBUTIONS AND CONCLUSIONS

The current study contributes to different aspects and educational environments. First, the flipped classroom approach will become more popular because of the continuous development of technology-based tools, computer-oriented learning and self-directed learning. Distance-learning courses, blended-learning modules and face-to-face programmes

may employ the flipped classroom approach as one of the instructional methods, particularly in the university environments where lecturers should foster critical thinking and self-regulation in adult learners and students. The current study provides a direction that university lecturers may follow and reform their current teaching and learning approaches.

Second, university leaders, department heads and instructional designers may use this study to inform educational change and re-design current courses, programmes and curricula. Due to the technology development, many students tend to enrol in courses and modules with peer-to-peer, self-control, and interactive exercises and activities. With the application of the flipped classroom approach, theoretical courses, such as mathematics and introduction to engineering, may introduce additional exercises and activities during lessons and other student interactions. The results of the current study may serve as a sample for curricular changes and class plans.

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BIOGRAPHY

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