J. Korean Earth Sci. Soc., v. 38, no. 5, p. 357−366, September 2017
https://doi.org/10.5467/JKESS.2017.38.5.357
ISSN 1225-6692 (printed edition)
ISSN 2287-4518 (electronic edition)

Earth System Science (ESS) Course for Urban Planning and Engineering Undergraduate Students

Younkyeong Nam* and Sung-Hyo Yun

Pusan National University, Pusan 46241, Korea

Abstract: Urban planning and engineering undergraduate students need to understand the earth physical systems and that how human beings interact with the earth systems to planning and engineering urban area. The eco-friendly or geo-friendly design and planning of an urban area is a critical issue not only for economic benefits but more importantly for the sustainable future of urban life. However, little study has been done dealing with the urban engineering students' understanding of the earth as a system and what pedagogical approach is appropriate to improve their understanding of the earth as a system. This study is to investigate the impact of a purposely designed ESS course on urban engineering students' understanding of the earth as a system and their perceptions about the instructional approaches of the course on their learning competency. This study utilized a mixed-methodology with three main data sources: concept maps, student's perception survey about their learning competency, and course contents. Both the survey and concept maps were analyzed quantitatively as well as qualitatively. The result of this study showed that the urban engineering students' experience of team-based research about the topic they chose based on their own interest had a positive impact on their understanding of the earth as a system and their learning competency. The results of this study suggest that structuring and presenting the earth system contents in the context of engineering students' understanding and their future career be effective not only for the improvement of students' content knowledge but also for the enhancement of their learning competency such as creativity and problem-solving skills in everyday life situation.

Keywords: urban planning and engineering, earth system science, learning competency

Introduction

Over the last four decades, our understanding of the earth as a system has dramatically improved. As a result, topics and structures of college level earth science courses have been merged and transformed to a new discipline called, Earth System Science that deals with earth system issues more holistically and explicitly (Author, 2016). Understanding of the earth as a system is important not only to the students who is majoring earth science related disciplines (geography, geology etc.) but also to the students in certain engineering disciplines such as urban planning and engineering since they need to apply specific earth system knowledge for their careers and expertise. In particular, urban planning and engineering students need to understand earth physical systems and how human interact with earth systems to plan urban area more effectively. Eco-friendly or geo-friendly design and planning of urban area is a critical issue not only for economic benefits but more importantly for sustainable future of urban life.

However, our knowledge of undergraduate students' understanding of the earth as a system is still in its infancy. Several studies have been conducted with students who are in natural science or in earth science related discipline (geography or geology) and indicated that the depth and breadth of undergraduate students' knowledge of earth systems are limited and often include misconceptions (Jang & Nam, 2012; Jeong & Han, 2010, Libarkin & Kurdziel, 2006; Sell et al., 2006; Shelton & Hedley, 2002; Raia, 2005). Due to the interdisciplinary nature of ESS, there are few studies of what students in different discipline

*Corresponding author: ynam@pusan.ac.kr
Tel: +82-51-510-2707
Fax: +82-51-510-7495

should know about earth system and thus little grounding for curriculum design, pedagogical approach, and research. Unfortunately, there is no study dealing with urban planning and engineering students' understanding of the earth as a system and what pedagogical approach is appropriate to improve their understanding of the earth as a system.

Recently, various instructional approaches have been introduced to make undergraduate courses more effective to engage students in learning such as hybrid teaching methods. One of the popular hybrid teaching approaches in higher institutions is flipped classroom. Flipped classroom approach seems to be used in K-12 classrooms (e.g. Fulton, 2012) and various disciplines including medicine and engineering in higher education institute (e.g. Lai & Hwang, 2016). There has been increasing evidence that this approach is beneficial to student learning including; improving students' academic achievement and interests in learning, improving students' self-directed learning skill, and so on (e.g. Fulton, 2012; Sahin, et al., 2015). Recently, flipped classroom approach has been used for various disciplines and grade levels in educational context of South Korea, such as social science (e.g. Jang, 2015; Park, 2015). However, flipped approach is relatively new in higher education and there is lack of research about the impact of flipped classroom on engineering students' learning.

Thus the primary purpose of this study is to investigate the impact of a flipped classroom approached ESS course on urban planning and engineering students' understanding of the earth as a system. A major instructional approach of the specially designed ESS course was giving students opportunity of researching and presenting an ESS topic that they are interested in as well as relevant to their major and future career as a team work task. The team presentation happened at the beginning of each class before the lecture about the weekly topic was given. In addition, this study investigates participant students' perceptions about the instructional approaches of the course on their learning competency and what kind of earth system knowledge they are personally interested in and they perceive more meaningful for their future career.

Specific research questions of this study are:

1) Does urban planning and engineering students' experience of team-based research and presentation have positive impact on their understandings of the earth as a system?

2) Does urban planning and engineering students' experience of team-based research and presentation have positive impact on their learning competency?

3) What are important and relevant topics of earth system science for the students who are majoring urban planning and engineering?

Method

This study utilized a mixed-methodology to investigate how the earth system course affects first-year urban planning and engineering students' understandings of the earth as a system, their perceptions of the course impact on their learning engineering and knowledge that is meaningful for their future career.

Course context and participants

An earth science course is a required course for graduation in urban planning and engineering major in South Korea. The earth system science course described in this study was opened for the first and second year urban planning and engineering students in a college of engineering in a mid-size university in South Korea. This course was specially designed to teach earth systems concepts in the context of urban engineering. The major objectives of this course were to help students understand the core concepts of earth system and apply the knowledge in the urban planning and engineering context while participating in the course. The course content includes general earth science disciplinary knowledge (geology, oceanography, meteorology, etc) and the application of the knowledge in urban planning and engineering context. The instructor presented the concept of earth system at the beginning of the course and asked students to work as a team to prepare a research presentation about the topic assigned in each week. The students needed to study an assigned earth system concept as homework prior to the class of the topic. In addition, each student team (3-4 students) need to choose a topic in the scope of the earth system content assigned in the week and prepare a research presentation about what kinds of earth system knowledge they were interested in, how the topic is relevant to their major (urban engineering) and how they would apply the knowledge to the context of urban engineering.

Each student team presented their research bi-weekly throughout the semester and their performance was evaluated by peers and the instructor. Criteria for evaluating team presentation was developed and given by the instructor. Each team's performance was evaluated based on four categories: 1) Quality of the science content, 2) presentation attitude and skill, 3) team work (collaboration), 4) quality of presentation material and conventions. Each team presented at least five different topics throughout the semester.

A total of 53 'urban planning and engineering' major undergraduate students (37 male and 16 female students) participated in the study. Most of them was freshman (N=50) and about 40% of the students (N=20) took earth science course during their high school years.

Data collection

The data for this study came from three main sources: 1) concept maps were collected three times during the semester (at the beginning, middle, and the end of the course) to probe participant students' understandings of the earth as a system, 2) the change of students' perception of the course's impact on their learning competency were measured by a group of Likert scale survey items that includes four sub-categories (improvement of earth system knowledge and scientific learning competency, perceptions of peer-evaluation, and team-work skill), 3) student's perception about the course content based on their personal interest verses necessity for their future career were collected by a Likert scale survey items. In addition, open-ended questions and student teams' presentation materials were collected throughout the semester to triangulate the results of student perceptions about the course impacts and the ESS topics covered during the semester.

Data analysis

The Likert scale survey items was analyzed quantitatively; 1) changes in students' perceptions about the course impact on their learning competency was analyzed by comparing agreement rate and frequencies of each item between the middle and the end of the semester. We decided that a criterion indicated the positive impact of the course addressed in each item: the total frequency of "Strongly agree" and "Agree" responses on the item is higher than 60% of the total responses. If the frequency of each Likert scale item response met this criterion, we decided that the response of the item indicated the positive impact of the course addressed in the item. 2) descriptive statistics were also used to define relative order of the different kinds of earth system topics that the students perceived as most interesting or meaningful for their major and future careers.

Open-ended survey items and student teams' presentation were analyzed by interpretive and qualitative analysis methods utilizing combined content analysis (Patton, 1990). For these data, a coding scheme was established and validated by the author and three other researchers. First the researchers analyzed a smaller number of open-ended responses to establish coding categories and themes. Based on these initial categories and themes, all of the qualitative data were analyzed to discern emerging patterns in the data.

Student concept map about earth system were analyzed qualitatively and quantitatively. First, a qualitative method has been used to analyze the structure of the concept map. Based on the qualitative concept map analysis method developed by Kinchin et al., (2000), we followed two distinguishable steps. First, we defined different layers in each concept map. Most of the students constructed the concept maps as a radial structure by placing "earth system" at the center. We defined the first layer concepts that are connected to the core concept and the second layer concepts that

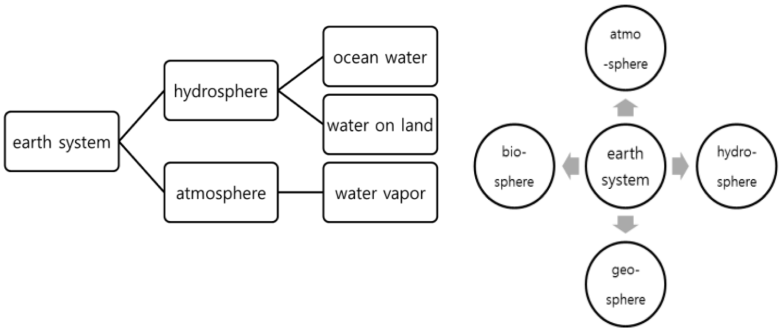
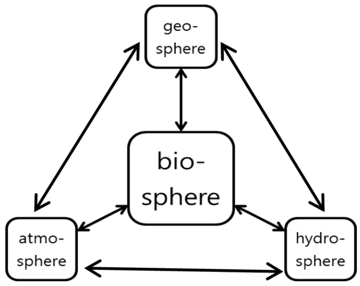
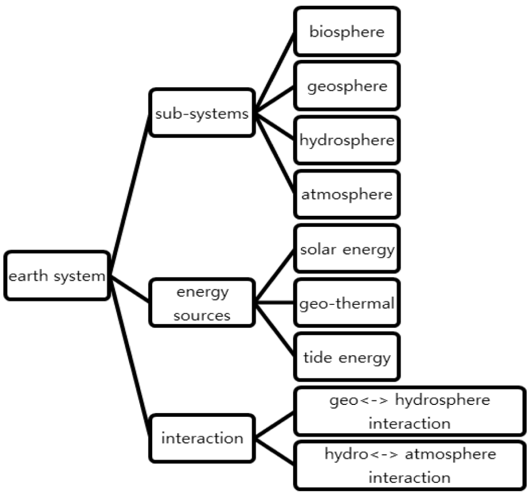
Structure	Simplified examples
Radial structure with sub-systems (A)	
Sub-system interaction focused structure (B)	
Sub-system characteristics focused structure (C)	

Fig. 1. Three representative concept map structures simplified by the concept map analysis.

connected to the first layer concepts, and so forth. Most of the concept maps had three or more layers but a few of them had two layers. Second, we made an analytic table that presents common structures between concepts in different layers. This process helped us to find the most common structure of the concept maps. Figure 1 presents three representative structures of the concept map that were simplified from concept map analysis results.

Third, each student's concept map is scored by a modified method of Novak and Gowin (1984). Table 1 show a comparison of the scoring system between the Novak and Gowin (1984) and the modified scoring system.

Each student concept map was scored by two researchers. To establish the reliability of the concept map analysis results, an inter-rater reliability test was run on both pre and post concept map analysis results

Table 1. A modified scoring system of concept map analysis: modified from Novak and Gowin (1984) to weight on interactions between earth system concepts

Novak & Gowin (1984) (point)	A modified scoring system (point)
Valid propositional link (1)	① valid connection between two concepts (1) ② the levels between two concepts are valid (1). ③ connection between the concept and an example is valid (1). ④ lower level concept is not an example but valid to connect (1).
Hierarchy between concepts (5)	① a higher level concept is explained by the lower level concepts (5) ② a higher level concept is connected with two or more lower concepts (5) ③ one lower level concept is considered as an example (1)
Cross connections Valid (10) Not-valid (2)	① Valid cross connection between same or different layers (10) ② Cross connection with a valid link and proposition - Only a cross connection line exit that link two concept (2) - A cross connection line, example and a simple proposition exits (6) - A cross connection with valid proposition of scientific content (10) ③ Additional explanation in the open-ended question - An example is explained even if there is only a cross connection line exits in the concept map (6) - A science concept is correctly explained even if there is only a cross connection line exits between concept in the concept map (10)
Example (1)	① example connected to a concept is valid (1) ② if an example is cross connected to a concept, it is considered as a cross connection.

using Cronbach's coefficient alpha (pre: α=0.991, post: α=0.993). A paired samples t-test with $p<.01$ was run to examine the mean score difference between the pre and post concept map. An additional question about the concept map topic (atmospheric circulation and water cycle) was also analyzed qualitatively to triangulate the concept map analysis result. This process helped us to clarify the relationships between the nodes (concepts) regarding the layer where the concept was placed and the propositions between the concepts.

Result

The ESS course impact on the urban planning and engineering students' understanding of the earth as a system

The concept map analysis result shows that the structure of the concept map at the beginning of the semester has a pattern between students; the concept of the 'earth system' at the center and the other sub-systems were connected to the concept of earth system like a tree branches; a radical structure (A). In other words, at the beginning of the semester, students mainly focused on describing physical components and sub-systems of the earth system. On the post concept maps collected at the end of the semester, students described more interactions between the sub-systems and the components of the subsystems. Table 2 present numbers of concept map categorized in each structure at the beginning (pre) and the end of the semester (post).

Table 2. Concept map structure at the beginning and the end of the semester

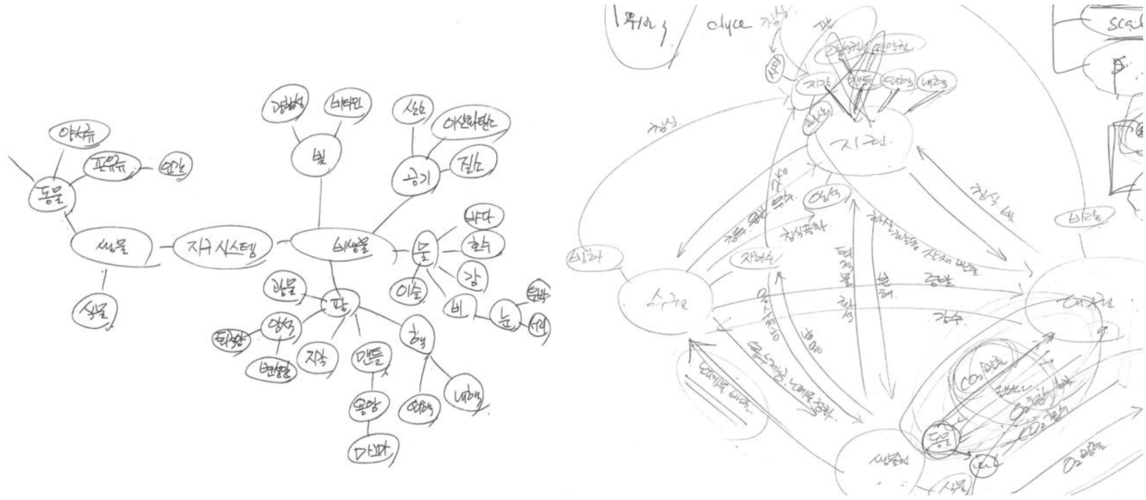
Pre (N=39)			Post (N=35)		
(A)	(B)	(C)	(A)	(B)	(C)
37	1	1	19	16	0

Based on the analysis process, we found differences between the pre concept maps and the post concept map: 1) the overall structure of the maps had changed from (A) to (B), 2) the major nodes connected to the central concept of earth system (first layer concepts) had changed, and 3) the complexity of the concept map has changed. In addition, most of the first concept maps were a radial structure with the "earth system" concept at the center and other concepts connected to the central node "earth system" as tree branches.

Table 3. Pre-post comparison of the concept map score

Category	A paired t-test (N=33)			
	M (pre-post)	SD	t	p
Total	33.50-41.69	20.52	-2.294	.028*
Valid Propositional Link	12.12-6.18	6.38	5.341	.00**
Hierarchy	6.67-3.86	6.02	2.675	.00**
Cross Connection	13.45-29.33	17.96	-5.077	.00**
Example	2.16-2.31	3.04	-.286	.77

*p< .05 **p< .01



(1) Pre concept map (2) Post concept map

Fig. 2. An example of pre and post concept map from a student.

This result is also evidenced by the concept map score in different categories suggested by Novak and Gowin (1984); valid propositional link, hierarchy, cross connection, example. A modified scoring system based on Novak and Gowin (1984) was used to score each concept map. Table 3 presents concept map score based on both total score and each category at the beginning and the end of the semester.

As the Table 3 shows, the total score of post concept maps is significantly higher than the pre concept maps. Interestingly two categories including 'Valid Propositional link' and 'Hierarchy' showed an opposite result, significantly decreased scores between pre and post concept maps. The significant increase of the score is mainly due to the significant score increase of the category 'Cross connection'. In other words, the post concept maps had more cross connections than the pre concept maps, which represent interactions between earth system concepts.

Figure 2 shows an example of a pre and post concept map from a student. Compared to the pre concept maps represented as a radial structure (A), the post concept maps show more interactions between sub-systems (B) showing the process of earth system interactions. The direction of the arrows that connected the nodes showed that the students understood earth systems has been developed throughout the semester as they described more complex and cyclic processes of the earth systems.

Table 4. Positive response rate (%) about learning competency between the middle and the end of the semester

Category (Mid-Final)	Sub category (Improvement of ~)	Mid N=51	Final N=50	Mid-Final (%)
Earth System Knowledge (56.9-68.5)	earth system knowledge	60.8	64.0	3.22
	general earth system knowledge outside of the class material	56.9	70.0	13.14
	Increase of interest in contents and knowledge in ESS	58.8	74.0	15.18
	Recognition about the importance ESK	51.0	66.0	15.02
Learning Competency In Science (51.0-67.2)	Improvement of information searching skills about earth science knowledge and materials	74.5	86.0	11.49
	problem solving skills related to ESS in everyday life	27.5	54.0	26.55
	Improvement of self-directed learning skill	52.9	60.0	7.06
	Improvement of creativity	41.2	68.0	26.82
	Improvement of critical thinking skill in ESS	58.8	68.0	9.18
Team Work Skill (81-80.4)	presentation preparation skill	88.2	94.0	5.76
	team collaboration skills	74.5	76.0	1.49
	communication skill	78.4	74.0	-4.43
	Recognition about the importance of team work during problem solving	80.4	80.0	-0.39
Perception about Peer Evaluation (68.0-72.0)	understanding about the criteria for peer evaluation	74.5	76.0	1.49
	understanding about desirable attitude for peer-evaluation	68.6	74.0	5.37
	positive attitude toward peer-evaluation method(reliability)	60.8	66.0	5.22

Urban planning and engineering students' perception of the impact of the instructional approach using team based project and peer evaluation on their learning

The analysis of the Likert scale items about students' perception of their learning competency as shows that students' perceived the course structure and instructional methods of using team-work based research and presentation is very helpful for their learning competencies in four aspects. At the end of the semester, on average, more than 60% of the students agreed that the course positively affect their learning competency in all four categories (improvement of earth system knowledge and scientific learning competency, perceptions of peer-evaluation, and team-work skill). The agreement rate has increased toward the end of the semester that 72% (N=36 out of 50) of the students agreed or strongly agreed about the positive impact of the course. Table 4 presents the agreement rate (%) change of each categories and sub-categories between the middle and the end of the semester.

Among the four subcategories, team-work skill has the highest agreement rate both in the middle (80.4%, N=40) and at the end of the semester (81%, N=41). The agreement rate of the subcategory of 'Earth System Knowledge' increased significantly from 56.9 to 68.5%. The agreement rate of the subcategory of 'Learning Competency in Science' (information literacy of earth science knowledge and materials, problem solving skills related to ESS in everyday life, self-directed learning skill in ESS, creativity, and critical thinking skill) increased more significantly between in the middle (51.0%) and end of the semester (67.2%). In particular two items in the subcategory increased significantly (problem solving skills related to ESS in everyday life (27% increased) and creativity (27%). The subcategories of 'Team Work Skill' and 'Perception about Peer Evaluation' had higher agreement rate from the middle of the semester and the agreement rate did not change much toward end of the semester. In other words, as the students experienced team based research about the ESS topic relevant to their major, they recognized the effects of the course structure (team based research in ESS topics that are relevant to their major) on their learning competency, particularly about the earth system knowledge gain and the science learning competency.

In addition, the analysis of the students' responses on the open-ended questions about their perceptions of

Table 5. Students' perceptions about the instructional approach

Benefits (N=143)	Limitations (N=84)	Suggestions (N=45)
- Presentation skill (25.9%) - Science knowledge gain: everyday life (22.3%) - Team work skill (20.9%) - More interested in learning earth science (10.7%) - Information literacy skill (8.6%) - Learning competency (8.6%)	- Stress for presentation preparation (38.1%) - Difference in team work contribution (19.1%) - Presentation time management (14.3%) - Reliability of peer-evaluation (9.5%) - Choosing a right topic for presentation (5.9%)	- Evaluation between team members (24.4%) - Reduce the frequency of presentation (24.4%) - Increase time for discussion and instruction (15.6%) - More communication between teams for choosing a team presentation topic (13.3%) - More efficient presentation time management (11.1%) - Bigger score difference between teams (8.9%)

the instructional approach reveals some important insights about the instructional approach. Table 5 presents the analysis result based on three categories of students' perceptions; beneficial and limited aspects of the instructional approach and their suggestions to make the instructional approach better.

The most frequent response about the benefit of the course approach was the improvement of 'Presentation skill' (25.9%), 'Science knowledge gain' (that is applicable to everyday life situation) (22.3%), and the improvement of 'Team work skill' (20.9%). On the other hand, students expressed their stress to prepare the presentation (38.1%), and asked more reliable method to grade their team work based on individual team member's contribution rate (19.1%). In addition, the students suggested that 'Evaluation between team members' (24.4%) would make all the team members contribute fairly for the team task, and to reduce the frequency of presentation (24.4%) and increase time for discussion and instruction (15.6%).

Urban planning and engineering students' perceptions of the ESS topics relevant to their major and future career

In the Likert scale survey items measuring students' perceptions about the ESS topics, students were asked to indicate the level of their interests using 5 point scale (5: very interested-1: not at all interested) as well as the level of relevancy with their major (5: very relevant-1: not at all relevant) for their major and future career about each topic. Depending on the course schedule, a different list of topics was given in the middle (19 ESS topics) and at the end of the semester (16 ESS topics). The result shows that there are certain ESS topics that the students were more interested (>3.5) in as well as perceived as important for their major and future career (>3.5); weather and climate (4.0 vs. 4.1), severe weather condition (3.9 vs. 4.0) and climate change (4.1 vs. 3.8), earth quake (4.0 vs. 4.5), natural disaster related to water (3.8 vs. 4.2) and volcano (3.8 vs. 3.9), atmospheric circulation/wind (3.6 vs. 3.9), geologic feature by ocean wave (3.7 vs. 3.8) and volcanic activity (3.6 vs. 3.6), and water cycle and reservoir (3.6 vs. 3.8).

Interestingly, there were some topics that students were interested but did not think they were relevant to their major and career. Students were interested in the topics related to the astronomy (stars and universe (3.9 vs. 2.4), solar system and planets (3.7 vs. 2.4)), the origin of the earth (3.9 vs. 2.8), plate tectonics (3.8 vs. 2.8), glacier and glacial terrain (3.6 vs. 2.7), and cloud formation (3.6 vs. 2.9), but they did not perceive that these topic are important for their major and future career (<3.0). On the other hand the topic of rocks and minerals was considered as one of the most important topic for their major and future career (4.0) but they were not very interest in the topic (2.8).

In addition, the analysis of the open-ended question shows that there are 8 ESS topics that more than 10% of the students perceived as important for their future career; The topics are listed from the highest to lowest frequency rate; 1) weather (30%, N=19) and climate (30%, N=19), 2) characteristics of submarine topography (19%, N=10) and coastal terrain (19%, N=10), 3) volcanic terrain (17%, N=9), 4) severe weather (15%, N=8), 5) impact of ocean waves on coastal topography (13%, N=7), 6) minerals (11% N=6). Most of the students also mentioned the reasons of choosing these topics. Students' answers showed that they need to understand the ESS knowledge and topics listed above topics for more safe urban design and planning and to save more energy. In other word, students considered 'safety' and 'sustainable future' by efficient urban planning as the most important values of urban planning and engineering.

Conclusion and Implications

This study shows that urban planning and engineering students' experience of team-based research about the topic they choose based on their own interest and relevance to their major and future career had positive impact on two important aspects of their learning: learning competency of earth system knowledge and understandings of the earth as a system.

The results of the study can be summarized as following:

First, the instructional approach used in the study positively impact on the students' understanding of the earth as a system. This result is evidenced by the change of concept map structure. At the beginning of the semester, most of the students' concept map was categorized as a radical structure (type A) but at the end of the semester, almost half of the students' concept map had been changed to the sub-system interaction focused structure (type B). In addition the total score of the concept map measured by a modified scoring system from Novak and Gowin (1984) had been increased. In particular, the score of 'Cross connection' category increased significantly whereas the category of 'Valid propositional link' and 'Hierarchy' decreased. This result indicates that students' understanding of interactions between earth systems has been improved.

Second, the instructional approach used in the study positively impact on the students' learning competency in four aspects: knowledge gain in earth system, learning science competency, team work skill, and perceptions of peer evaluation. Particularly, the category of earth system knowledge and learning science competency has been improved significantly from the middle of the semester to the end of the semester. This result shows that the instructional approach helped the students improve their learning competency throughout the semester.

Finally, the result shows a difference between the topics that students are interested in earth system science and that students perceived as important/relevant for their major and future career. The results of this study suggests that structuring and presenting earth system contents in the context of engineering students' major and future career is effective not only for the students' content knowledge improvement but also for enhancing their learning competency such as creativity and problem solving skills in everyday life situation.

This study also has important implications for future design of earth science course for engineering majoring students, specifically urban planning and engineering students. First, When designing a natural science course for engineering students, topics and concepts of the course should be carefully chosen based on the students' interests and relevance of their major. Second, giving opportunity of researching and presenting about an interesting topic that is relevant to their major has to be considered as a potential instructional approach for engineering students to help them as a better engineer: improving team work skill and learning competency. Finally, collaboration between engineering students, experts in engineering education, and the instructor of natural science would be beneficial to design a better course for engineering major students for their future career readiness.

Acknowledgment

This work was supported by a 2-Year Research Grant of Pusan National University

References

Fulton, K.P., 2012, 10 reasons to flip: A southern Minnesota school district flipped its math classrooms and raised achievement and student engagement. Phi Delta Kappan, 94(2), 20-24.

Jang, E.J., 2015, A study on Korean language instruction applying flipped learning, Korean Journal of Teacher Education, 31(2), 199-217. (in Korean)

Jang, M. and Nam, Y., 2012, Pre-service elementary teachers' conceptions on the relative sizes of celestial bodies. Journal of Korean Earth Science Society, 33(7), 645-657. (in Korean)

Jeong, J. and Han, S, 2010, The conceptions of astronomical distance of elementary school teachers, Journal of Korean Earth Science Society, 31(7), 827838. (in Korean)

Kinchin, I.M., Hay, D.B., and Adams, A., 2000, How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. Educational research, 42, 43-57.

Lee, H. and Lee, H., 2016, Effects of Systems Thinking on High School Students' Science Self-Efficacy, Journal of Korean Earth Science Society, 37(3), 173185. (in Korean)

Lai, C.L. and Hwang, G.J., 2016, A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. Computers & Education, 100, 126-140.

Libarkin, J., Kurdziel, J., and Anderson, S., 2007, College student conceptions of geological time and the disconnect between ordering and scale, Journal of Geoscience Education, 55(5), 413-422.

Nam, Y., 2016, Developing a framework of conceptual understandings of earth systems, Journal of Korean Earth Science Society, 37(5), 309-322.

Novak, J. and Gowin, D.B., 1984, Learning how to learn. New York: Cambridge University Press.

Park, S.J. 2015, Development of the revised model of flipped classroom and analysis of its educational effects, Research in Social Studies Education, 22(2), 1-21. (in Korean)

Patton, M., 1990, Qualitative evaluation and research methods (2nd Ed.). Newbury Park, CA: Sage

Raia, F., 2005, Students' understanding of complex dynamic systems. Journal of Geoscience Education, 53(3), 297-308.

Sell, K.S., Herbert, B.E., Stuessy, C.L., and Schielack, J., 2006, Supporting student conceptual model development of complex earth systems through the use of multiple representations and inquiry. Journal of Geoscience Education, 54(3), 396-407.

Sahin, A., Cavlazoglu, B., and Zeytuncu, Y.E., 2015, Flipping a college calculus course: A case study. Educational Technology & Society, 18(3), 142-152.

Shelton, B.E. and Hedley, N.R., 2002, Using augmented reality for teaching earth-sun relationships to undergraduate geography students. In Augmented Reality Toolkit, The First IEEE International Workshop (pp. 8-pp). IEEE.

Manuscript received: May 10, 2017
Revised manuscript received: June 5, 2017
Manuscript accepted: July 31, 2017