Factors influencing students' capstone design sentiments: a case of industrial and management engineering

Moon-Soo Kim & Gwang-Ho Wi

Hankuk University of Foreign Studies
Yongin City, Republic of Korea

ABSTRACT: The effective and successful implementation of the capstone design curriculum has been extensively researched. This study was focused on the emotions of students who participated in a capstone design course and the factors behind these emotions. An attempt was made to quantify students' emotions through the sentiment analysis of text mining based on their review data about the capstone design. Also, a survey to identify the factors that affect these emotions was conducted with students after the course. The causal analysis indicated that, first, the statistically significant positive factor in the positive sentiment was group interaction with teaching staff, while the organisation of the course, individual rapport, need for other major's knowledge, and students' own enthusiasm had a negative effect. Second, the factor that increased the negative sentiment was students' own enthusiasm, and the factor that decreased it was the learning value of the course. Lastly, on the composite sentiment, the enthusiasm and scope of the course had a negative influence, while group interaction with teaching staff - positive. The identified factors and their influence on students could inform future capstone design curricula.

INTRODUCTION

In engineering education that is directly connected to industrial sites, student-centred project-based learning (PBL) is a model that is comprehensively used in various engineering education courses, and in particular, capstone design, a representative curriculum of PBL, focuses on student project teams. The capstone design can be the most essential curriculum that solidifies major knowledge and cultivates practical skills through the collaborative learning process to solve real problems.

Numerous explorations of the educational effectiveness of capstone design [1-4] and factors affecting the achievement of participating students have been conducted across a variety of disciplines [5-7]. However, capstone design is a more difficult curriculum compared to others in engineering schools, requiring students to form autonomous teams, select project topics, and go through a collaborative learning-based problem-solving process to produce the final project result. Therefore, students in lower grades have to go through a preparation process, demonstrate interest in this subject and interact with seniors who have taken the capstone course, which may, in many cases, cause the transfer of the seniors' emotions about the curriculum to the lower-grade students [8]. The authors believe that these feelings will have a significant impact on students' preparation and participation in the capstone design curriculum. Therefore, it can be a meaningful task to examine some crucial factors that affect students' feelings about capstone design and analyse the implications that could lead to improvements in the capstone design curriculum.

Unlike previous studies, this study was focused on the emotions of students who experienced capstone design and the factors that influence these emotions. Using the sentiment analysis technique of text mining, the authors quantified the emotions felt by capstone design students based on their review data recorded immediately after taking the course. Also, in order to identify the factors that affect these emotions, a survey was conducted with students taking the course based on a revised students' evaluations of educational quality (revised SEEQ) questionnaire as a multidimensional student evaluation tool [4].

From 2013 to 2020, a survey based on the revised SEEQ was conducted annually with students about the capstone design curriculum in the Department of Industrial and Management Engineering (IME) at Hankuk University of Foreign Studies (HUFS) in Korea. In addition, each student's emotions were quantified through sentiment analysis, a text mining technique, on the course reviews included in the final report submitted by the same students in the capstone design curriculum. This study sought to examine how and what factors affect the quantified emotions of students.

TEXT MINING AND SENTIMENT ANALYSIS IN EDUCATION

Text mining is a methodology related to the process of extracting useful information from text data based on machine learning and statistics. It applies data mining algorithms to extract information, but unlike data mining based on

structured data, language processing technology is required because unstructured text data must be structuralised and features extracted. Therefore, in order to derive meaningful information, text mining requires an appropriate pre-processing procedure and the application of an extraction algorithm suitable for the objective of each analysis [9]. Text mining has been actively applied in various fields relatively recently, and various studies are being conducted as a methodology for analysing unstructured data in the education field as well. It is mainly used to analyse the vast and diverse descriptive opinions of study subjects [10-15].

Sentiment analysis is a text mining methodology that determines and quantifies the degree of emotion for words in a document based on an emotion vocabulary. It has been studied in a wide area of domain, such as movie reviews, teaching reviews [16-18], product reviews [19], e-learning [20], travellers' reviews [21], etc. Sentiment analysis may be broadly classified into machine learning emotion analysis and dictionary-based emotion analysis. Machine learning-based sentiment analysis shows higher accuracy than dictionary-based sentiment analysis when there is sufficient data, but when the amount of data is small, dictionary-based sentiment analysis shows higher accuracy. In addition, the sentiment analysis technique suitable for each emotion type differs depending on the characteristics of the data. If the data used for machine learning training does not contain information that can clearly distinguish between positive and negative emotions, it is difficult to apply machine learning-based sentiment analysis, and in this case, dictionary-based analysis is more appropriate [22]. Therefore, the dictionary-based sentiment analysis technique was used to analyse students' emotions regarding the capstone design curriculum in this study.

RESEARCH METHODOLOGY AND DATA

Sentiment Analysis Procedure and Data

In the capstone design curriculum of the IME Department at HUFS, all teams must submit a final report regardless of whether the student project passed or not. This final report contains information on what each student felt or learned while working on the project during one semester. This includes reviews that can be written freely without a set format, expressing regrets, expectations about the Department or curriculum, etc. Most of the reviews written by students are self-reflective and contain a lot of information about project performance and team members. A dictionary-based emotional analysis was performed on 171 reviews over eight years from 2013 to 2020 as shown Figure 1.

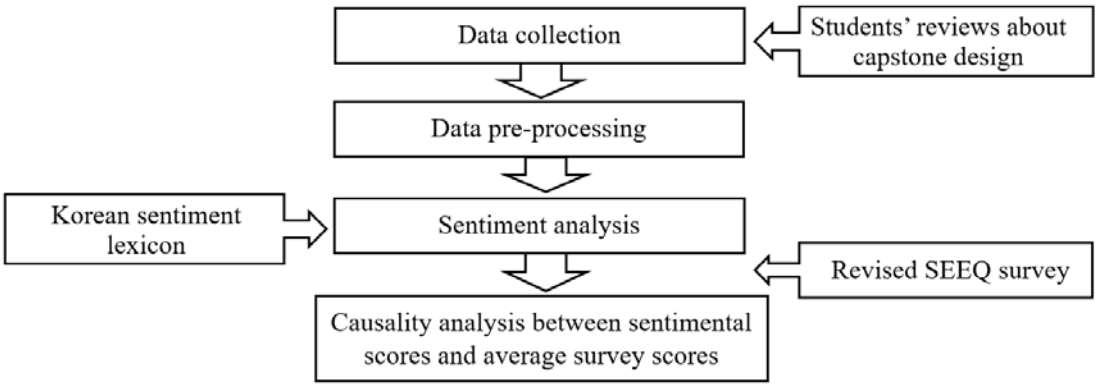

Figure 1: Causality analysis procedure between sentiment scores and survey variables.

To analyse Korean morphemes in the 171 student reviews about the capstone design curriculum, several pre-processing steps were performed using the Korean natural language processing (KoNLP) package to extract the meaningful words for analysis. Sentiment analysis can calculate an emotion score according to data characteristics by tokenising pre-processed words, checking whether the tokenised word corresponds to the emotion dictionary, and assigning an emotion score to the document to which the word belongs. First, words in sentences were tokenised using the tidytext/tidyr program in the R package, and then the Korean sentiment lexicon (KNU) [23] was used to correspond to the sentiment type and score for each word in student reviews. Using this sentiment lexicon, the sentiment type and score for the words written in the student reviews are: strong positive (2), weak positive (1), neutral (0), weak negative (-1) and strong negative (-2).

In this study, in order to consider the impact on emotions, the sentiment score was calculated as a positive score, negative score, and a composite score by adding the positive and negative score as shown in Table 1 below. Here, the negative sentiment score was originally a value below 0, but changed to an absolute value for analysis convenience, so the composite sentiment score is the value obtained by subtracting the negative sentiment score from the positive one. The standard deviation of the negative sentiment score is larger than the positive one, which shows that the range of negative emotions that students feel through capstone design performance is greater than the range of positive emotions. Further, the mean of the composite sentiment score is slightly greater than 0, which is encouraging as it indicates that students feel more positive than negative about the capstone design curriculum. However, because the magnitude is very small, the need is to increase positive emotions or to reduce negative emotions. Because the standard deviation of the negative sentiment scores is larger, ways to lower extremely high negative sentiments are likely to be more effective.

Students' Evaluation and Data

As a thorough examination of the teaching and learning effectiveness of an educational course is by nature multifaceted, implying the multidimensionality of students' evaluations, it is important to choose appropriate dimensions (i.e. factors) for that examination [24]. According to Marsh, the SEEQ demonstrated that student ratings were clearly multidimensional, quite reliable, reasonably valid, relatively uncontaminated by many variables often seen as sources of potential bias, and are seen to be useful by students, faculty and administrators [25].

In this study, in order to identify the factors that affect students' emotions about the capstone design curriculum, a survey was conducted at the end of capstone design for students enrolled in the course for eight years from 2013 to 2020, based on the revised SEEQ questionnaire modified from the original SEEQ, which included ten factors in terms of the curriculum aspect, three factors in the teaching staff aspect and four factors in the students themselves aspect [4].

In terms of the curriculum aspect, ten dimensions (or factors) in the revised SEEQ were used, and the total number of question items was 41 as of 2020, more than 30 of the original SEEQ. For the evaluation of the teaching staff perspective, a total of five question items were related to enthusiasm, organisation and team interaction, and a total of 12 question items referred to learning/value, enthusiasm, group interaction and individual rapport to evaluate students themselves. The questions were formulated using a five-point Likert scale, such as 1 (strongly agree); 2 (agree); 3 (average); 4 (disagree); and 5 (strongly disagree). The authors of this article collected only the survey results from 171 students who wrote capstone reviews from 2013 to 2020, and calculated the values, i.e. average values of responses to questions on related 17 factors in three aspects as shown in Table 1.

Table 1: Sentiment/students' survey variables and descriptive statistics.

Variables			Frequency	Min	Max	Median	Mean	SD
Sentiments	Y_1	Positive sentiment	171	0	8	2	2.66	1.91
	Y_2	Negative sentiment	171	0	9	2	2.53	2.25
	Y_3	Composite sentiment	171	-6	7	0	0.13	2.52
Curriculum	X_1	Learning/value	171	1	5	2.6	2.65	0.62
	X_2	Enthusiasm	171	1	4	2.6	2.47	0.59
	X_3	Organisation of the course	171	1	5	2.5	2.58	0.67
	X_4	Group interaction	171	1	4.25	2.25	2.37	0.63
	X_5	Individual rapport	171	1	5	2	2.39	0.84
	X_6	Breadth of coverage	171	1	3.5	2	2.04	0.61
	X_7	Multidisciplinarity	171	0	6	3.33	2.72	1.02
	X_8	Examination/grading	171	1	4.33	2.66	2.67	0.63
	X_9	Assignments	171	1	4	2.33	2.25	0.64
	X_{10}	Workload/difficulty	171	1	4.33	2.33	2.36	0.68
Teaching staff	X_{11}	Enthusiasm	171	1	4	2	2.2	0.59
	X_{12}	Organisation of the course	171	1	4	2.5	2.42	0.69
	X_{13}	Group interaction	171	1	4	2	2.29	0.81
Students themselves	X_{14}	Learning/value	171	1	4.25	2	2.13	0.61
	X_{15}	Enthusiasm	171	1	3.33	2	1.94	0.56
	X_{16}	Group interaction	171	1	3.66	2	1.93	0.54
	X_{17}	Individual rapport	171	1	5	2	2.38	0.87

Multiple Regression Analysis

In order to analyse how and what factors influence students' feelings about capstone design, the following multivariate regression model was constructed. The coefficients of 17 independent variables for each sentiment type were estimated using the Minitab 19 statistical software.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots . + \beta_n X_n + \varepsilon_i \quad (1)$$

RESULTS

In this study, assuming 17 variables in three aspects about capstone design as factors influencing students' emotions, a multivariate regression equation was estimated with a sample size of 171. However, the explanatory power and goodness of fit of the estimated regression equation were not good. Therefore, the forward selection method of the Minitab software was used to increase the explanatory power and goodness of fit by adding independent variables. Through this estimation process, as shown in Table 2, eight variables for the positive sentiment, five variables for the negative sentiment, and six variables for the composite sentiment have the best explanatory power and statistical fit for each sentiment regression.

Table 2: Multiple regression estimation for students' sentiment types in regard to the capstone design curriculum.

Positive sentiment			Negative sentiment			Composite sentiment		
	β_j	t		β_j	t		β_j	t
Constant	2.577***	3.52	Constant	-2.438**	-2.04	Constant	0.138	1.02
$X_{1(Learning/value)}$	0.242	1.30	$X_{1(Learning/value)}$	-0.434**	-2.02	$X_{2(Enthusiasm)}$	-0.492*	-1.78
$X_{3(Organisation\ of\ the\ course)}$	-0.401*	-1.86	$X_{7(Multidisciplinarity)}$	0.311	1.61	$X_{3(Organisation\ of\ the\ course)}$	-0.108	-1.39
$X_{5(Individual\ rapport)}$	-0.319*	-1.74	$X_{10(Workload/difficulty)}$	0.268	1.40	$X_{6(Breadth\ of\ coverage)}$	-0.461*	-1.88
$X_{7(Multidisciplinarity)}$	-0.345**	-2.18	$X_{13(Group\ interaction)}$	-0.277	-1.41	$X_{8(Examination/grading)}$	0.424	1.61
$X_{9(Assignments)}$	-0.207	-1.33	$X_{15(Enthusiasm)}$	0.354*	1.69	$X_{11(Enthusiasm)}$	0.285	1.40
$X_{11(Enthusiasm)}$	0.245	1.57				$X_{13(Group\ interaction)}$	0.449*	1.90
$X_{13(Group\ interaction)}$	0.793***	4.46						
$X_{15(Enthusiasm)}$	-0.386**	-2.24						
Ad_R^2	0.2104		Ad_R^2	0.0877		Ad_R^2	0.1289	
F	5.31***		F	2.38**		F	3.03***	

*p < 0.1, **p < 0.05, ***p < 0.01

Firstly, the factors that have a statistically significant impact on students' positive sentiment about capstone design include the organisation of the curriculum, individual rapport during the curriculum, multidisciplinary factors required for the curriculum from the curriculum aspect, group interaction from the teaching staff aspect and lastly, students' enthusiasm in terms of the students themselves aspect. What is noteworthy is that among these factors, the only factor that has a positive effect on students' positive sentiment about the capstone design curriculum is interaction with teaching staff. Capstone design involves frequent and diverse forms of interaction between the head professor in charge of the progress and operation of the curriculum, the advisors who guide each team, the course teaching assistants, etc. Through this, students are provided with the necessary things, such as information, knowledge, know-how, material and emotional support in order to proceed with their projects. Thus, this appears to have a significant impact on positive emotions.

However, other than interaction with teaching staff, the remaining four statistically significant factors all have negative effects on their positive sentiment about the capstone design curriculum. In terms of the curriculum aspect, the organisation of the curriculum, human relationships within the curriculum and the required multidisciplinary characteristics all have the effect of lowering students' positive emotion. Unlike other curricula taught according to a planned syllabus, capstone design is a student team-led learning process, so there are difficulties in progressing the curriculum, which seems to have resulted in lowering students' positive sentiment. In addition, the relationships between students in inter-team- and intra-team-based collaborative learning are also considered to be an unfavourable circumstance. Also, besides the knowledge of industrial management engineering, the requirement of knowledge in other disciplines, such as computer science or survey skills or professional report writing, has the effect of lowering their positive sentiment about the capstone design curriculum. Moreover, from the students themselves aspect, their enthusiasm also appeared to be lowering their positive emotions. It is likely to be caused by inherent anxiety and worry rather than favourable thoughts about the capstone design curriculum.

Secondly, the factors that are statistically significant in regard to students' negative sentiment about the capstone design curriculum are the learning value factor from the curriculum aspect and students' enthusiasm from the student themselves aspect. Table 2 shows a regression equation in which the negative sentiment increases as the negative emotion score value increases. Therefore, factors with negative estimated coefficients have the effect of lowering negative sentiment, which is the right direction to proceed.

The fact that the learning value factor through the curriculum is lowering students' negative emotions indicates that students have a sufficient emotional understanding of the learning value of capstone design. On the other hand, students own enthusiasm shows similar results to the positive sentiment estimation. Rather than positive enthusiasm, anxiety and worry when taking the capstone design curriculum seem to amplify negative emotions. Therefore, in order to reverse this negative enthusiasm to a better one, it is necessary to make students aware of the various effects that can be achieved through carrying out their capstone design project.

Lastly, the factors that have a statistically significant influence on the composite sentiment are the elements that induce enthusiasm by the capstone design itself, the breadth of the project's coverage and the group interaction with teaching staff factor. To induce students' enthusiasm by the curriculum seems to have a negative effect on their composite sentiment due to the difficulty in the project's execution and the unfamiliarity of capstone design. Moreover, it seems understandable that the uncertainty and broad scope of the project would have a negative impact on the overall sentiment toward the capstone design curriculum.

The group interaction with teaching staff had a positive effect, with statistically significant values, similar to the positive sentiment regression estimation, and although it was not statistically significant in the negative sentiment

estimation, it had the effect of lowering the students' negative emotions about capstone design because its coefficient is -0.277. Moreover, the coefficient values of group interaction with teaching staff were relatively larger for the positive and composite sentiment estimation, i.e. 0.793 and 0.449, respectively, than other coefficients, indicating that this factor encouraged far more amicable feelings in students participating in the capstone design curriculum. Therefore, in order to effectively improve positive and overall emotions about the capstone design curriculum, more emphasis should be placed on strengthening group interactions with teaching staff, and constant efforts made to increase students' understanding of the learning value of capstone design in order to lower negative feelings about the curriculum.

CONCLUDING REMARKS

Many studies have been conducted on various methods to improve the educational effectiveness of capstone design, but there are few studies on the emotions of students participating in capstone design curricula or the factors influencing those emotions. Hence, this pilot study was undertaken to examine the factors that influence the emotions of students who had experienced capstone design. The authors tried to quantify the emotions felt by capstone design students based on their reviews recorded after taking the course by using the sentiment analysis technique.

In order to identify the factors that affect these emotions, a survey was conducted on students taking the course based on a revised SEEQ. Emotions were quantified by dividing them into three types such as positive, negative and composite sentiments. Also, a multiple regression analysis was performed for each sentiment type using the dependent variables of three emotional elements and the scores for each of the 17 factors evaluated through the survey as independent variables.

Through multivariate regression analysis, it was found that several factors had various effects depending on the type of sentiment. However, a common characteristic is that the group interaction with teaching staff factor had a good positive effect on any type of students' sentiment. In particular, it had a greater impact on the positive and overall emotions than other factors. The importance of interaction with faculty members was confirmed to be the most important factor not only in the educational effectiveness of the capstone design curriculum, but also in the emotions felt by students.

Further, the authors were able to identify various factors that worsen the emotions of each type, and it is necessary to come up with a plan to improve the emotional effects caused by these factors. For example, awards for excellent project outcomes, improvement of the capstone design image through competitions, morale boosting by teaching staff, cheering events for teams, industry-academia co-operation support events, practical team and individual counselling systems for capstone students, students' career support through utilisation of project outcomes to the industries, etc. However, detailed investigations on specific and diverse measures for each factor influencing the capstone design curriculum, as well as in-depth studies including a psychological approach to students' emotions using sentiment analysis of text mining are necessary as further research directions.

Despite the scope of this research being confined to a single academic field and the limitations of sentiment analysis techniques, the analysis approach and results of this study are expected to be widely applied and utilised in capstone design and other curricula in various disciplines.

ACKNOWLEDGEMENTS

This research was supported by the Basic Science Research Programme through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (NRF-2017R1A2B4005858) and Hankuk University of Foreign Studies (HUFS) research fund of 2023.

REFERENCES

1. Hotaling, N., Fasse, B.B., Bost, B.F., Hermann C.D. and Forest, C.R., A quantitative analysis of the effects of a multidisciplinary engineering capstone design course. *J. of Engng. Educ.*, 101, **4**, 630-656 (2012).
2. Julien, B.L., Lexis, L., Schuijers, J., Samiric, T. and McDonald, S., Using capstone to develop research skills and graduate capabilities: a case study from physiology. *J. of University Teaching and Learning Practice*, 9, **3**, 1-15 (2012).
3. Chan, C.K.Y., Wong, G.C.K., Law, A.K.H., Zhang, T. and Au, F.T.K., Evidence-based conclusions concerning practice, curriculum design and curriculum reform in a civil engineering capstone design course in Hong Kong. *Innovations in Educ. & Teaching Inter.*, 54, **3**, 260-274 (2017).
4. Kim, M-S., The effects of a capstone design course in industrial and management engineering: students' evaluation. *World Trans. on Engng. and Technol. Educ.*, 18, **4**, 410-416 (2020).
5. Chaparro-Pelaez, J., Iglesias-Pradas, S., Pascual-Miguel, F.J. and Hermandez-Garcia, A., Factors affecting perceived learning of engineering student in problem based learning supported by business simulation. *Interactive Learning Environments*, 21, **3**, 244-262 (2013).
6. Joo, Y., Lim, K. and Lee, S., Project-based learning in capstone design courses for engineering students: factors affecting outcome. *Issues in Educ. Research*, 29, **1**, 123-140 (2019).
7. Kim, M-S., Factors affecting performance of student project teams in capstone design. *Global J. of Engng. Educ.*, 26, **1**, 13-19 (2024).

8. Kim, M-S., Lessons from a capstone design course with a 3D printing project. *Global J. of Engng. Educ.,* 21, **3**, 179-188 (2019).
9. Hotho, A., Nürnberger, A. and Paaß, G., A brief survey of text mining. *J. for Language Technol. and Computetional Lingistics*, 20, **1**, 19-62 (2005).
10. Sliusarenko, T., Clemmensen L.H. and Ersbøll, B.K., Text mining in students' course evaluation: relationships between open-ended comments and quantitative scores. *Proc. 5th Inter. Conf. on Computer Supported Educ.,* Aachen, Germany, 564-573 (2013).
11. Choi, J.W. and An, D.K., A study on the data analysis of the written comments in lecture evaluation. *J. of Digital Convergence,* 14, **11**, 101-106 (2016).
12. Min, H. and Yoon, H., A study on perception differences between professor & student's evaluation of courses by open-ended response: a network and content analysis. *J. of Learner-Centered Curriculum and Instruction*, 17, **11**, 307-330 (2017).
13. Ha, J.Y, and Rah, M.J., What contributes to lecture satisfaction or dissatisfaction in university students? *CNU J. of Educational Studies*, 38, **3**, 61-77 (2017).
14. Kaur, A. and Kaur, H., Framework for opinion mining approach to augment education system performance. *Inter. J. of Inno. Technol. & Creative Engng.*, 8, **6**, 493-497 (2018).
15. Lee, C.S., Analysis of descriptive lectures evaluation using text mining: comparative analysis pre and post COVID-19. *J. of The Korea Society of Computer and Infor.*, 27, **10**, 211-222 (2022).
16. El-Halees, A., Mining opinions in user-generated contents to improve course evaluation. *Proc. Software Engng. and Computer Systems: Second Inter. Conf.*, 27-29 June, Kuantan, Pahang, Malaysia. Berlin, Heidelberg: Springer, Part II 2, 107-115 (2011).
17. Sagum, R.A., de Vera, J.G.M., Lansang, P.J.S., Narciso, D.S.R. and Respeto, J.K., Application of language modelling in sentiment analysis for faculty comment evaluation. *Proc. the Inter. Multi Conf. of Engineers and Computer Scientists*, 18-20 March, Hong Kong, 1 (2015).
18. Altrabsheh, N., Cocea, M. and Fallahkhair, S., Sentiment analysis: towards a tool for analyzing real-time students' feedback. *Proc. of 2014 IEEE 26th Inter. Conf. on Tools with Artificial Intelligence*, Limassol, Cyprus, 419-423 (2014).
19. Avanco, L.V. and Nunes, M.G.V., Lexicon-based sentiment analysis for reviews of products in Brazilian Portugues. *Proc. 2014 IEEE Brazillian Conf. on Intelligent Systems,* Sao Paulo, Brazil, 277-281 (2014).
20. Ortigosa, A., Martín, J.M. and Carro, R.M., Sentiment analysis in Facebook and its application to e-learning. *Computers in Human Behavior,* 31, 527-541 (2014).
21. Alaei A.R., Becken, S. and Stantic, B., Sentiment analysis in tourism: capitalizing on big data. *J. of Travel Research*, 58, **2**, 175-191 (2019).
22. Kim, E. and Song, M., A study on social big data-based public opinion and affect on TV advertising of oral contraceptive: focusing on *Merceron* TV advertising. *J. of PR in Advertising and Public Relations*, 10, **2**, 39-63 (2017).
23. Park, S., Na, C., Choi, M., Lee, D. and On, B., KNU Korean sentiment lexicon: Bi-LSTM-based method for building a Korean sentiment lexicon. *J of Intelligence Infor. Systems*, 24, **4**, 219~240 (2018).
24. Kim, M-S., Development and effect of a Web-based problem-based learning system for an accounting course in engineering education. *World Trans. on Engng. and Technol. Educ.*, 14, **3**, 394-403 (2016).
25. Marsh, H.W., Students' evaluations of university teaching: dimensionality, reliability, validity, potential biases, and utility. *J. of Educ. Psychology*, 76, **5**, 707-754 (1984)