Sentiment analysis and research issues for engineering capstone courses

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ABSTRACT: In engineering education, capstone design is one of the most essential curricula that solidifies major knowledge and cultivates practical skills through collaborative learning. Students must undergo several preparatory courses, demonstrate interest in the subject, and interact with seniors who have completed the capstone course. Seniors' feelings about the capstone design course are often conveyed to younger students. Therefore, this study does not focus on existing lecture satisfaction or course achievement, but on the emotions felt through curriculum performance. Using sentiment analysis on the course review data collected over 14 years, and included in the report submitted upon completion of the course, positive, negative and neutral emotions of fourth-year students who took the capstone design course are examined. In particular, the analysis focuses on changes in emotions by year, differences between male and female students, and differences in emotions depending on whether or not the capstone design was passed. Through the emotion analysis results, various ways are discussed to improve the capstone design and future research directions for sentiment analysis methods in engineering education.

INTRODUCTION

Sentiment analysis (SA), an analysis technique for unstructured data obtained from humans, is used in a wide variety of fields. In particular, it has been widely used in customer management in most industries through sentiment analysis of various replies and feedback from customers on the wired and wireless Internet. It also plays an important role in education, where students' comments are essential to evaluate the effectiveness of teaching and learning systems.

In an on-line environment, especially on-line learning portals like Coursera, millions of students join these massive open on-line courses (MOOCs) every year and can share their opinions about the course content and quality. Further, they also comment about their learning experiences in blogs, on-line forums or student response systems, etc. SA on this vast on-line student comments not only provides valuable insights to college administrators and professors, but also plays a critical role in influencing student decisions about which courses to take [1].

With the development of on-line education and lecture systems, SA is also developing and being widely used. However, SA in engineering education, especially for existing face-to-face education courses, is considered relatively less useful, hence a paucity of relevant research in this specific area. Accordingly, this study examines the usefulness of SA in engineering education by using a case of SA for a capstone course, which is the most essential curriculum that solidifies major knowledge and cultivates practical skills through the collaborative learning process to solve real problems. The study identifies also future research directions for sentiment analysis in engineering education, including the capstone curriculum.

SENTIMENT ANALYSIS IN ENGINEERING EDUCATION

Sentiment analysis is the process of identifying and classifying users' opinions from a piece of text into different sentiments [2]. Usually, in most educational fields, sentiment and emotion are used without much distinction, but there is a strict difference between the two terms. Emotion is defined as a strong feeling deriving from one's circumstances, mood or relationships with others, and is a short and intense response caused by a specific object or event [3].

According to Plutchik, emotions are divided into eight groups: joy, anticipation, anger, disgust, fear, trust, surprise and sadness [4]. Also, various emotions resulting from a mixture of these emotions, such as being interested, bored, and pained, were presented. Meanwhile, sentiment can be defined as a positive or negative feeling that determines a human's opinion and indicates a combination of social emotions, cognitive processes and behaviours [5]. Unlike emotions, sentiments are built and maintained for a longer period [6]. Most SA use the information (explicitly or implicitly) obtained from emotion analysis [7]. Therefore, SA, a text mining methodology, determines and quantifies the degree of emotion for words in a document based on emotion vocabulary.

SA is widely used in customer management with unstructured data, such as customer comments or replies in various industrial fields. In the field of education, SA is also used to analyse the relationship between learners' emotions, behaviour, performance and achievements to examine learners' satisfaction and attitude, to evaluate instructors; also sentiment analysis methods and systems are objects of study and design [8]. Research in the field of education is mainly focused on analysing the emotions of learners in educational institutions, such as K-12 and universities [1][2] or engaged in on-line education systems, such as MOOCs [6][8], which may be due to the diverse and extensive opinions of many learners that can be collected and utilised.

For this reason, research on conducting SA at the level of a single curriculum, such as capstone design, is scarce. However, considering the importance of capstone design in engineering education and the extensive existing studies conducted on this topic, various emotional analyses and utilisation of capstone design seem very important and essential. Capstone design is well known to be more difficult for learners than other courses in engineering colleges, 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. Students in lower grades have to go through a preparation process through interest in this subject and interaction with current seniors undertaking the capstone, and therefore, there are many cases where the emotions about the curriculum felt by the current seniors are transferred to them [9]. The author believes that these feelings will have a significant impact on students' preparation and participation in the capstone design curriculum.

A CASE OF SENTIMENT ANALYSIS ON ENGINEERING CAPSTONE DESIGN

Capstone Data and Sentiment Analysis Procedure

In this study, SA was performed based on the review data of students who participated in the capstone design conducted at the Department of Industrial Management and Engineering (IME), Hankuk University of Foreign Studies (HUFS) in Korea, for a total of 14 years from 2006 to 2020 (excluding 2008, when the data was lost). SA may be broadly classified as machine learning emotion analysis and dictionary-based emotion analysis. Machine learning-based sentiment analysis shows higher accuracy than dictionary-based SA when there is sufficient data, but when the amount of data is small, dictionary-based SA shows higher accuracy. In addition, the SA technique suitable for each emotion type differs depending on the characteristics of the data. If the data used for machine learning training do 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 [10]. Therefore, the dictionary-based SA technique was used to analyse students' emotions regarding the capstone design. Figure 1 shows the SA procedure for the capstone design review, using the Korean Natural Language Processing package (KoNLP).
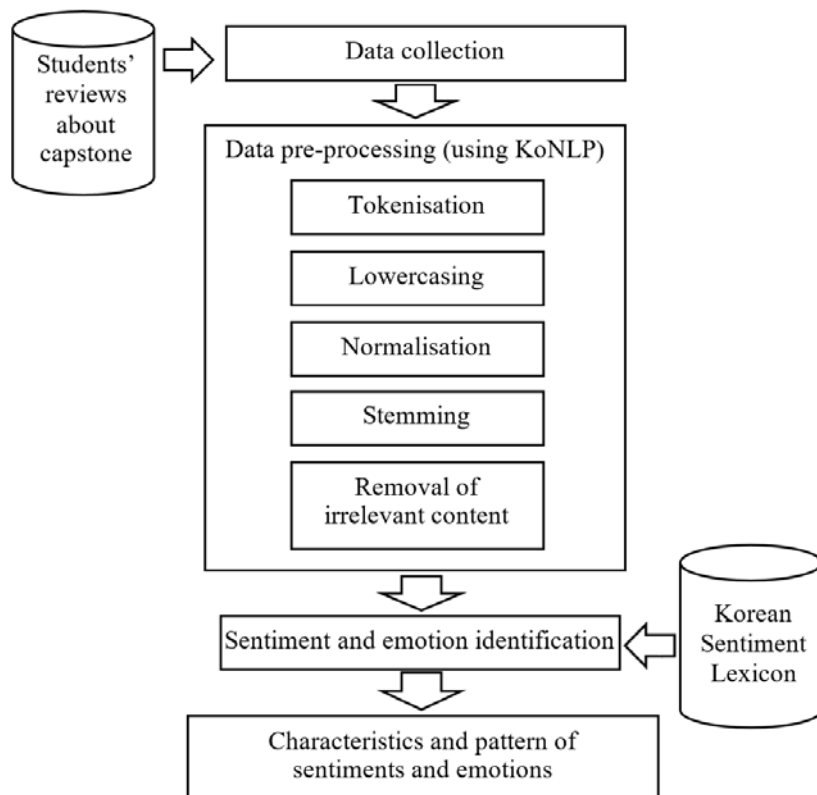

Figure 1: Sentiment analysis procedure for capstone design.

In the capstone design of IME 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. Dictionary-based emotional analysis was performed on 414 reviews covering over 14 years from 2006 to 2020. In particular, the 414 data set consisted of 284 male students and 130 female students, including 356 students who passed and 58 students who did not pass.

To analyse Korean morphemes in the 414 student reviews about the capstone design, several pre-processing tasks were performed using the KoNLP package to extract 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 pre-processed, through tokenisation using the tidytext/tidyr program in the R package, and then the *KNU Korean Sentiment Lexicon* [11] was used to correspond to the emotion type and score for each word in student reviews. First, the author identified and responded to the 10 emotions provided by the Korean Sentiment Lexicon [11], calculated the proportion of each emotion, and analysed differences by gender. Second, in order to clearly understand the emotional characteristics of students regarding the capstone, three polar sentiments, such as positive, negative and neutral were scored as strong positive (2), weak positive (1), neutral (0), weak negative (-1) and strong negative (-2). Using emotional scores, students' emotional characteristics and patterns were analysed according to gender, pass/fail, time, etc.

Characteristics of Capstone Emotions and Sentiments

Figure 2 shows the distribution of the 414 data set according to the 10 emotion types classified by the Korean Sentiment Lexicon [11] and the proportion of male and female students. The biggest emotions students felt were happiness and sadness. Then, the emotions of fear and anger came next. It can be seen that unfriendly emotions, such as sadness, fear, and anger are expressed more often than the friendly emotions of happiness and interest in the capstone curriculum.
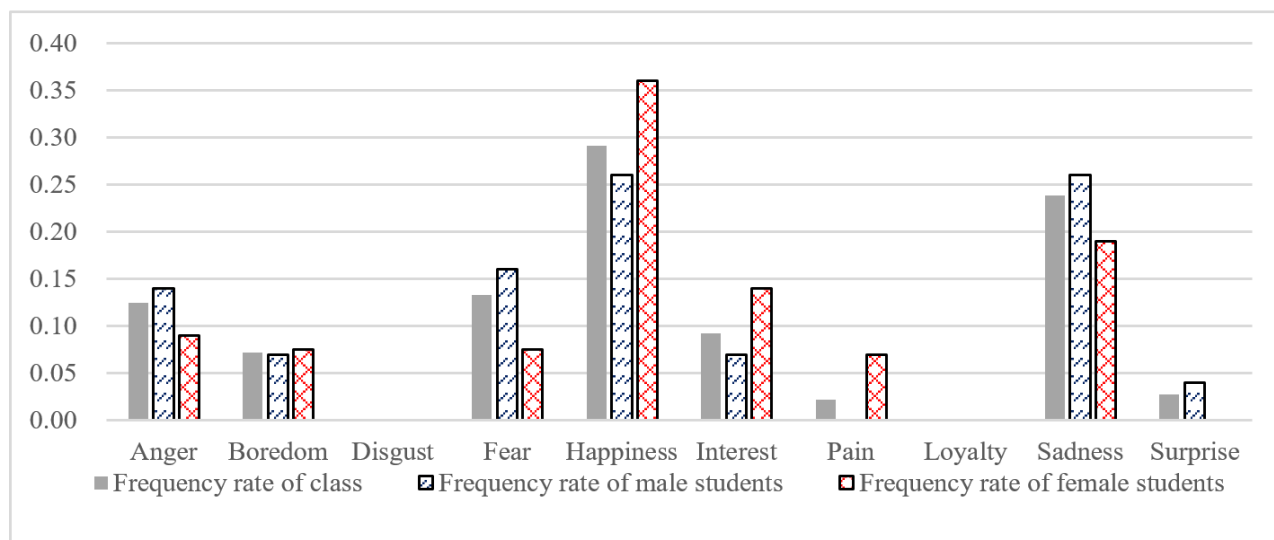

Figure 2: Frequency rate of emotions in the capstone class.

There are some differences in feelings about the capstone depending on gender. In the case of male students, the proportion of happiness and interest, which are friendly emotions toward the capstone, was significantly lower at 33% compared to 50% of female students. Moreover, the unfriendly emotions of sadness, fear and anger were significantly higher among male students at 63% and among female students at 43%. Students who took the capstone course were ill-disposed toward it, and male students show more unfriendly emotional characteristics than female students. Still, the fortunate thing is that the biggest feeling about the capstone is happiness. This seems to indicate that the results obtained while participating in the capstone course are giving students a sense of accomplishment.

According to a review study of sentiment analysis in the field of education, most studies had more than 1,000 data size [8], and it can be seen that more data sets are needed to analyse various emotions. However, the data sets of this size in this study are somewhat lacking. Accordingly, using the Korean Sentiment Lexicon [11], various emotions were mixed, classified into three sentiments, scored, and their characteristics analysed.

Figure 3 next page shows the proportion of student sentiment scores based on gender and whether or not the student passed the capstone project. As shown in Figure 2, where all students' friendly emotions toward the capstone were lower than their unfavourable feelings, Figure 3 also demonstrates that the positive sentiment was lower than the negative sentiment. However, in the sentiment analysis by gender, female students' positive sentiment was relatively low and negative sentiment was relatively high compared to male students. This is a somewhat different result from Figure 2. Meanwhile, the positive sentiment of students who did not pass the project evaluation were significantly lower than that of students who passed, but this did not seem to lead to significant negative sentiment, see Figure 3 (r).
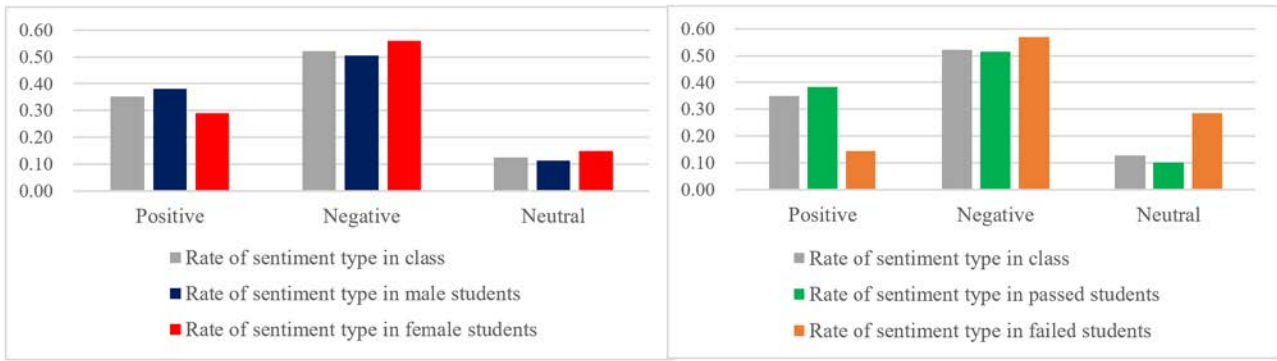
Figure 3: Rate of sentiment type by gender (l) and by pass/fail in the capstone class (r).

Next, in order to understand the dynamic changes in students' sentiments toward the capstone over time, the changes in the average scores of the three types of sentiment by year were analysed and are shown in Figure 4. Here, excluding neutral sentiment, positive and negative emotion scores were analyses, and a composite score that is the difference between them calculated. Except for 2013 and 2019, negative sentiment scores tend to be slightly higher than positive sentiment scores in most years. The average negative sentiment score was 11.52, the average positive sentiment score was 10.82, making the average negative emotion score approximately 0.7 higher. Although the difference between these sentiment scores is not statistically significant, students on average used more words with negative feelings than words with positive feelings in their reviews.
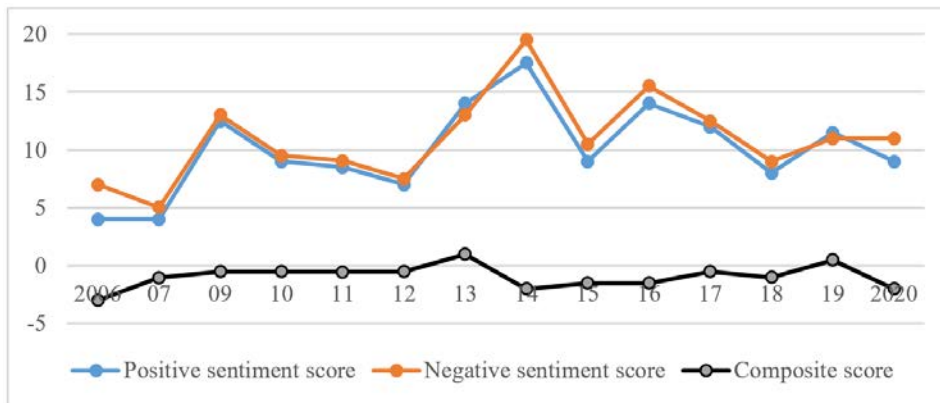

Figure 4: Capstone sentiment score trend by year.

RESEARCH ISSUES OF SENTIMENT ANALYSIS FOR CAPSTONE DESIGN

By using sentiment analysis of the reviews of students who took capstone design from 2006 to 2020, the author analysed the emotional phenomenon of students regarding the capstone in more detail, and through this, the necessity and importance of sentiment analysis in engineering education were demonstrated. In particular, considering the importance and educational effectiveness of capstone design in engineering education, various research issues related to capstone design and sentiment analysis may be considered. In order to derive research issues related to capstone design and sentiment analysis, a related simple conceptual model is presented in Figure 5.
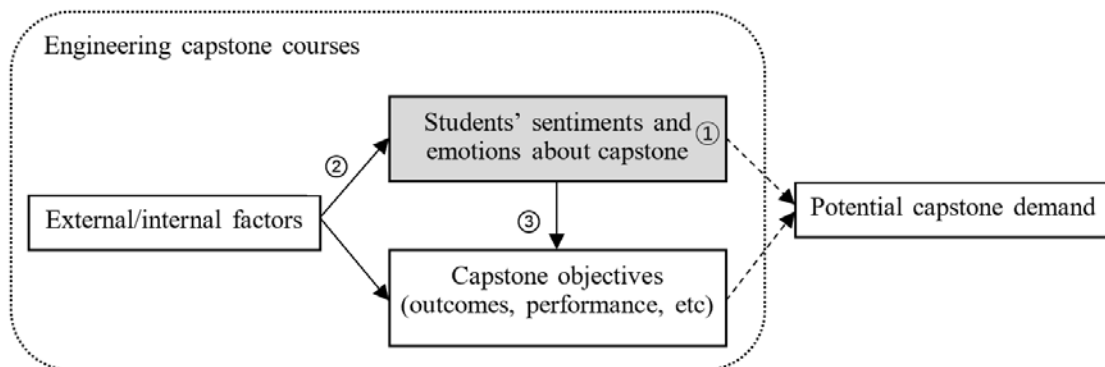

Figure 5: A conceptual model for capstone and sentiment analysis.

As shown in the Figure 5, research issues related to the capstone course and sentiment and emotion analysis can be discussed in three parts.

First, as in the case analysed in this study, analyses of the sentiments and emotions of students participating in capstone design are conducted periodically and continuously. Since sufficient data from students is needed to identify sentiments and emotions that can be used in the capstone curriculum, a Web and app-based database that can accumulate formal and informal documents, maintain and manage them is important. Designing and developing information systems operating this database can also be considered an essential research field. Through this, one can analyse changes in sentiments and emotions every year or semester. In addition, students' emotions at the beginning of the capstone curriculum are often formed by transferring the emotions and information of seniors who took the capstone earlier [9].

The emotions at the end of the capstone course appear as solidification or change in existing emotions or new emotions emerge through students' experiences and achievements. Therefore, analysis of dynamic changes in student emotions toward capstone design will also be very useful information for improving the capstone design curriculum. Moreover, research in terms of sentiment analysis methodology is also an important issue. Since the sentiment analysis of capstone design at the individual course level has a smaller data size compared to sentiment analysis in the existing education field, the accuracy and reliability of identifying and classifying emotions and sentiment inevitably decreases, so it is also necessary to improve this aspect.

The second issue refers to a research field that identifies and analyses factors that directly and indirectly affect the formation of students' emotions and sentiments. As mentioned earlier, emotions at the beginning of the semester become fixed, there could some change in existing emotions or new emotions can be formed while experiencing the capstone design course. Identifying factors that influence the formation of these emotions is a very important research topic for improving the capstone curriculum. A pilot study by Kim and Wi [12], despite limitations in data size and technical limitations in emotion identification and quantification, is a good example of identifying major influencing factors through causal analysis; in this case a total of 17 factors from the capstone curriculum, teaching staff and students themselves can have impact on students' sentiment scores.

The third issue, is about a study on how students' emotions about the capstone design course affect the achievement of the capstone's educational goals. Through analysis of how emotions affect the results that can be obtained through the capstone, it will be possible to identify emotions that need to be formed, reduced and eliminated. In addition, it can be used as important information in curriculum design to achieve capstone education goals.

As for other research, analysing the impact of sentiment analysis results on the demand for future potential capstone education is also identified as meaningful research in the long term, and this appears to be a research area of interest not only at the departmental level, but also at the university level.

CONCLUDING REMARKS

The capstone design curriculum, in engineering education, is one of the most essential curricula that solidifies major knowledge and cultivates practical skills through a collaborative learning process to solve real-world problems. Students must undergo several preparatory courses, demonstrate interest in the subject, and interact with seniors who have completed the capstone course. Seniors' feelings about the capstone design are often conveyed to younger students.

Therefore, this study was focused on the emotions felt by students in capstone design and sentiment analysis conducted using the capstone design course of a specific department as a case study. In addition, future research issues were discussed while considering the importance and necessity of sentiment analysis in the capstone curriculum. Based on a simple conceptual model, major research issues were divided into three categories and presented with a focus on sentiment analysis in the capstone curriculum.

In order to maximise the positive effects that students gain through capstone design, various and extensive studies have been conducted on capstone design in engineering education. In the context of such research, this study proposed research issues in which sentiment analysis, a text mining technique, can be applied limited to the capstone curriculum as a methodology to analyse unstructured data. However, it is expected that more precise, in-depth and extensive research will be possible with the development of emotional analysis techniques in the future.

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