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A Comparative Analysis of Students' Evaluations of Online and Offline Capstone Design Course

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ABSTRACT
The College of engineering's capstone design is student-team-centred learning based on project-based learning and is one of the most important courses for students aiming to be competent professional engineers capable of solving real industrial problems. Therefore, in order to resolve the capstone problems, various face-to-face contacts such as frequent industrial site visits, multiple meetings with diverse people including team members, and repeated contacts with course-supervising and team-advising professors are prerequisite processes. However, according to the transition to fully online education due to the global pandemic of COVID-19, capstone design courses for 2020 and 2021 were also conducted online. Based on the modified students' evaluations of educational quality (SEEQ) with 3 perspectives such as curriculum, teaching-staff and students themselves, this study compares their evaluations of offline capstone designs from 2013 to 2019 and online capstone designs in 2020 and 2021 in the context of COVID-19. In 3 perspectives, the difference in students' evaluation of the online capstone between the beginning and the end of the course shows a positive effect, which is better than the offline capstone. Also, in various dimensions for each perspective, the online capstone shows a better evaluation than the offline capstone. These findings suggest that the online capstone design curriculum can be expected to have educational effects as well as students' satisfaction with the online curriculum in the future.

Keywords: Capstone design, PBL, COVID-19, Online, Offline, Modified SEEQ, Comparative analysis, Students' evaluation

I. INTRODUCTION

The global pandemic of COVID-19 has radically changed political, economic and social life. In particular, it had a great impact on the education system, a process of teaching and learning. The capstone design in engineering education, student-team-centred learning based on project-based learning and one of the most important courses for students aiming to be competent professional engineers, is no exception. Capstone course has many and diverse advantages for students(Bordogna et al., 1993; Palmer & Hall, 2011), and in order to achieve these effects, various learning activities such frequent industrial site visits, multiple meetings with diverse people including team members, and repeated contacts with course-supervising and team-advising professors are required to solve real problems based on team cooperative learning. Kim(2020) examined various effects from the 3 educational perspectives of the course with 9 dimensions, teaching-staffs with 3 dimensions and the student with 4 dimensions based on the students' evaluations of educational quality (SEEQ) collected before and after the capstone course of Industrial & Management Engineering (IME) from 2013 to 2019 of Hankuk University of Foreign Studies (HUFS) in Korea. This study compares and analyzes the educational effect of online capstone design for two years of 2020 and 2021 under the COVID-19 situation with offline capstone designs during the previous years.

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II. STUDY BACKGROUND

1. Capstone design as a PBL

A number of teaching strategies and methods have been

suggested to reduce the incongruence between the real world and the classroom. Among those, an effective solution is project-based learning (PBL), especially for engineering students. In most engineering school the capstone design course based on project-based learning seeks to prepare engineering students for work in the industry by challenging teams to synthesize solutions to open-ended, real-world problems, typically through the employment of project-based learning activities based on industrial problems(Barrows, 1994; Reynolds & Hancock, 2010). Participation in the capstone design provides students with the opportunity to transition from student communities of practice to professional communities of practices, i.e., from the classroom to real industry. Further, working with a client-advisor from the field (industrial engineers, start-up companies, company representatives, teaching staffs, laboratories, their alumni, etc.) in a type of apprenticeship, students are challenged with real-world needs. Typically, in one or two semesters of the course, teams define a problem, plan their approach, propose creative solutions, analyse the proposed solutions, produce or implement the solutions, and then communicate them internally and externally(이태식 외, 2009; 이회원 외, 2010; 김문수, 2015).

PBL class is based on using knowledge through cooperative learning process based on learner-centred or self-directed learning and applying popularly to engineering education. It renders student many advantages: the students participating in PBL can develop teamwork skills and experiences; they can cultivate the leadership and sense of ownership in the learning through the problem-solving process; they can learn the self-regulation and devotion, and be able to nourish respective competitiveness; they can understand the multidisciplinary and systematic aspects situated in engineering application problems empirically; they can also gain experience to cope with actual engineering application problems professionally; they can learn how to review or to reflect on the results of each project task, and they can develop capabilities of official documentation, presentation and communication; the learners can also attain capabilities to deal with incomplete or inaccurate information. Thus, such those educational and professional advantages of PBL have encouraged universities to open PBL courses from freshman to senior level(Palmer & Hall, 2011; Hotaling et al., 2012).

2. Capstone design at HUFS IME

The HUFS IME Capstone is a compulsory course for 4th grade students since the spring semester of 1996 as a gateway to graduation and is equivalent to five academic credits. The students taking this mandatory course select their teams and projects autonomously, which are concerned with actual industrial issues are usually recommended to students. The capstone course might be divided into 3 types: the pre-course; the class-course; and post-course. In the pre-course to be carried out before the semester, the activities using team building system such as team organization, the search for a project and the preliminary study associated with the project are performed. The main work in the pre-course is preparing the proposal and presentation in the first week of the class-course. The class-course begins with oral presentations and submitting proposals by all teams to open the IME department on Saturday of the 1st week. And the mid-term evaluation with oral presentation and interim report to decide to go or stop on Saturday of the 8th week and the final-term evaluation with oral presentation and final report to decide pass or fail the team project on Saturday of the 16th week. The formal project execution is initiated upon appointment of dedicated faculty member to each project team, i.e., advisor-to-team, together with the determination of the final subject of each project. The department has usually assigned a professor as an advisor to one or two project teams for 16 weeks. During the semester, each project team must provide a biweekly presentation of their project's progress in the class and the informal project activities are facilitated by weekly meeting with advisor-to-team. Further, through frequent visits to, and meetings with industrial clients, the project team can learn about real industrial issues and explore methods of coping with such issues(Kim, 2019).

3. Capstone design under COVID-19

After the COVID-19 outbreak, during the two spring semesters of 2020 and 2021, all teaching and learning activities of capstone course including all presentations, three

evaluations by faculty members, weekly meetings with advisor-to-team and team itself meeting, etc., have been moved to online class using Webex, Zoom and Google meet, etc. Also, the IME Capstone has been changed to a selective course instead of a mandatory one for students. It has is a very important meaning in terms of the effectiveness of capstone design because students with strong project execution motivation and willingness to actively participate in online team cooperative learning activities are more likely to participate.

From 2011 to 2019, on average 48 senior students have enrolled in capstone class and 11 project teams consturcted, but only 12 and 19 senior students took the class with 4 and 5 teams formed during two semesters of 2020 and 2021, respectively. Before the COVID-19 crisis, the average pass rate of the capstone course was about 70%, but since the capstone course was changed from a mandatory course to a selective one, it showed a 100% pass rate after that. Most of the students who completed the capstone design course stated that they had or experienced the benefits of the mentioned PBL references. In particular, they pointed out that the greatest experience in dealing with the real problems of the industry and solving them through team collaborative study is the greatest gaining confidence in working life after graduation regardless of online and offline courses.

After enrolling at IME, students have heard many stories from professors and seniors about the various benefits and challenges of the capstone design process. In such an atmosphere, students begin to prepare the capstone design through the department's curriculum. Students at the end of the third year are fully aware of the entire course and past achievements of the capstone course through a formal orientation period, become familiar with the department (online orientation in case of 2020 and 2021), and expect many benefits mentioned in previous studies. However, while students have high expectations for the educational effect of capstone design, they are also anxious about whether they will succeed. As this expectation of students' capstone design is changed to a full-scale online course in response to COVID-19, how it will affect the educational effect by students will provide a very important implication for the operation of the capstone design.

III. RESEARCH METHODOLOGY AND DATA

1. Students' survey and evaluation

In order to compare the various aspects of students' evaluations on online capstone and offline capstone design, the modified students' evaluations of educational quality (SEEQ) performed in the previous study was applied(Kim, 2020). The previous studies and the methods applied in this study are summarized as follows. Because teaching and learning effectiveness of education courses by nature multifaceted, implying the multi-dimensionality of students' evaluations, it is important to choose appropriate dimensions that are to be carefully examined(Marsh, 1991). Having reviewed a number of previous studies and evaluation schemes, students' evaluations of educational quality (SEEQ), being used in numerous subsequent theoretical and empirical studies(Marsh & Bailey, 1993; Marsh & Roche, 1997; Marsh et al, 2002; Umbreit & Gursoy, 2005; Tsinidou et al., 2010), appears to be suitable for a comprehensive level for several years, including the student, curriculum, and teaching-staff perspectives of capstone course. According to the previous studies, 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(Marsh, 1984).

The SEEQ has originally 9 dimensions to evaluate courses of diverse academic disciplines at graduate and undergraduate levels; learning/value with 5 evaluation items, enthusiasm with 5 items, organization with 4 items, group interaction with 4 items, individual rapport with 3 items, breath of coverage with 4 items, examination/grading with 3 items, assignments with 2 items, and workload/difficulty with 3 items(Marsh, 1987).

Adopting modified SEEQ dimensions, students evaluated the before and after capstone designs of the IME. The evaluation by students was divided into 3 educational perspectives: the capstone design curriculum, the capstone design teaching-staff, and the students themselves who participated in the capstone design. The biggest difference from the existing SEEQ is that the teaching-staff part and

the participant part were separated from the existing SEEQ, and the questions of the relevant dimensions were surveyed to the students. This is because the capstone design has a curriculum that is differentiated from other curriculums, and because the role of teaching-staff, and student participation as a team member are important. In the case of long-term research and analysis of the modified SEEQ model and questionnaire, it is possible to analyze changes in the evaluation of students' curriculum, which is expected to be of great help in improving the capstone process.

In terms of the curriculum perspective, nine dimensions of the existing SEEQ were used, and the total number of question items was 39 as of 2017, more than 30 of the SEEQ. For the evaluation of the teaching staff perspective, a total of 5 question items were composed of enthusiasm, organization, and team interaction, and a total of 12 question items were composed of learning/value, enthusiasm, group interaction, and individual rapport to evaluate students themselves. Using the modified SEEQ questionnaire, a survey was conducted at the beginning of capstone design for students enrolled in the course for 9 years from 2013 to 2021, and then the same survey was again conducted with the same questionnaire at the end of the course, i.e., a total of 18 surveys. 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). Additionally, the students were asked to list their previous relevant classes and to provide population profile data including age, student identification number, and so on. Therefore, a statistical analysis on 18 surveys for 9 years enables us to examine the differences by each question item, dimension, and perspective before and after the course including difference between online capstone for the period from 2020 to 2021 and offline capstone for the period from 2013 to 2019.

As mentioned above, IME students recognize the various effects and difficulties of the capstone design course before taking the course, and expect positive educational effects. Therefore, most students generally give positive evaluations on three perspectives of the course. However, through continuous interactions between the student team and teaching-staffs, interactions between team members within the team, large and small problem solving processes, and multiple evaluation processes to the teams in the course, students' final survey is more objective and experience-based evaluations. Therefore, it is necessary to pay attention to the interpretation of the evaluation difference between the beginning and end of the course.

The modified SEEQ at the beginning of class can be interpreted as reflecting students' expectations differently in different curricula, and at the end of class, it can be interpreted as an evaluation result based on the students' experience of performing the capstone team project. Therefore, if the difference between the opening and closing evaluations for each element is relatively small, it can be interpreted that the capstone design process is to meet the students' initial expectations. On the other hand, a large difference indicates that the effect is greater than expected or, conversely, not very close to expectation. Therefore, in this case, the capstone course and department-level education management will be required.

2. Data

From 2013 to 2021, a total of 337 students actually took IME capstone design, but the number of students who responded to the survey was 344 at the beginning and 296 at the end. After the COVID-19 outbreak, because the IME Capstone has been changed to a selective course from of a mandatory one for students, the number of students enrolled in 2020 and 2021 is relatively small. And in general, the

Table 1 Number of survey respondents and actual number of participants by year

Year	No. of respondents at the start	No. of respondents at the ending	Actual No. of participants
2013	43	37	43
2014	50	54	49
2015	53	37	47
2016	58	53	55
2017	50	37	50
2018	31	21	32
2019	30	26	30
2020	12	12	12
2021	17	19	19
Total	344	296	337

differences between three numbers in Table 1 are due to the students dropping the course in the case of teams that did not pass the midterm evaluation and responds of students of different grades, etc.

IV. Results

1. Effects on Multi-dimensions between Online vs. Offline Capstone Design

The table 2, 3 and 4 show the before and after student evaluations on various educational dimensions in three perspectives by three periods such as all period (2013 to 2021), offline capstone period (2013 to 2019) and online capstone period (2020 to 2021). The table 2 shows paired-t-test results of students' evaluation of the capstone design curriculum, i.e., the evaluation of students during 3 periods in nine dimensions of the capstone design curriculum as the first educational perspective. It shows very diverse results for each dimension as well as time period. In the t-test for the mean difference of evaluation by dimension between the start and the end of the course, only the group interaction was not significant in the offline capstone, but the group interaction was rather significant in the online capstone. Meanwhile, during the online capstone period since the COVID-19, learning/value, examination/grading, assignments, and workload/difficulty dimension were not significant.

In addition, group interaction and examination/grading dimensions were not significant in the entire period due to the effect of online capstone evaluation. Although the number of respondents is small, these changes of statistical significance by dimensions mean that students' evaluation of the educational effect of online capstone curriculum for 2 years should be carefully analysed.

During the offline capstone period five dimensions such as enthusiasm, organization of the course, individual rapport, assignments, workload/difficulty, etc. resulted in smaller results than expected, i.e., positive values of mean differences, indicating that the students positively evaluated the capstone process in such dimensions, but on the contrary, for learning/value, breadth of coverage, and examination/grading, the results were larger than expected. However, during the online capstone period all the differences in the mean were positive. Compared with offline capstone, the meaning and implications of statistical results according to each evaluation dimension of online capstone design are as follows.

Group interaction evaluates whether intra-team and inter-teams communication, information exchange, and discussions have been actively conducted through the capstone course. As capstone design performs autonomously organized team-based projects, it seems to be a self-evident result that there is little difference between the high expectations for this at the beginning and the evaluation at the end of the course in the offline capstone courses. This positive effect showed statistical significance in the online capstone period, and is judged to be stronger. This

Table 2 Paired-t-test results of students' evaluation of the capstone design curriculum

Evaluation dimension of curriculum	All Period (2013-2021)	Offline (2013-2019)			Online (2020-2021)		
	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$
Learning/value	-0.11**	2.11	2.24	-0.12***	2.03	2.02	0.02
Enthusiasm	0.14***	2.65	2.55	0.10*	2.66	2.19	0.49***
Organization of the course	0.14***	2.76	2.65	0.11**	2.70	2.34	0.36**
Group interaction	0.06	2.46	2.45	0.01	2.66	2.19	0.47***
Individual rapport	0.22***	2.62	2.42	0.20**	2.60	2.27	0.33*
Breadth of coverage	-0.12***	2.30	2.50	-0.20***	2.37	1.71	0.67***
Examination/grading	-0.09	2.63	2.74	-0.11*	2.87	2.65	0.23
Assignments	0.34***	4.20	3.84	0.36***	4.01	4.00	0.01
Workload/difficulty	0.17***	3.84	3.68	0.16***	3.85	3.63	0.23

*p-value less than 0.10; **p-value <0.05; ***p-value <0.01; $Mean^S$: Mean at the start of the course; $Mean^E$: Mean at the end of the course; $Mean^D$: Mean Difference

is because during the online capstone period, each team carried out the project more frequently and using various methods such as online meeting, SNS, conference call, etc. regardless of time and place. Thus we believe it is an empirical case related to 'experience and development of teamwork' among the advantages of PBL discussed in the previous studies.

Secondly, during both periods of offline and online capstone, the aspects of enthusiasm, the organization of the course and individual rapport had a statistically significant positive effect. It was found that enthusiasm was showing more than expected effects by evaluating whether it improved learning motivation through the capstone design curriculum. This seems to be related to 'self-motivation and student ownership of the problem, solution and learning' from the aforementioned PBL benefits. And in the aspect of the organization of the course, similar effects are evaluated, which means that prior information on the curriculum is sufficient, and students are fully aware of the passing and non-passing criteria, and curriculum management procedures. In addition, individual rapport evaluated the relationship with other students in the process of performing the capstone, and it is understood that the friendly relationship has improved considerably.

On the other hand, in both the off-and online capstone courses, assignments and workload/difficulty dimensions were expected to be considerably low at the beginning of the course, but the tasks, task intensity, and difficulty individually assigned by the team during the capstone course were evaluated to be much greater than expected. In the offline capstone, assignments (0.36) showed the largest difference in the average evaluation level, and workload/difficulty (0.16) showed the third largest difference. This means that students are actually experiencing the process of solving individual and group solutions to problems arising from project implementation. Thus it seems to be an effect related to 'experience of problem solving and the design process,' 'experience of authentic engineering problems and professional practices' and 'development of self-regulation, agency, commitment and competence' of the PBL benefits. This interpretation can also be applied to student evaluation of online capstone. However, in the case of online capstone, the differences were not statistically significant as relatively low positive values. This seems to show that the online capstone process is somewhat inferior in actual individual and group solution process ability compared to the offline process.

Thirdly, learning/value, breadth of coverage, and examination/grading are dimensions that do not meet the initial expectations, and the difference in the mean of each dimension was statistically significant in the offline capstone courses. In the online capstone, however, students' evaluation of these three dimensions surprisingly showed exactly the opposite. This positive effect in the three dimensions of online capstone seems to be due to the fact that the online capstone is operated as a selective course, and the students' project performance and team cooperative learning motivation are very high. In addition, because the online capstone courses were operated more flexibly than the existing courses regardless of time and place, student team operation and cooperative learning could be proceeded more efficiently. In spite of showing a positive effect of online capstone, the result of offline capstone is followed throughout the entire period from 2013 to 2021.

The dimension that showed the least expected result was breadth of coverage, which was effective in terms of differentiation from other courses or inclusion of practical contents, but was far less than expected in question items such as utilization of various majors and acquisition of the latest theories. In particular, many students pointed out that the use of knowledge in a specific major such as computer science is required too much when performing a team project, implying the necessity of using knowledge in various majors. This is related to 'exposure to the multi-disciplinary and systems nature of engineering problems' in PBL benefits, and is considered a dimension that needs to be improved in the future IME capstone design curriculum. On the other hand, in terms of examination/grading, students' evaluation is indicated as an expected result. In other words, three official presentation competitions, several reports, and evaluation of the final outcome have enough room for students to lower their level of evaluation below expectations for the capstone curriculum, and in the case of credits, due to the relative evaluation rule, the results of the students' surveys were poor. Therefore, it seems necessary to improve

Table 3 Paired-t-test results of students' evaluation of the capstone design teaching-staff

Evaluation dimension of teaching-staff	All Period (2013-2021)	Offline (2013-2019)			Online (2020-2021)		
	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$
Enthusiasm	0.01	2.47	2.46	0.01	2.47	2.39	0.08
Organization of the course	-0.02	2.38	2.41	-0.03	2.22	2.19	0.03
Group interaction	-0.04	2.31	2.37	-0.06	2.24	2.10	0.14

*p-value less than 0.10; **p-value <0.05; ***p-value <0.01; $Mean^S$: Mean at the start of the course; $Mean^E$: Mean at the end of the course; $Mean^D$: Mean Difference

the relative evaluation rules for the capstone design curriculum. Lastly, in terms of learning/value, the evaluation value through the curriculum was not better than the students' initial expectations. It was evaluated whether the curriculum was interesting, was easier than other curriculums, and improved understanding of the major. The results of these question items were worse than the evaluation of the benefits of the curriculum and whether they were helpful in the career. However, the level of learning/value evaluation at the beginning and end of classes shows the best results than the levels of other dimensions.

The table 3 shows paired-t-test results of students' evaluation of the capstone design teaching-staff in three dimensions for the second educational perspective during the 3 periods. The mean differences on the all dimensions, as shown in the table, are not statistically significant for all three periods. However, in the case of online capstone, the evaluation of faculty and staff improved slightly after the start of the class. The evaluation of students on three dimensions, such as the head professor, team-advisors, and TA in the second educational perspective, is judged to be more than usual and continue from the beginning to the end of the class over all periods. For the third educational perspective, the table 4 shows paired-t-test results of students' evaluation of the students themselves who participated in the capstone design during the 3 periods. This is an evaluation of oneself who participated in capstone design course for four dimensions. While there is no improved dimension with statistically significant in the offline capstone course, the group interaction in the online course shows statistically significant and a relatively high positive effect. As mention earlier, this is because students can more effectively maintain and expand the online relationship between team members as they are accustomed to interacting within and between various teams online as they proceed with the project and their ability to use related technologies and services improves. On the other hand, at the level of 'Individual rapport' the results were worse than the start of the class in the question items of expanding intimate relationships or helping other team members during all three periods. It gives us a great implication. At the departmental level, educational measures, regardless of online and offline courses, are required to keep the original motivation and confidence of participants at least through the capstone curriculum implementation process.

2. Effects on Three Perspectives between Online vs. Offline Capstone Design

Table 5 summarizes and compares the expectations and

Table 4 Paired-t-test results of students' evaluation of the students themselves

Evaluation dimension of students themselves	All Period (2013-2021)	Offline (2013-2019)			Online (2020-2021)		
	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$
Learning/value	-0.05	2.13	2.20	-0.07	2.11	1.92	0.19
Enthusiasm	0.09*	1.97	1.90	0.08	2.09	1.91	0.18
Group interaction	0.01	2.17	2.21	-0.04	2.31	1.90	0.41***
Individual rapport	-0.26***	2.08	2.37	-0.29***	2.26	2.29	-0.03

*p-value less than 0.10; **p-value <0.05; ***p-value <0.01; $Mean^S$: Mean at the start of the course; $Mean^E$: Mean at the end of the course; $Mean^D$ Mean Difference

Table 5 Paired-t-test results of students' evaluation of 3 perspectives of the capstone design

Evaluation perspective of capstone design	All Period (2013-2021)	Offline (2013-2019)			Online (2020-2021)		
	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$	$Mean^S$	$Mean^E$	$Mean^D$
Curriculum	0.08**	2.84	2.77	0.07*	2.86	2.55	0.31***
Teaching-staff	-0.02	2.39	2.42	-0.03	2.31	2.26	0.09
Students themselves	-0.06	2.09	2.17	-0.08*	2.20	2.01	0.19

*p-value less than 0.10; **p-value <0.05; ***p-value <0.01; $Mean^S$: Mean at the start of the course; $Mean^E$: Mean at the end of the course; $Mean^D$: Mean Difference

results of students by detailed dimension in each perspective of education during the 3 periods. In the case of all periods, the results are similar to those of offline capstone evaluation. That is, it shows a statistically significant positive effect on the capstone design curriculum, and shows a negative effect although there is no statistical significance in the other two perspectives. It is evaluated that the students who have taken the course for 9 years have a better learning effect than initially expected through the capstone design curriculum. In particular, the positive effect on the curriculum is greater in the online capstone than in the offline. Furthermore, the online capstone, which has been changed since the COVID-19, has changed the negative effects of two educational perspectives of the offline capstone into positive effects although they were not statistically significant. It seems to be thanks to the several advantages of online capstone, such as efficient online technologies regardless of time and place, conversion to selective course of capstone design, and voluntary participation of students with strong will to carry out team projects.

V. CONCLUSIONS

The global pandemic of COVID-19 had a great impact on the engineering courses, especially, on the capstone design. However, despite the COVID-19 pandemic, the process of teaching and learning capstone can be never stopped, as capstone design is known for a number of educational benefits, including facilitating student identity transitions into professional engineers. In 2020 and 2021, the IME department has changed the capstone design to a selective course under the Corona situation and operated all teaching and learning activities online as well as tried to support all students' team cooperative learning activities online. Thus this study aimed to compare the educational effect of online capstone design from 2020 to 2021 under the COVID-19 situation with the offline capstone designs in previous years, which examined various effects from the three educational perspectives of curriculum with 9 dimensions, teaching-staffs with 3 dimensions, and students with 4 dimensions through surveys based on the modified SEEQ questionnaire conducting at the beginning and end of course for IME students enrolled in the capstone design course for 7 years from 2013 to 2019.

Thanks to the several advantages of online capstone, such as efficient online technologies regardless of time and place, conversion to selective course of capstone design, and voluntary participation of students with strong will to carry out team projects, we found more diverse and better results on educational effects of the online capstone course than those of the offline capstone. In particular, the grand prize (1 team) and the encouragement awards (2 teams) in the project competition of Korean Institute of Industrial Engineers for undergraduate students, 5 teams including poster paper presentations at the conference of Korean Society for Engineering Education, all 19 people of 2021 have significant objective achievements and major knowledge. We believed that the utilization and competence through online capstone have been obtained. Exceptionally, however, in the evaluation of students themselves, although the individual rapport dimension showed better results than in the previous offline capstone evaluation and there is no statistical significance, it still showed a negative effect. Therefore, the efforts to improve effect of the individual rapport dimension is still the one that needs to be most urgently in IME capstone design in the online capstone as well.

In addition, in online capstone design operation, the depth and scope of the project topics to be solved by the student teams and the degree of industry-university relationship

is weaker than that of offline capstone design. In order to deal with more realistic industrial issues, it is necessary to establish close industrial-educational cooperation at the department and school level, such as online collaboration for matching student teams to firms.

The number of online capstone samples is 31, so there is no problem in statistical analysis of the T-Test, but the difference from the existing offline capstone is a limitation of this analysis. The increase in the number of samples according to the online capstone implementation and the effect analysis according to student characteristics such as gender, project pass/fail, GPA level, etc. are left for the further study.

Since launch of IME capstone design course in 1996, it has been positioned as a department-specific culture (Kim, 2019). In order for sustaining the course with better PBL benefits for students regardless online or offline or both, the departmental efforts and faculty commitment for students' self-engagement and motivation in the online and offline process of capstone course are critically important. In the future, when face-to-face classes are in full swing, this online capstone experience is expected to be a useful reference to improve the educational effect of offline capstone or hybrid capstone.

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