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A Web-based system to build teams for project-based learning courses: an industrial engineering case

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ABSTRACT: Engineering schools have opened many diverse courses based on project-based learning, which is a student-centred learning model that imposes more responsibility on students for their own learning than the traditional lecture-based approach. While project-based learning courses provide engineering students with educational achievement and problem-solving capability, there are numerous difficulties in the solving process of their projects. Above all, at the initial stage they encounter the difficult situation of building a team to carry out their project. This study aims to develop a team-building support system (TSS) to help students construct their team in project-based learning (PBL) courses. The TSS provides various course-tailoring method to choose team members according to the objectives and characteristics of the PBL courses based on three algorithms, the coincidence degree-based, closeness-based and successful record-based algorithms. The responsive Web design technology applied in the system enables users to build a team regardless of time and place. Thus, the TSS is expected to enable students and teaching staff to effectively implement their project at the initial stage of courses, furthermore, it can be extended to PBL courses of other disciplines.

Keywords: Project-based learning (PBL), team-building support system (TSS), course-tailoring method, industrial engineering, engineering education

INTRODUCTION

Project-based learning (PBL) is a representative learning model of constructivism learning theory [1]. PBL is a naturally occurring instructional method of a learning process in which students produce outputs with team members after team building to cooperate and to use information to conduct reality projects [2][3]. Students cooperate with co-workers to draw a method of solving a problem and study the process of producing a common solution [4]. Further, in PBL courses, such as a capstone course in an engineering school, students have to work within a team, and they can acquire knowledge of problem-solving through cooperative communication. Whether the learning effect is positive or not depends on how students cooperate with team members [5][6]. While there are many courses that apply PBL in engineering education and they enjoy a degree of satisfaction [7], there has been relatively little analysis on how they are applied to classes, and whether students are interested or face difficulties. Therefore, when recognising the importance of PBL in engineering education, and in class-progress based on PBL, they should be strategically enabled to progress through a class without facing difficulties.

As an example, based on the class syllabus of the required classes of the Department of Industrial Management Engineering (IME) at Hankuk University of Foreign Studies (HUFS) in Korea, the percentage of classes in which PBL has been introduced has reached 47%. In addition, from a survey of students who have taken the capstone course of the Department of IME at HUFS in Korea, over 74% of students in 2014 to 2015, and 80% in 2016 responded that the team-building process is one of the most difficult tasks for the project execution [8].

The study is to develop a Web-based system (team-building support system: TSS) that supports students taken the PBL-based courses in the IME discipline to organise their teams effectively. The TSS is designed to provide students with various course-tailoring methods to choose team members according to the objectives and characteristics of the PBL courses based on three algorithms: coincidence degree-based, closeness-based and successful record-based algorithms, which are useful and effective in the construction of teams.

The remainder of this article is comprised of four sections. Section two deals with the literature review focusing especially on PBL and team building methods. Section three examines the construction method of team members applied to the TSS. The system development method, architecture, functions and case for the TSS present in the following section. Finally, in the last section, the author discusses future research and provides a conclusion.

LITERATURE REVIEW

Project-based Learning in Engineering Education

Palmer and Hall have defined PBL as an integration of the following components based on results of previous studies [9]. First, it pursues a solution of target problems or intends an accomplishment of respective tasks of learners through educational activities inducing the learning of learners. Second, the learners should play respective roles as a member of a project team to achieve a project assigned thereto. Third, the projects assigned to teams are typically realistic problems requiring multidisciplinary approaches and a considerable amount of time. Fourth, as was discussed before, the projects comprise the development of concrete artificial outcomes in general (design, product prototype, computer software, etc). Fifth, the completion of each project requires a corresponding report of summarised details and process activities to the finalisation of each project and an open presentation thereof. Sixth, the instructors are typically supposed to play a role as an advisor and coordinator rather than that of an authoritarian.

According to results obtained from previous studies, the benefits the learners could attain from PBL are summarised as follows. Above all, the learners participating in PBL can develop teamwork skills and experiences. Secondly, the learners can cultivate the leadership and sense of ownership in the learning through the problem-solving process. Thirdly, the learners can learn the self-regulation and devotion, and be able to nourish respective competitiveness. Fourthly, the learners can understand the multidisciplinary and systematic aspects situated in engineering application problems empirically. Fifthly, the learners can also gain experience to cope with actual engineering application problems professionally. Sixthly, the learners 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. Finally, the learners can also attain capabilities to deal with incomplete or inaccurate information.

Contrarily, the learners frequently encounter difficulties in the PBL environment in that they often find that the skills or problem-solving ways learned from each project task cannot be used or applied to other project tasks. Instructors should point out the methods the learners learned before and ways identifying how to apply the methods to the problem in the objective of each course clearly. They should lead the learners in applying the learned methods or skills to current project tasks, and if necessary, they should also provide the learners with pertinent information or knowledge [10]. Thus, the system to provide learners with an environment in which they can solve diverse problems through participant-directed learning and with necessary information or knowledge for the learning is needed for the education of engineering disciplines.

The degree of teacher-centred planning and direction of the student's learning activities in relation to the desired objective varies along a sliding scale. Three fundamental types of project work can be distinguished: the task project, the discipline project and the problem project [11].

The *task project* is characterised by a high degree of planning and direction on the part of the teacher (teaching objectives) involving a large task that has to be solved. Both the problem and the subject-oriented methods are chosen in advance, so that for the student, the primary concern is to complete the project according to the guidelines provided. At times, there can be such a narrow framework that students do not have the opportunity to make their mark on the starting point or the process, but instead follow a strictly directed process in which the choices are made for them in advance. This is especially unfortunate, given that the defining factor for student motivation is that they should feel that the project belongs to them (and not the teacher). Therefore, this type of project cannot be recommended.

The *discipline project* is usually, though not necessarily, characterised by a high degree of direction from the teacher (study programme requirements), in that the disciplines and the methods are chosen in advance. It may, however, still allow the groups to identify and define the problem within the guidelines of the described disciplines (which are described in the theme descriptions). Metaphorically, this type of project can be compared to a football game in which the playing field is specified. Similarly, some overriding guidelines are given for the game, but the ball has not been kicked off, and thus the group must enter the field and set the game into play.

The *problem project* is a full-scale project in which the course of action is not planned in detail by the teachers. The problem formulation directs the choice of disciplines and methods and the problem itself arises from the problem-oriented theme. In other words, within the same work environment theme, the group can work with widely different disciplines and subject methods. In terms of the analogy of a football game, this means that the students have the ball, but lack the playing regulations and a marked playing field. A considerable amount of the work, therefore, involves marking the field and defining the playing rules, before the game can be started.

The engineering discipline consists of a hierarchical knowledge structure and cannot proceed with the problem-solving process without the basic and essential concepts, as well as theories of individual discipline [12]. In other words, the scope, and the scope of application of project-based learning, including the type of project discussed above, can be vastly diverse according to class levels from freshmen to seniors. Therefore, PBL courses by class level require a variety of project team sizes, periods and construction methods. This creates a fundamental challenge in the construction of a project team for learners and professors.

A team, traditionally, can be defined as …*a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen others as an intact social entity embedded in one or more larger social system, and who manage their relationship across organisational boundaries* [13]. A definable set of characteristics common to all collaborative work teams includes: a definable membership, awareness of one's membership, a shared sense of purpose, member interaction, and ability to act as an individual unit, as well as a unit of individuals [14]. Teams are a primary mechanism for accomplishing organisational work; hence, team building, team size and cooperation between team members are critical factors in project execution.

Many researchers have studied how groups develop into functional teams and select group processes to accomplish their tasks. In addition, a number of modified and complementary alternative models to Tuckman's original model [15] have been proposed [16][17]. Most of liner progression models are similar to Tuckman's model, which highlights the four sequential stages of forming, storming, norming and performing: forming refers to a period in which members are selected and try to determine their positions in the team, procedures to follow and the rules of the team; storming starts when conflicts arise as team members resist the influence of the group and rebel against accomplishment of the task; norming begins when the team establish cohesiveness and commitment to its tasks; finally, performing refers to working together to achieve its goals and becoming more flexible in following their procedures for working together. Although Rickards and Moger [17] highlighted empirical observations of specific teams reveal complexities that cannot be explained as a simple stage sequence of Tuckman's model, it may have considerable face validity as a general sequence. Each stage of Tuckman's model is an essential step for a team, much like other linear models, if the first step is not accomplished, the latter stages will not be successful [18]. So, team building is the most critical step for project accomplishment in the PBL-based courses for engineering schools.

Furthermore, there are several studies about factors that affect team performance, such as the problems caused by the distribution of projects to teams (for example, workloads and size of the projects), difficulties in project management and collaboration problems within groups [19][20]. A solution to these problems seems to depend on team formation. For example, elimination auction by Bardach presents a computer program for matching students to particular projects, where students are asked to vote or bid for the projects from a project pool according to several rules [21]. And the diverse factors also affect team formation and performance. Sahin discussed two approaches to build teams in terms of project subjects [22]. The top-down approach to assemble teams by students with an interest in a particular project subject has several disadvantages: well-adjusted teams may not be built, and project subjects have to be defined in advance, thus, either a very limited project pool is offered to students or they cannot freely select any of the real-life project subjects they may be interested in. On the other hand, in a bottom-up approach, teams are built first, and then a subject is decided upon by team members. Thus, this approach seems to be more advantageous in terms of project subjects. However, the PBL-based courses of engineering schools, which cover various courses from freshman to senior classes, have to support both approaches.

While the previous studies identify some team problems, they have proposed several solutions to team building and team management problems for industrial and business projects. However, in engineering education, students as team member candidates are inexperienced, and every PBL-based courses might be their first encounter with project team issues. Students can be sensitive, and they need to be guided very carefully through their every experience in project tasks and management. In addition to students' project skills, group participation and relationships are crucial and need to be taken into account during the team building process.

TEAM BUILING METHODS

PBL-based Courses in IME

Eighteen of the 38 major courses offered by the Department of IME in HUFS are based on PBL classes. The degree of PBL by grade for 18 PBL-based courses in the IME was analysed by the duration of the project and the percentage of projects reflected in the grade evaluation. Figure 1 shows that the higher the grade, the higher the proportion of mid- and long-term projects than short-term projects. When 18 courses were divided into three types: short-term projects of less than 4 weeks, mid-term 4 to 8-week projects, and long-term projects of 8 or more weeks, there were 12 courses with mid- and long-term projects. This is about 67% of the 18 courses. Figure 2 also shows that the higher the grade, the higher the reflection ratio to the grade evaluation. While the sophomore's reflection ratio is less than the freshman's reflection ratio, in the PBL courses for junior and senior students, the reflection ratio of project performance is getting higher. Especially, in the capstone course of the senior year, the students have to execute their own 16 week term projects with 100% of the reflection ratio of project performance to the course evaluation.

Engineering students not only have to concentrate on the project over a long period of time during the semester, but the project also acts as a burden to them as the grade year goes up, because their performance on the project represents a high proportion of the grades. Also, as a result of the analysis of the feedback of the graduation project of 82 students who participated in the capstone design class from 2014 to 2015, it has been established that although 47% of students who were in the fourth grade had a lot of experience of the project, they had difficulty getting information about project participants at the beginning of the project. In February 2016, interviews of the 20 current IME students at HUFS showed that 55% of the students had difficulty in forming a team, because they could not obtain information of the project participants [23]. Furthermore, there was a very limited time for building the project teams.

A semester is about 15-16 weeks, including examinations and presentations; hence, team building processes should be completed in quite a short time. When the teacher lets the students build their project teams, the students cannot finalise building the teams in two weeks, because of problems caused by relationships between students, emotionality, avoiding responsibility, etc. These delays result in there being limited time to complete the project work. Therefore, team performance and project quality may suffer. Since all team member candidates are students, they are likely to behave in ways considered unprofessional, such as gravitating toward their best friends or academically successful students, especially in lower grade year. Empirical observations reveal that sometimes, students can be unwilling to be in the same project team with certain students, because of hidden conflicts between them, but they may not express this directly, causing unnecessary tension or strife. This situation decreases the motivation and total effectiveness of the team [22]. Therefore, it is necessary to support the students in building their teams by the grade year and PBL-based courses, i.e. course-tailoring methods.

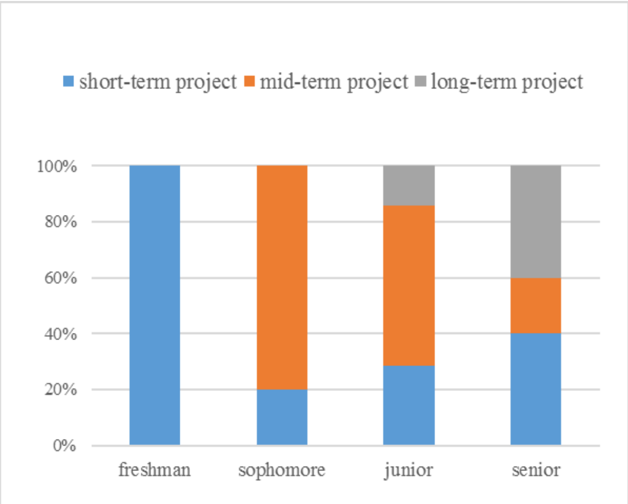


Figure 1: The percentage of project duration by grade.

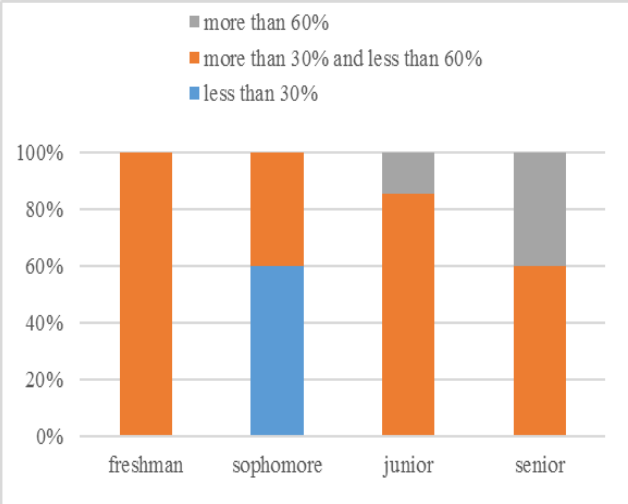


Figure 2: Grade reflectance of project performance.

Algorithms for Team Building

This study aims to develop a Web-based team-building support system that can be applied to an engineering discipline, to help students taking diverse PBL-based courses, as well as professors. Although the study's objective is not to propose a specific algorithm for forming a team, the efficient and effective algorithms from the previous studies are essential in developing the system. The author applied the three algorithms, the closeness-based, coincidence degree-based and successful case-based algorithms, to support building teams for diverse PBL-based IME courses. According to the grade year, course characteristics or students' needs, students can choose and use one or more of the algorithms to build their teams for the PBL-based courses.

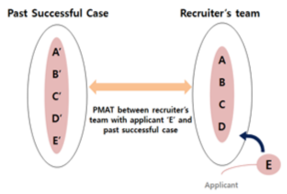
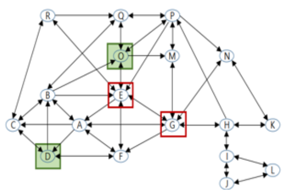
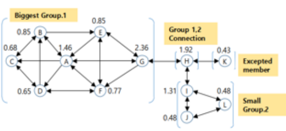
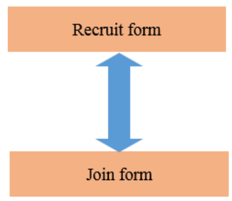
Algorithm	Successful case-based	Closeness-based		Coincidence degree-based
Basic idea	It provides the matching ratio with past successful cases, to compare the similarities between the current virtual team members and the team members of successful cases in the past courses. (ex, capstone design course)	It provides the matching ratio on closeness to identify closeness between recruiter and applicant.	It also enables the professor to construct a team whose sociability value provides a uniformly distributed team by the highest value of the student.	It provides the matching ratio on coincidence to match information posted on the recruit notice with applicant information such as specialist ability, class information, available tool, and tag.
Basic Model				
Main formula	$PMAT_k = n_k \times \frac{GPA_k}{4.5} \times 100$ n_k=Normalization of distance figure based on similarity differences between objects of a past successful group and objects of a group composing a team k=k^{th} group	$C'^{E}(i) = \frac{(1/(m_{a,b}+m_{b,a}))}{\sum_{i=1}^{n} i(i+1)}$ $m_{a,b}$= shortest distance from a to b $m_{b,a}$= shortest distance from b to a n=number of team member+number of new member	$C(i) = C_D(i) + C_C(i) + C_B(i)$ $C_D(i) = d(m_i)$ = Number of nodes connected directly to a node $C_C(i) = \left[\sum_{j=1}^{n} d_{ij}\right]^{-1}$ = The reciprocal of sum to the shortest path to any other path from the node. $C_B(i) = \sum_{j<K} g_{jk}(i)/g_{jk}$ = Connection degree of the nodes with a node connected to other node	$\frac{\text{Number of Specialist Ability}}{N_A} \times n + \frac{\text{Number of Available Tool}}{N_T} \times (n-1)$ N_A = Number of Specialist Ability in Recruit Notice N_T = Number of Available Tool in Recruit Notice n= Weight

Figure 3: Algorithms applied to PBL-based courses of IME, HUFS (adopted from [8]).

The closeness-based algorithm is to form a team based on the matching ratio to identify closeness or familiarity between recruiter and applicant in the course. It also enables the professor to construct a team the sociability value of which provides a uniformly distributed team by the highest value of the student. So, it can be more effectively applied to the PBL courses of lower grade years, such as the freshman or sophomore years. The second coincidence degree-based algorithm supports the selection of a member by the matching ratio on coincidence to match information posted on the recruit notice with applicant information, such as specialist ability, class information, available tools, etc. Therefore, it can help sophomore and junior students in forming teams of PBL-based courses. Lastly, the successful case-based algorithm provides the most suitable candidates to be team members by similarity measures between a currently virtual team and the past successful team based on the credit of major subjects taken by students and their GPA. Through several simulation tests for the case of the 2016 capstone course of the Department of IME at HUFS in Korea, the successful case-based algorithm with an 85% matching rate showed better performance than the existing team-building method, randomly constructed among students, with 38% [8]. Thus, the successful case-based algorithm can be suitable for the courses with the higher degree of PBL in junior and senior years.

TEAM-BUILDING SUPPORT SYSTEM (TSS) FOR PBL-BASED COURSES

System Development Methodology and Architecture

The TSS aims to help students construct their team in project-based learning courses, and their professor to identify closeness between the students and construct a team to improve team performance. Currently, students of the Department of IME, HUFS have many projects in major classes. Most students encounter a difficult situation in building a team, like the lack of project participant information and trouble understanding the current status of the team in the initial stages. However, professors randomly construct teams according to grade and gender, regardless of team performance. TSS support for efficient team building decision-making for students and their professor allows the construction of teams that can attain better educational effect.

The TSS interworks with the existing system the *CapstoneIME* [24], which is used only by students in the capstone design course as a Web-based project management system, so enabling the professor and students in the project-based learning courses to be used. The four general procedures used to construct the system, i.e., analysis, design, development and implementation [25], are applied to develop the TSS. Overall procedures are as follows. The analysis as a preparatory step in order to identify the team building components includes reviews of related references and the existing team building system. In the case of the existing system, it used the team building components as the characteristics or personality of team members. In the second step, the design is related to the system structure and main function. In addition, this step includes designing the database and algorithm: successful case-based, closeness-based and coincidence degree-based algorithms. To construct the system in the development step, the author used the Windows Server 2012 as a Web server, and JSP, Java, html, JavaScript and CSS as languages with Apache-tomcat 7.0, Eclipse (Eclipse IDE for Java EE Developers) as development tools, and Microsoft SQL Server 2012 Management Studio for the DBMS. The last implementation step to improve the system has a test on whether the data of the output screen is consistent with the result of algorithms, as well as debugging of the programming. Further, the responsive Web design technology applied in the system enables users to build a team regardless of time and place.

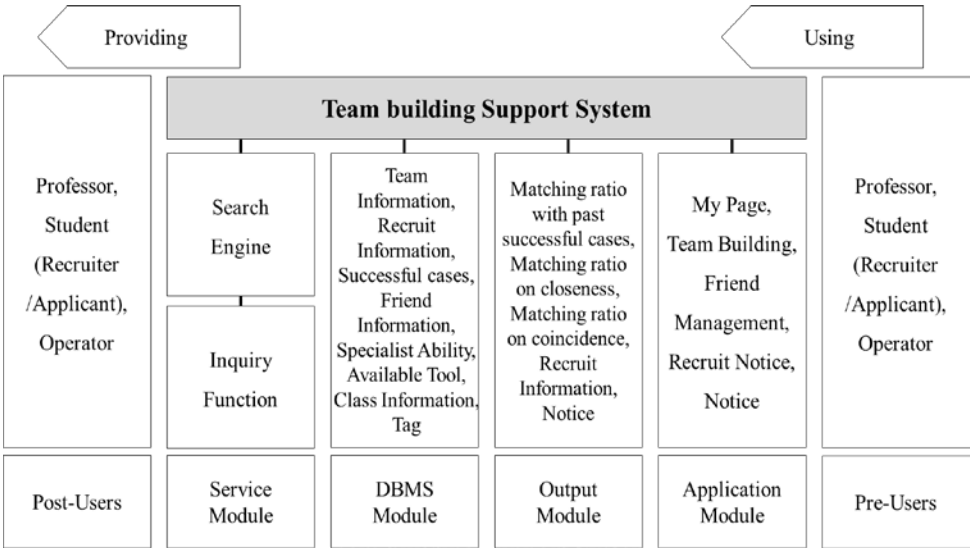


Figure 4: The TSS architecture.

The TSS is divided into the inputs required by team building, algorithms and outputs according to the user and the features of a project. Projects are classified into three categories: capstone design project, project-based learning courses and contest projects. While students taking the capstone design can use three algorithms to build their teams, the students in the project-based learning courses or some students to prepare the contest may use closeness-based and coincidence degree-based algorithms. On the other hand, when a professor wants to construct teams in his/her course, he/she can construct teams based on the sociability value calculated from the closeness-based algorithm in the TSS. The TSS enables the professor to construct a team the sociability value of which provides a uniformly distributed team by the highest value of the student. The coincidence degree-based algorithm, which is suitable for PBL-based courses in more than junior and contests, provides the matching ratio on coincidence to match information posted on the recruit notice with applicant information, such as specialist ability, class information, available tools, tags, etc.

Figure 4 shows the system architecture, which was designed for using and providing for the three types of users: professor, student (recruiter/applicant) and operator. The users have access through the application module and produce diverse outputs on the output module, which will be stored and managed in the DBMS module. The service module including search engine and inquiry function provides the project participant information, team current status and recruit notices.

System Functions

Figure 5 shows the structure of the menu of the TSS, which has classified sub-menus according to the three types of users: professor, student (recruiter/applicant) and operator. When the user is a student, the TSS is comprised of five sub-menus: *my page*, *friend management*, *recruit notice*, *team management* and *notice*. The *My Page* menu supports identifying and modifying user information, such as specialist ability, class information, available tools, tags, etc. The second menu, *friend management*, includes each user's friend information; and the third menu, *recruit notice*, includes recruit information according to the three categories of the project or courses: capstone design, project-based learning courses, and contest.

A student who wants to construct a team can post a recruit notice and look for team members, and the student who is looking for a team can apply to the team. The recruit notice supports the team building decision-making, such as matching ratio with past successful cases, matching ratio on closeness, and matching ratio on coincidence for both recruiter and applicant. The fourth menu, *team management*, includes each user's team information according to the categories of project; and the fifth menu, *notice*, includes notices about team building written by the professor.

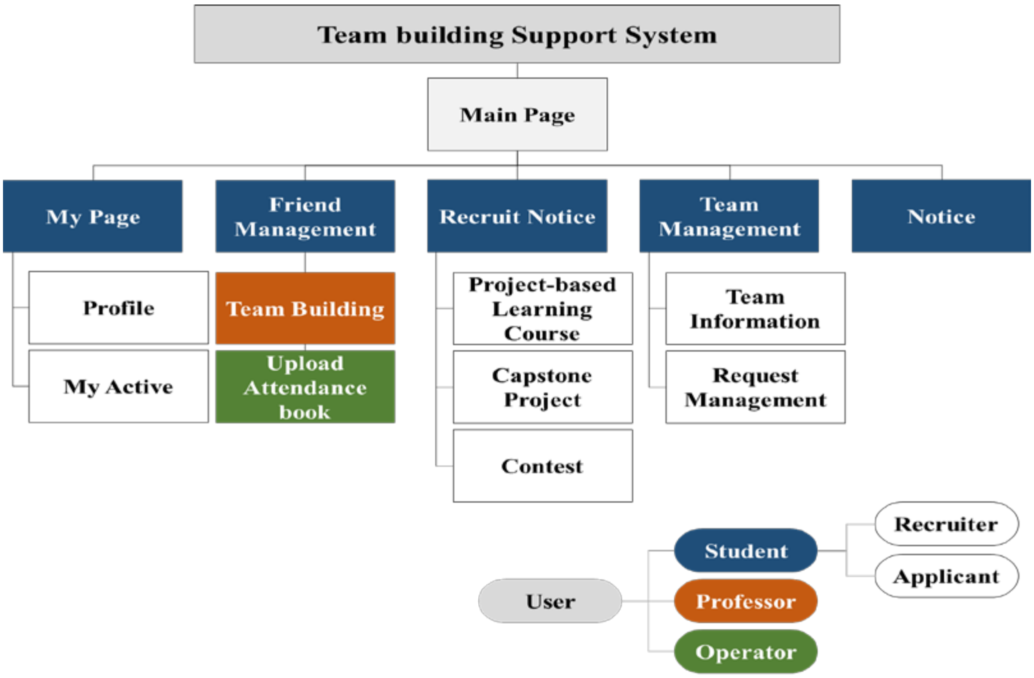


Figure 5: The menu structure of the TSS.

When the user is a professor, they can construct a team through friend information registered by students in the team building menu, instead of the friend management menu. The team building menu supports the construction of team applied sociability value calculated from the closeness-based algorithm, so it can be expected to produce educational effects. The menu upload attendance book operator can manage class information of the student and support the student in identifying five specialist abilities in industrial engineering or production/physical distribution, system analysis, information system and quality.

Example of a PBL-based Course

The main users of the TSS are students who are classified into recruiters who are looking for team members, and applicants who are looking for teams. The process by which a student constructs a team through the TSS is as follows. First, the recruiter posts the recruiter notice, including title, recruitment period, volume of recruitment, requirement specialism ability, available tools, etc. Figure 6 shows the screen of posting the recruit notice. Second, the applicant can identify recruit information arranged in order of suitability in the recruit notice menu. Figure 7 shows the screen of the detail recruit notice, which is comprised of the content of the project and the matching ratio displayed as a graph.

Finally, the recruiter can identify the status of application and check the matching ratio, while constructing the virtual team, including the applicant. If the recruiter is satisfied with the virtual team, the recruiter can send a message that requests team building to the team member in the screen of the request management (see Figure 8.) When all team members agree with the virtual team, the applicant can be a team member.

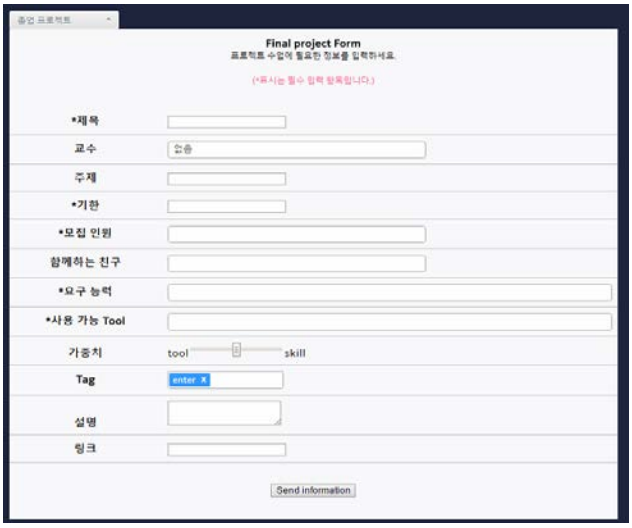


Figure 6: The screen of posting the recruit notice.

Figure 7: The screen of the detail recruit notice.

The Pilot Result

Since its development in late 2016, the TSS has been piloted for the students in the capstone course in the spring semester in 2017. A simple 5-point scale survey of necessity, convenience and usefulness of the system for students who formed a team using TSS was conducted and 31 responses were obtained. The necessity of the whole system was 4.1 points on average. Senior students in the capstone course were aware that the TSS could help in teaming in project-based learning. However, in terms of convenience and usefulness, system improvement was more necessary.

Figure 9 shows that TSS elements that have been rated below 3.00 in the survey will need to be improved or newly added. The satisfaction score of TSS was 2.76. And the confidence in the future performance of the team, especially using the TSS, was lowered to 2.69. In addition to the unfamiliarity and initial instability of the TSS, lack of information on new team members, communication easiness on the system between candidates and the team members, and communication easiness on system with the teaching staffs are also important factors, and these points should be improved in the future.

The TSS is a system to support teaming in IME PBL-based curricula, so the actual satisfaction and requirements of each curriculum may be different. Therefore, it is necessary to deal with the improvement of TSS based on surveys in each curriculum.

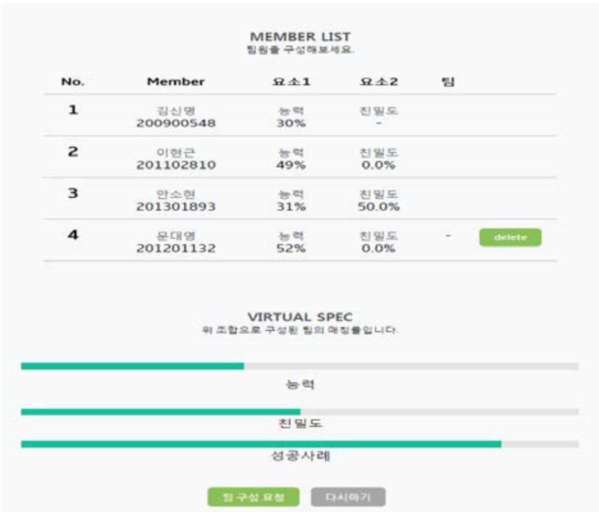


Figure 8: The screen of request management.

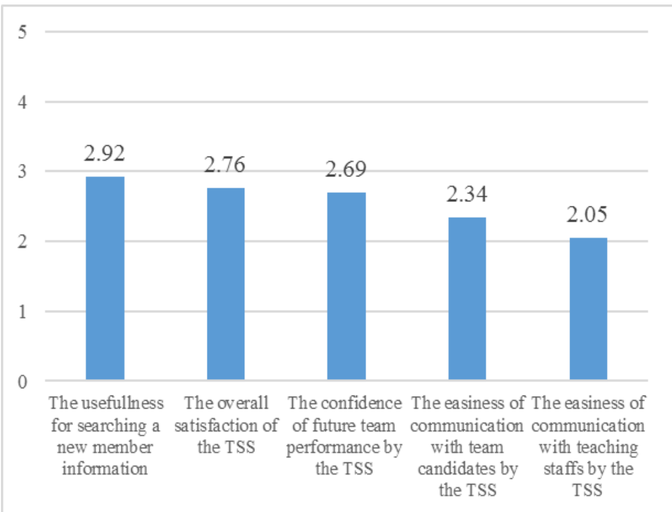


Figure 9: The TSS elements to be improved from the survey.

CONCLUSIONS

The PBL-based curricula in the engineering school have been recognised as one of the most important educational courses for students to become professional engineers capable of solving industrial real problems. Thereby, the degree of interest and concentration in this programme of teaching staff and participants from external enterprises is as high as that of the students. However, intramural students are in need of flexible support and help to cope with diverse difficult issues encountered with their project-based learning. Above all, at the initial stage, they encounter the difficult situation of building a team to carry out their project. This study aims to develop a TSS to help students construct their team in project-based learning courses. The TSS provides various course-tailoring methods to choose team members according to the objectives and characteristics of the PBL courses based on the three algorithms: coincidence degree-based, closeness-based and successful record-based algorithms. The necessity of the system was highlighted by students through the pilot test of the TSS on the capstone course.

The IME department at HUFS has 47% with PBL-based curricula, i.e. 18 major courses, which vary according to the curriculum and grade characteristics. However, the TSS provides only three teaming algorithms. Therefore, it is necessary to develop sophisticated algorithms that reflect the characteristics of diverse curricula and characteristics of each grade in the future. And it could be that there are some unexpected problems in the application of the TSS to actual PBL-based curricula, likewise those of existing systems, together with requirements for further improvements from students and teaching staff. Revealed problems and requirements for further improvement of developed the TSS should be resolved through continuous modification or correction. The system expects that they could play a role for forming teams for students and teaching staff in the PBL-based IME curricula, and to support and help the students to become future professional engineers, competent and capable of solving real industrial problems. Furthermore, although the developed TSS system is for an IME-discipline-specific system, it is expected to be applicable to the PBL-based courses of other engineering disciplines.

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