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A team-building algorithm based on a successful record for a capstone course

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ABSTRACT: The capstone course in engineering schools is one of the most important courses for students aiming to become competent professional engineers capable of solving real industrial problems. Collaborative work and active interaction are prerequisite for resolving the project. From the project outset, however, they confront the problem of organising team members. This study proposes an algorithm based on the member information of successful team records from the past capstone courses, which enables students to organise an autonomous team to carry out their project successfully. The successful cases-based (SC) 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 Industrial Engineering, Hankuk University of Foreign Studies in Korea, the SC algorithm with 85% matching rate showed better performance than the existing team-building method based on a random construction of teams from among students, with 38%. The author believes that the accumulation effect of successful cases information over the years will make the SC algorithm more effective for students' team-building activity in the capstone course.

Keywords: Capstone design, project-based learning, team-building algorithm, successful cases-based algorithm, industrial engineering

INTRODUCTION

Project-based learning (PBL) is a naturally-occurring instructional method of learning process in which students draw outputs with other team members after team building for cooperation. Students also use information to conduct reality projects similar to those offered by a professor [1][2]. Students cooperate with co-workers to draw a method of solving a problem and study the process of producing a common solution [3]. Further, in the PBL course, such as the capstone course in an engineering school, students have to work as part of a team, and they can acquire experience in problem-solving through cooperative communication. Whether the learning effect is positive or not depends on how students cooperate with other team members [4][5].

In reality, at the initial stage of the capstone project, building an autonomous team is quite a high hurdle to confront, compared with several other problems. For example, from the survey on students who had taken the capstone course in the Department of Industrial Management Engineering at Hankuk University of Foreign Studies in Korea, over 74% of students in 2015 and 80% in 2016 responded that the team-building process is one of the more difficult pieces of work in the project execution. This study proposes a team-building algorithm to enable the carrying out of an effective PBL for students taking the capstone course. In order to increase their project performance, the algorithm is based on the member records of successful teams in past capstone courses. The successful cases-based (SC) algorithm, therefore, may provide a similar team construction to the past successful teams.

The remainder of this article is comprised of three sections. The second section deals with the related algorithms, focusing especially on methods matching members. In the third section, the author examines the details of the SC algorithm and provides the simulation test to compare the SC algorithm with the current team-building method. In the last section, he discusses future research and provides a conclusion.

RELATED ALGORITHMS FOR TEAM BUILDING IN ENGINEERING EDUCATION

Besides educational use, many firms in the industrial area have become interested in how to build an effective team for industrial objectives. Thus, there have been various methods for building a team through matching suitable members, such as clustering, fuzzy matching method, max-sum method and skill parity method. Those algorithms have been applied in various fields including sports and job research, as well as in the education area. Clustering algorithms like

K-means clustering and agglomerative clustering have a function to bind objects with similar characteristics [6][7]. In team building, the diversity factor is important, because it allows groups to have a wide range of task knowledge, skills and abilities. Also, it enables having a different perspective on a given task, so teams can discuss it more and seek information to enhance the quality of their decision. Therefore, diversity can contribute to team performance [8][9].

Through a clustering algorithm, students are classified by their characteristics and also distributed to teams, to ensure the diversity of the team. Furthermore, it enables a team member to be selected who is similar to a past team member for a new team if students want. However, since the clustering algorithm requires various information about target students, it has limitations in applying it to PBL courses.

Secondly, the fuzzy matching algorithm has usually been used on job searching sites by providing a degree of matching of their requirements between job recruiters and seekers [10]. Although it is possible to find a team that can satisfy the requirements of both sides, it may not be suitable for a number of students who participate in the PBL.

Thirdly, the max-sum strategy algorithm has been applied to form a team to maximise the sum of ability for positions to form the best team [11]. The ability score of players is recorded in each position, and players are arranged in only one of the positions by applying the rule maximising the sum of score of the team for building the best team [12]. Because the algorithm selects team members based on best performance criteria, it recommends excellent students to build a team when applied to the PBL course and to exclude the others. Thus, it may not be suitable for educational purposes.

The last related one is a skill-rarity algorithm that preferentially allocates the members who have a rare skill after arranging the projects in order of value [13]. This method is a more powerful algorithm for a target team's performance than the performance of other teams in the PBL course.

Although the algorithms reviewed for building the team are useful in each area, the purpose and lack of information in the PBL environment require the development of a new algorithm to help students form teams with high potential for success in all their projects. The next section deals with a new algorithm using the information of the past PBL courses.

SUCCESSFUL CASES-BASED ALGORITHM

The Procedure of the Successful Cases-based (SC) Algorithm

The purpose of the SC algorithm is to support students in building teams similar to past cases (or teams) that obtained high scores in their projects. Matching ratios with past successful cases is provided to teams that intend to recruit new team members or students who want to participate in some teams, and they can also consider each other in regard to team building through this matching ratio. The SC algorithm developed in this study calculates the matching ratio between the team being composed and past successful cases by calculating the average similarity of a group process for optimisation of clustering [14]. Figure 1 shows the SC algorithm procedure.

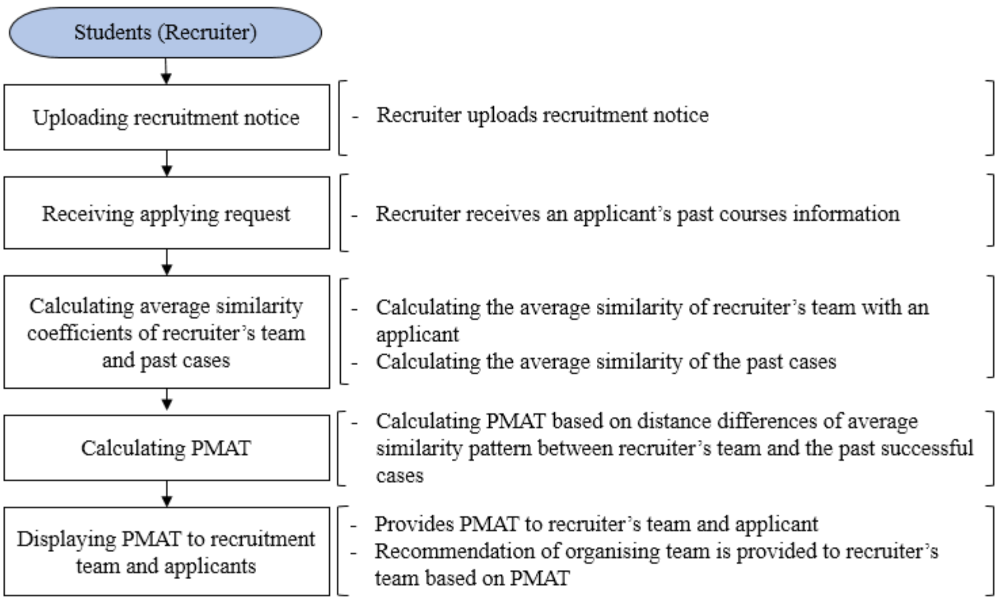


Figure 1: The SC algorithm procedure.

The algorithm begins with a notice from the recruiter who wants new members in the team and requests from applicants who want to join the team. For example, when an applicant requests to be a member of the kth recruiting team in the capstone course, the algorithm calculates the average similarity coefficient ca_{ik}, based on their major courses taken before the capstone course, for all team members in the kth recruiting team, as well as the average similarity coefficient pa_{ik} for all team members in every past successful team as shown in Figure 2 and Figure 3. The measures using information on major courses are taken or not according to the fact that the project execution depends mainly on the knowledge the team members have, and how well they understand and apply methodologies to solve their problems. By using the two average similarity coefficients of the recruiting team and past successful teams, the algorithm calculates the Euclidean distance d_k between the recruiting team and one of the past successful teams that indicate the dissimilarity between two teams. To normalise d_k between 0 and 1, the algorithm sets simply it n_k as $1/(1+ d_k)$ that indicates approaching to 1 if the recruiting team is becoming more similar to the past successful team, i.e. it can mean the recruiting team has a high possibility of success. Lastly, the SC algorithm in Figure 1 calculates $PMAT_k$ using n_k and the GPA_k of the past successful team k, i.e. $PMAT_k = n_k \times GPA_k/4.5$, where 4.5 is the perfect score of the capstone course.

Average similarity coefficient ca_{ik} of each members and applicant in the k[th] team
($where, ca_{ik} = \sum_{i \in G_k} \frac{cr_{ik}}{|G_k|-1}$ where cr_{ik} is the sum of Pearson coefficient (S_{ij}) using major courses whether are taken or not and G_k is object set and $|G_k|$ is the number of the set in the k[th] team).

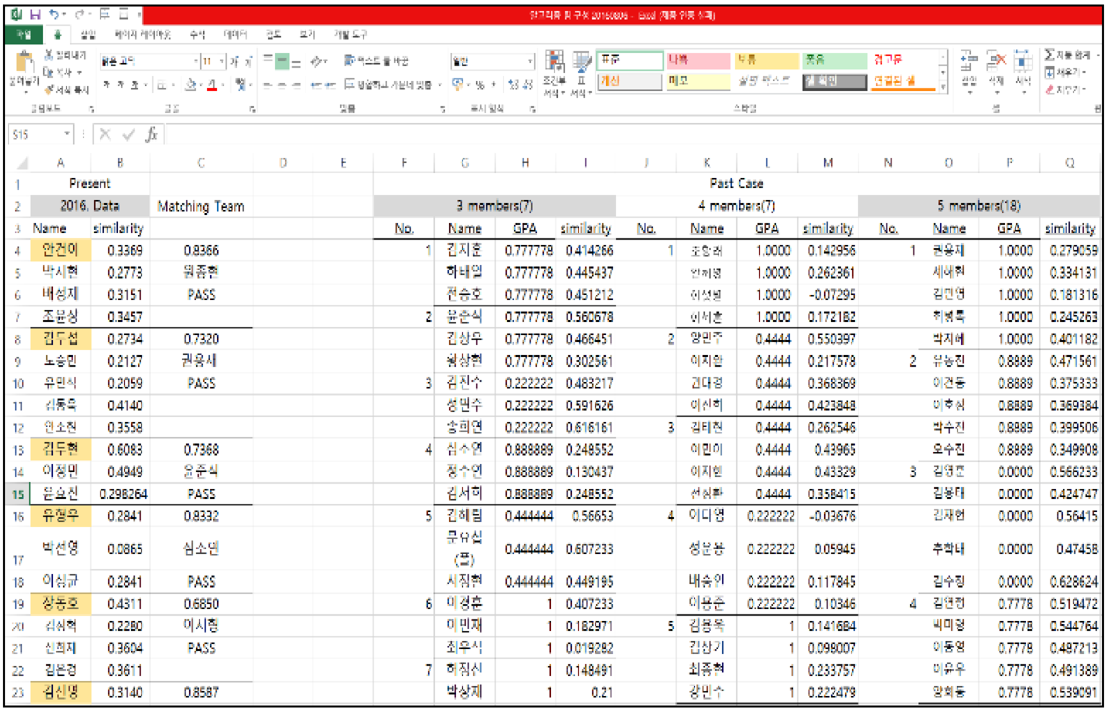
The k[th] recruiting team	Member 1	Member 2	Member 3	Member 4	$Applicant_i$	Average similarity
Member 1	-	S_{12}	S_{13}	S_{14}	S_{15}	ca_{1k}
Member 2	S_{21}	-	S_{23}	S_{24}	S_{25}	ca_{2k}
Member 3	S_{31}	S_{32}	-	S_{34}	S_{35}	ca_{3k}
Member 4	S_{41}	S_{42}	S_{43}	-	S_{45}	ca_{4k}
$Applicant_i$	S_{51}	S_{52}	S_{53}	S_{54}	-	ca_{5k}

Figure 2: The average similarity coefficients of the recruiting team.

Average similarity coefficients pa_{ik} of members in the k[th] past successful case (for all success teams)
($where, pa_{ik} = \sum_{i \in P_k} \frac{pr_{ik}}{|P_k|-1}$ where pr_{ik} is the sum of Pearson coefficient (S_{ij}) using major courses whether are taken or not and P_k is object set and $|P_k|$ is the number of the set in the k[th] team).

The k[th] past successful team	Member 1	Member 2	Member 3	Member 4	Member 5	Average similarity
Member 1	-	S_{12}	S_{13}	S_{14}	S_{15}	pa_{1k}
Member 2	S_{21}	-	S_{23}	S_{24}	S_{25}	pa_{2k}
Member 3	S_{31}	S_{32}	-	S_{34}	S_{35}	pa_{3k}
Member 4	S_{41}	S_{42}	S_{43}	-	S_{45}	pa_{4k}
Member 5	S_{51}	S_{52}	S_{53}	S_{54}	-	pa_{5k}

Figure 3: The average similarity coefficients of the past successful team.



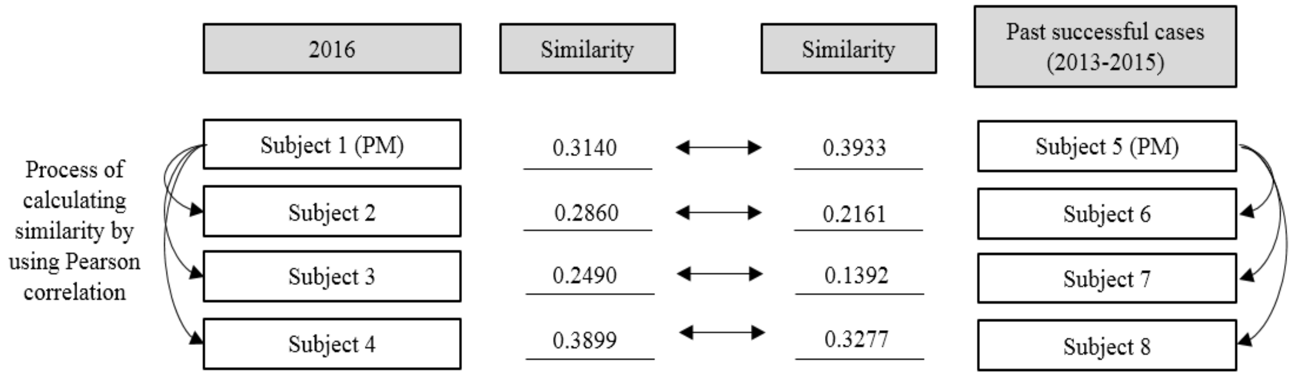
	A	B	C	F	G	H	I	J	K	L	M	N	O	P	Q
1	Present			Past Case											
2	2016. Data		Matching Team	3 members(7)				4 members(7)				5 members(18)			
3	Name	similarity		No.	Name	GPA	similarity	No.	Name	GPA	similarity	No.	Name	GPA	similarity
4	안건이	0.3369	0.8366	1	김지훈	0.777778	0.414266	1	조항래	1.0000	0.142956	1	권용재	1.0000	0.279059
5	박시현	0.2773	원종현		하태일	0.777778	0.445437		안치영	1.0000	0.262361		서대휘	1.0000	0.334131
6	배성지	0.3151	PASS		전승호	0.777778	0.451212		이선빈	1.0000	-0.07295		김민영	1.0000	0.181316
7	조윤상	0.3457		2	윤준식	0.777778	0.560678		이시훈	1.0000	0.172182		최병록	1.0000	0.245263
8	김두섭	0.2734	0.7320		김상우	0.777778	0.466451	2	양민주	0.4444	0.550397		박지혜	1.0000	0.401182
9	노승민	0.2127	권용세		최상현	0.777778	0.302561		이지완	0.4444	0.217578	2	유능진	0.8889	0.471561
10	유민식	0.2059	PASS	3	김진수	0.222222	0.483217		김다경	0.4444	0.368369		이건동	0.8889	0.375333
11	심동욱	0.4140			성민수	0.222222	0.591626		이신혜	0.4444	0.423848		이후식	0.8889	0.369384
12	안소진	0.3558			송희연	0.222222	0.616161	3	김태진	0.4444	0.262546		박수진	0.8889	0.399506
13	김두현	0.6083	0.7368	4	심수연	0.888889	0.248552		이민이	0.4444	0.43965		오수진	0.8889	0.349908
14	이정민	0.4949	윤준식		정수연	0.888889	0.130437		이지현	0.4444	0.43329	3	김영조	0.0000	0.566233
15	윤요진	0.298264	PASS		김서희	0.888889	0.248552		서상환	0.4444	0.358415		김봉태	0.0000	0.424747
16	유정우	0.2841	0.8332	5	김혜림	0.444444	0.56653	4	이다영	0.222222	-0.03676		김재현	0.0000	0.56415
17	박선영	0.0865	심소연		구유심 (콤)	0.444444	0.607233		성윤봉	0.222222	0.05945		추학내	0.0000	0.47458
18	이심규	0.2841	PASS		서진혁	0.444444	0.449195		배승이	0.222222	0.117845		김수정	0.0000	0.628624
19	상동호	0.4311	0.6850	6	이정훈	1	0.407233		이용준	0.222222	0.10346	4	김연정	0.7778	0.519472
20	심상혁	0.2280	이시형		이민재	1	0.182971	5	김봉욱	1	0.141684		박미경	0.7778	0.544764
21	신희지	0.3604	PASS		최우식	1	0.019282		김상기	1	0.098007		이동영	0.7778	0.487213
22	김은경	0.3611		7	허진시	1	0.148491		최종혁	1	0.233757		이유우	0.7778	0.491389
23	김신영	0.3140	0.8587		박상재	1	0.21		강민수	1	0.222479		장희동	0.7778	0.539091

Figure 4: Experiment of SC algorithm by using the Microsoft Excel program.

To give an example of the SC algorithm, one applies it to Microsoft Excel using the information of actual team construction and courses taken by students who participated in the capstone course from 2013 to 2016. Project managers (recruiters) of project cases performed in 2016 remained on their original teams but, the other team members were changed from all participants in 2016, and the team that obtained the highest PMAT was compared with past successful cases from 2013 to 2015.

In reality, the team starts with one person who is the project manager and sequence numbers were provided to the project managers. Also, to make up the count of real team members of each team in 2016, the data of past cases (from 2013 to 2015) were divided into 3-member teams, 4-member teams and 5-member teams. As shown in Figure 4, 13 teams existed in 2016, and there were 32 teams from 2013 to 2015 consisting of seven 3-member teams, seven 4-member teams and eighteen 5-member teams.

Figure 5 is a typical example of the experiment of the SC algorithm and shows that team building is processed on the basis of project manager (recruiter) Subject 1, who participated in the capstone course in 2016. The SC algorithm recommends Subject 2, Subject 3 and Subject 4 as team members based on the highest PMAT values.



$$\text{PMAT} = 1/(1+\sqrt{(0.3140-0.3933)^2+(0.2860-0.2161)^2+(0.2490-0.1392)^2+(0.3899-0.3277)^2}\times\underbrace{\frac{4.5}{4.5}}_{\text{Weighted GPA}} = 0.8587$$

Figure 5: The highest PMAT value in the example.

Performance of SC Algorithm

To show the proposed SC algorithm's performance, a comparative analysis for consistency with similar past cases in terms of project outcome (e.g. success or failure) between the results from random team building and the results from team building with the SC algorithm was performed as shown in Figure 6. The comparative analysis uses the 32 teams in 2013 to 2015 and 13 teams in 2016 of the previous experiment to provide an example of the subsection above. In the test, the project managers of 13 project teams performing in 2016 remained on their original teams, but all the other team members were changed in 2016, and the most similar team is found from the teams performed in 2013, 2014 and 2015 at the same time.

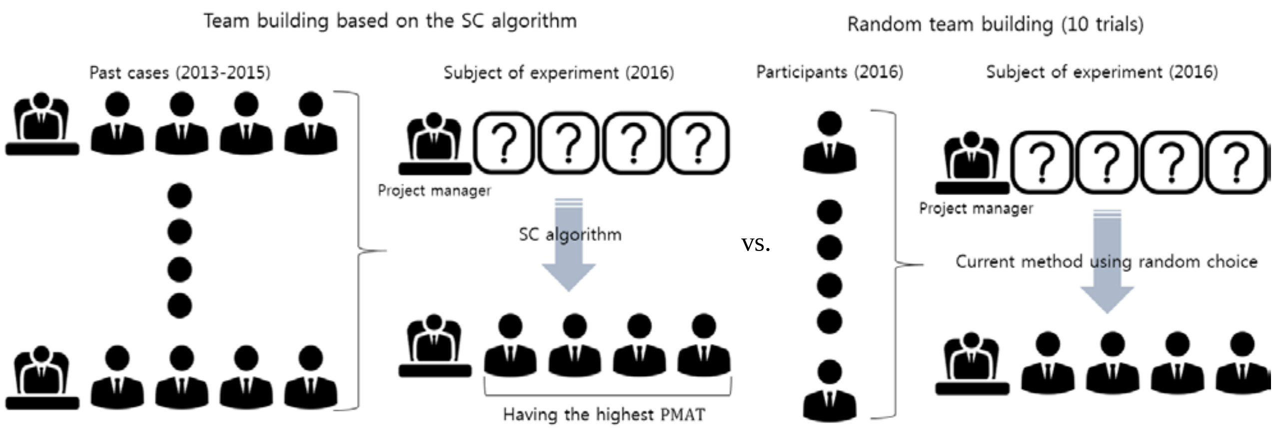


Figure 6: Comparison between the SC algorithm and the current team building.

After the most similar case is chosen, the PMAT value is calculated based on whether GPA of a similar case is high or low. If the GPA of the similar case is high, the PMAT of the experimental (recruiting) teams will be high. Meanwhile, the PMAT of the experimental teams will not be high. Because of these features, the SC algorithm can help students build teams similar to the past successful cases.

On the other hand, in random team-building experiments, which represent the current team-building method, except for project managers who were fixed, all other team members are assigned randomly to each team by using random number generation. Hereafter, this random team-building method chooses the most similar past case based on the information of courses taken by team members. Through the matching of the past team's record, such as success or failure of capstone course, over the ten random team-building experiments, 38% of the composed teams are matched with past successful cases on average as shown in Figure 7.

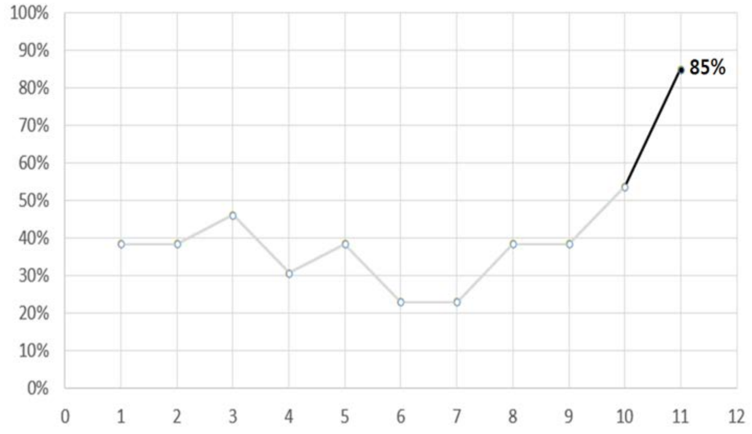


Figure 7: Matching percent with the past success teams between teams building by random experiments (1st to10th trial) and teams building by SC algorithm (11th trial).

While the team-building experiment with the SC algorithm is similar to the random team-building experiment, PMAT figures are utilised during the process of changing team members. By the time the PMAT figure reaches over 0.75, team members are changed continuously.

As a result of this experiment, 85% of composed teams, which means 11 teams out of 13 teams, are matched with successful cases during the 2013 to 2015 period. Because the matching percentage with past successful cases of team building by the SC algorithm is 47% higher than that of random team building, the SC algorithm seems to be superior to the current method and can help students construct a team effectively to execute their project in the PBL course.

CONCLUSIONS

In this study, the SC algorithm is proposed for the purpose of building teams similar to past successful cases in order to increase the performance of future team projects in engineering school capstone courses. As the SC algorithm measures the matching ratio based on the information of courses taken by students, it can give a high successful feasibility in capstone project execution to student teams. Furthermore, the comparison analysis between random team-building experiments and team building by the SC algorithm indicated that team building by the SC algorithm is much more similar to the previous successful performance than the existing method.

Because the proposed algorithm is basically dependent on the similarity of the past successful team features based on the information of courses taken by students, different information from students can affect the similarity and the algorithm. It means that the SC algorithm is extensible and applicable to the various group-based learning courses and cooperative team-based projects in industry, while it is limited if there is insufficient past information regarding project teams. Despite several limitations of the SC algorithm, the accumulation effect of information on successful team cases over the years will make it more effective for students' team-building activity in capstone course.

Other studies to utilise the algorithm to various PBL courses should be tested. First of all, an information system working the algorithm, such as a team-building support system should be developed as a Web-based system regardless of place and time. Second, in cases when there is no past course information, alternative algorithms should be considered and developed. Lastly, a new team-building model including all participants, such as teachers, students and interested industrial parties linked to the capstone project should be also considered.

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BIOGRAPHY

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