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# Appraisal Method for Project-Based Learning with Fuzziness

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***Abstract*—The subject of this research is to develop a method for quantitatively clarifying learning outcomes of project/problem-based learning (PBL) by quantifying experience and strategy of teachers by Fuzzy theory and considering the weight uniquely calculated by the ratio method, that is called "Appraisal Method" for PBL with fuzziness. We will show success factors and learning outcomes of PBL. Furthermore, we evaluate the relationship between them from the results of survey of students of Tokyo University of Science, Suwa. As a result, it is possible to clarify factors to pay attention to manage PBL taking experience of education experts into account. In addition, it is possible to objectively measure learning outcomes, which minimizes the subjectivity of teachers.**

***Keywords*—Project-based Learning, Fuzzy theory, Class evaluation, Fundamental competencies for working persons.**

## I. Introduction

Classes incorporating project/problem based learning (PBL) have been practiced in various ways by many educational institutions and have been introduced for the following purposes [1]:

i. to enhance students' abilities to self-learning in anticipation of their own future,
ii. to acquire firm foundational academic abilities in their specialty field,
iii. to make students motivate themselves and have the power to learn independently.

In PBL, students learn through a specific practical experience or a certain project, which is formulation and implementation of a plan to achieve a purpose within a period, by using the expert knowledge. From such as experience and learning, students improve the problem finding and resolution abilities, find shortcomings of their own knowledge, share knowledge mutually in team activities, and refine communication skills in the process. As a result, they can cultivate autonomy and a foundation to study themselves in the future. In other words, by acquiring these with PBL, they can acquire hard skills and soft skills to keep studying [3]. Hard skill refers to knowledge in specialized fields and the ability to utilize it is call soft skill.

Although there are parts with different expressions and contents, these can be understood that bachelor's literacy and fundamental competencies for working persons, which is proposed by Ministry of Economy, Trade and Industry Japan, can be said to be seeking the ability to use knowledge called soft skills [4,5].

PBL is often implemented depending on the experience and know-how of subject teachers. This know-how is summarized in various forms [6-9]. In addition, the operation and management method of PBL are not systematized at present. The relationship between PBL and learning outcomes is not clear, and it depends strongly on the ability of subject teachers at the start-up/planning stage. In response to above problems, we have studied the relationship between the success factors and learning outcomes of PBL [1,2]. We have made a success factor structure diagram stratifying success factors of PBL and a learning outcome structure diagram stratifying learning outcomes. By creating the relationship matrix based on these, we have quantitatively clarified the relationship between success factors and learning outcomes of PBL. However, the method of evaluating learning outcomes of each student by PBL varies depending on the educational institution.

The purpose of this research is to develop a method for quantitatively clarifying learning outcomes of PBL by quantifying experience and strategy of teachers by Fuzzy theory and considering the weight uniquely calculated by the ratio method. As a result, it can be expected to lower dependency on teachers' abilities and experiences, and to improve the learning outcomes of students. In this research, we verify the usefulness by collecting and analyzing data obtained in PBL practice at university. However, the method clarified in this research is expected to be applicable to a wide range of fields such as company employee education, education/teaching materials development of private preparatory school.

## II. Relationship Matrix Between Success Factors And Leaning Outcomes On PBL

In this section, we briefly summarize the relationship between success factors and learning outcomes of PBL.

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### A. *Success and Failure of PBL*

In order to decide success or failure of PBL, it is necessary to consider the characteristics of PBL. More specifically, PBL has two aspects of education and project. Success of PBL as an education is that students acquire soft skills and hard skills through courses and actions. On the other hand, success of PBL as a project means the achievement of the goal set for each project. For this reason, it is important for teachers and students to preliminarily learn project management system such as the Project Management Body of Knowledge (PMBOK®) [10-12] in advance for the project to succeed.

Since success and failure of PBL have different objectives of success as an education and success as a project, it is necessary to carefully discuss which one to prioritize and judge as success or failure. Table 1 shows success or failures of PBL in the case where priority is given to acquiring soft skills, which is the purpose of education. This paper is discussed from this point of view.

**Table 1.**
**Success and failure of PBL**

| Goal of Project \ Goal of education | Success | Failure |
|---|---|---|
| Success | Excellent | Poor |
| Failure | Good | Bad |

### B. *Success Factors of PBL*

In order to structure success factors of PBL, we refer to some operational manuals for PBL and "the Project Management Body of Knowledge". In addition, we interviewed professors and students who have taken PBL course "Project and Management". Summarizing these results using the nominal group method [13], success factors in PBL has been classified as shown in Table 2. Success factors in PBL can categorize eleven classifications within five categories. For later discussion, we add names ($x_1$, $x_2$, ..., and $x_{11}$) to success factors.

**Table 2.**
**Success factor structure diagram.**

| Category | Classification |
|---|---|
| Students' effort | A student ($x_1$) |
| | Group ($x_2$) |
| Teachers' interaction | A teacher ($x_3$) |
| | Group ($x_4$) |
| Cooperative framework of cooperator | Understanding ($x_5$) |
| | Communication ($x_6$) |
| Utilize resource | On-campus Environment ($x_7$) |
| | Off-campus Environment ($x_8$) |
| | ICT ($x_9$) |
| | Fundamental Resource ($x_{10}$) |
| Course design | Contents ($x_{11}$) |

### C. *Leaning Outcomes of PBL*

In the aspect of education, success of PBL means that students learn hard skills and soft skills. Acquiring of soft skills is equivalent to acquiring of practical skills. So-called "practical skills" mean the students' apply skills using knowledge that they obtained in classroom lectures of university when they go out into the world. The Ministry of Economy, Trade and Industry defined the practical skills as fundamental competencies for working persons and classified those into 3 items consisting of 12 elements. Soft skills defined in this paper refer to fundamental competencies for working persons. Table 3 shows soft skills, which are required for learning, by applying to 12 elements of fundamental competencies for working persons. We add names ($y_1$, $y_2$, ..., and $y_{12}$) to classifications and (Y1, Y2, and Y3) to categories of learning outcomes as shown in Table 3. Students' learning level for soft skills is quantitatively assessed from the incremental difference indicated by evaluating fundamental competencies for working persons before starting the project and after completing the class.

Success or failure of the project are determined by whether the project product achieved the goal. The assessment of project is independent of the type of project product.

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Expected learning knowledge is depending on the theme of project. It seems that the quantitative assessment of project is difficult. The competency required for each theme is investigated and a written examination is conducted for the students. This method can evaluate the students' learning level. In other words, the method of quantitative assessment is different between themes. Therefore, this paper does not classify hard skills in detail.

**Table 3.**
**Learning outcome structure diagram.**

| | Category | Classification |
|---|---|---|
| Soft skills | Ability to forward ($Y_1$) | Initiative($y_{1,1}$) |
| | | Ability to influence($y_{1,2}$) |
| | | Execution skill($y_{1,3}$) |
| | Ability to think through ($Y_2$) | Ability to detect issues($y_{2,1}$) |
| | | Planning skills($y_{2,2}$) |
| | | Creativity($y_{2,3}$) |
| | Ability to work in a team ($Y_3$) | Ability to deliver message($y_{3,1}$) |
| | | Ability to listen closely and carefully($y_{3,2}$) |
| | | Flexibility($y_{3,3}$) |
| | | Ability to grasp situation($y_{3,4}$) |
| | | Ability to apply rules and regulations($y_{3,5}$) |
| | | Ability to control stress($y_{3,6}$) |
| Hard skills ($Y_4$, $y_{4,1}$) | | |

*D. Relationship Matrix and Survey Items*

By creating the relationship matrix based on a success factor structure diagram and a learning outcome structure diagram, we quantitatively clarify the relationship between success factors and learning outcomes of PBL.

In order to clarify the relationship between success factors and learning outcomes, we carry out questionnaire survey subject to students of Tokyo University of Science, Suwa who take a PBL course "Project & Management". The number of question items for success factors and for learning outcomes become 16 and 25, respectively. These questions are prepared based on references [7-9, 14] and summarized by three preliminary surveys. All questions are prepared in five choices (5 means the highest and 1 means the lowest), and we aggregate the number of choices as a score.

Table 4 shows the correlation matrix of the questionnaire result for success factors. As the result, we find that multi-collinearity is low and each item is independent. this means that questionnaire items for success factors are valid. Table 5 shows the result of principal component analysis of success factors. Since the first component C1 is negative in all items, it shows that it represents a comprehensive learning outcomes. These results show that learning outcomes structure diagram is a valid model for expressing learning outcomes of PBL.

**Table 4.**
**Correlation matrix of success factors.**

| | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ | $x_7$ | $x_8$ | $x_9$ | $x_{10}$ | $x_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $x_1$ | 1.000 | 0.339 | 0.420 | 0.528 | 0.335 | 0.230 | 0.173 | 0.428 | 0.660 | 0.519 | 0.473 |
| $x_2$ | 0.339 | 1.000 | 0.608 | 0.526 | 0.488 | 0.397 | 0.567 | 0.212 | 0.295 | 0.328 | 0.555 |
| $x_3$ | 0.420 | 0.608 | 1.000 | 0.642 | 0.350 | 0.208 | 0.405 | 0.449 | 0.515 | 0.651 | 0.724 |
| $x_4$ | 0.528 | 0.526 | 0.642 | 1.000 | 0.333 | 0.192 | 0.244 | 0.570 | 0.772 | 0.668 | 0.545 |
| $x_5$ | 0.335 | 0.488 | 0.350 | 0.333 | 1.000 | 0.332 | 0.428 | 0.100 | 0.264 | 0.276 | 0.437 |
| $x_6$ | 0.230 | 0.397 | 0.208 | 0.192 | 0.332 | 1.000 | 0.567 | 0.100 | 0.119 | 0.015 | 0.239 |
| $x_7$ | 0.173 | 0.567 | 0.405 | 0.244 | 0.428 | 0.567 | 1.000 | 0.053 | 0.181 | 0.195 | 0.426 |
| $x_8$ | 0.428 | 0.212 | 0.449 | 0.570 | 0.100 | 0.100 | 0.053 | 1.000 | 0.599 | 0.717 | 0.435 |
| $x_9$ | 0.660 | 0.295 | 0.515 | 0.772 | 0.264 | 0.119 | 0.181 | 0.599 | 1.000 | 0.578 | 0.404 |
| $x_{10}$ | 0.519 | 0.328 | 0.651 | 0.668 | 0.276 | 0.015 | 0.195 | 0.717 | 0.578 | 1.000 | 0.639 |
| $x_{11}$ | 0.473 | 0.555 | 0.724 | 0.545 | 0.437 | 0.239 | 0.426 | 0.435 | 0.404 | 0.639 | 1.000 |

**Table 5.**
**Principal component analysis of success factors.**

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| $x_1$ | -0.294 | 0.019 | -0.319 | 0.428 | 0.444 |
| $x_2$ | -0.214 | -0.308 | -0.066 | -0.150 | -0.250 |
| $x_3$ | -0.241 | -0.066 | -0.022 | -0.243 | -0.167 |
| $x_4$ | -0.450 | 0.072 | -0.265 | 0.149 | -0.576 |
| $x_5$ | -0.200 | -0.374 | -0.375 | -0.151 | 0.502 |
| $x_6$ | -0.129 | -0.475 | 0.453 | 0.477 | 0.065 |
| $x_7$ | -0.176 | -0.529 | 0.272 | -0.108 | -0.14 |
| $x_8$ | -0.396 | 0.393 | 0.585 | 0.077 | 0.198 |
| $x_9$ | -0.321 | 0.143 | -0.226 | 0.393 | -0.145 |
| $x_{10}$ | -0.427 | 0.244 | 0.100 | -0.401 | 0.182 |
| $x_{11}$ | -0.278 | -0.12 | -0.003 | -0.361 | 0.105 |
| standard deviation | 1.879 | 1.112 | 0.712 | 0.705 | 0.625 |
| contribution ratio | 0.489 | 0.171 | 0.070 | 0.069 | 0.054 |
| cumulative contribution ratio | 0.489 | 0.660 | 0.730 | 0.799 | 0.853 |
| eigenvalue | 3.530 | 1.237 | 0.508 | 0.498 | 0.390 |

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## III. Mathematical Preliminaries For Appraisal Method With Fuzziness

In this section, we show the formulation of Fuzzy numbers with quartiles to carry out the management system on PBL, and the ratio method to do weighting to the factors of learning outcomes.

In most cases, decisions are made by human endeavor, while pursuing an ideal and rationality etc. Particularly, with increasing of the diversified value sense of the decision makers based on human knowledge and past experience etc., the decision situation has been become extremely complex. Decision makers may have access to different information/knowledge on which to base their decision, and/or they may place a different ordering/weighting on the PBL factors and the factor of learning outcomes since they own differences of values, beliefs, attitudes, and understandings for the given problem set. Therefore, how to deal with the complexity which arises commonly in decision situation rationally and efficiently is an important theme since it affects the quality of decision making.

In order to cope with such a theme with respect to human behavior such as human judgment, insight and intuition, we adopt the Fuzzy membership functions and the ratio method in this paper. Note that indexes *i*, *j*, and *k* are defined as integers after this.

### A. Quartiles and Fuzzy Numbers

Let $L$ be the number of success factors of PBL. When $x_i$ ($1 \le i \le L$) is shown as the Fuzzy numbers [15] with the membership function, the membership function $\mu_{x_i}(z)$ of $x_i$ are expressed as follows:

Let $q_{1i}$ and $q_{3i}$ be the first quartile and the third quartile of answer corresponding to success factor $x_i$, respectively. Then, when $z$ is an element of $x_i$, $\mu_{x_i}(z)$ is given as

$$\mu_{x_i}(z) = \begin{cases} 0 & \text{for } z \le q_{1i}, \\ (z - q_{1i}) / (q_{3i} - q_{1i}) & \text{for } q_{1i} < z < q_{3i}, \\ 1 & \text{for } q_{3i} \le z. \end{cases} \quad (1)$$

### B. The Raito Method

In this paper, we adopt the ratio method [16] so as to lend weights to the factors of learning outcomes.

The importance degrees of the factors of the learning outcomes in PBL are computed by using the ratio between the factors of learning outcomes as follows:

Let **F** be a matrix determined by a paired comparison among the factors of learning outcomes based on a contextual relation "degrees of importance". In **F**, the transitive law is satisfied.

Assume that reflexive law is not satisfied in **F**, and only each element corresponding to $f^i_{j,j+1}$ ($1 \le i \le M$ and $1 \le j \le N-1$) of the matrix is given by a paired comparison of learning outcomes $y_{i,j}$ and $y_{i,j+1}$ as an evaluation value, and satisfies $0 \le f^i_{j,j+1} \le 1$, $f^i_{j+1,j} = 1 - f^i_{j,j+1}$. $M$ and $N$ mean the number of elements within the same category and classification of learning outcomes, respectively. Then, $\mathrm{F}^i$ for learning outcomes $y_{i,j}$ can be found as follows,

$$\mathbf{F}^i = \begin{pmatrix} 0 & f^i_{1,2} & 0 & & 0 & 0 & 0 \\ f^i_{2,1} & 0 & f^i_{2,3} & \cdots & 0 & 0 & 0 \\ 0 & f^i_{3,2} & 0 & & 0 & 0 & 0 \\ & \vdots & & \ddots & & \vdots & \\ 0 & 0 & 0 & & 0 & f^i_{N-2,N-1} & 0 \\ 0 & 0 & 0 & \cdots & f^i_{N-1,N-2} & 0 & f^i_{N-1,N} \\ 0 & 0 & 0 & & 0 & f^i_{N,N-1} & 0 \end{pmatrix} \quad (2)$$

The degrees of importance of learning outcomes in the same category or classification are obtained as follows,

$$\begin{cases} W^{i\prime}_1 = \prod_{j=1}^{N-1} f^i_{j,j+1}, \\ W^{i\prime}_k = \prod_{j=1}^{k-1} (1 - f^i_{j,j+1}) \prod_{j=k}^{N-1} f^i_{j,j+1} \quad (1 < k < N), \\ W^{i\prime}_N = \prod_{j=1}^{N-1} (1 - f^i_{j,j+1}). \end{cases} \quad (3)$$

Normalizing Eq. (3), the weight vector $\mathbf{W}^i (= \{W^i_k\})$ of $\mathbf{F}^i$ can be found as follows,

$$W^i_k = W^{i\prime}_k / \tilde{W}^i, \quad (4)$$

where $\tilde{W}^i = \sum_{k=1}^{N} W^{i\prime}_k$. We apply formulas mentioned above to find the weights on the factors of the learning outcomes in PBL. Then, the matrix is constituted with a paired comparison by decision makers who take part in PBL.

## IV. Appraisal Method For Project-Based Learning With Fuzziness

In this section, we show the Appraisal Method of learning outcomes for students based on PBL with fuzziness (after this, Appraisal Method). The Appraisal Method covers the stages as follows:

### The Appraisal Method

*Step 1:* Distribute a questionnaire to the students to analyze the relationships between success factors and learning outcomes of PBL, and apply the multiple regression analysis to the results of the questionnaire.

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Using the forward selection method in the multiple regression analysis, we calculate the increment of contribution ratio $R_{i,j}^2$ when a factor $x_i$ added and the cumulative contribution ratio $R_j^2$ $(= \sum_{i=1}^{N} R_{i,j}^2)$ regard to learning outcome $y_{j,j}$.

*Step 2:* Compute the first and the third quartiles ($q_{1,i}$, $q_{3,i}$) for the success factor $x_i$ on the basis of the results of the questionnaire at Step 1, and formulate the membership functions at the PBL success factor.

*Step 3:* Compute the attainment degree of the learning outcome $y_{i,j}$ for student $k$. When the answer to questionnaire concerning the success factor $x_i$ of student $k$ is $x_i^k$, the attainment degree $A_j^k$ of a learning outcome $y_{i,j}$ is given by

$$A_j^k = \frac{\sum_{i=1}^{L} \mu_{x_i}(x_i^k) R_{i,j}^2}{R_j^2}. \quad (5)$$

*Step 4:* Compute the weights $\{W_j^i\}$ of the learning outcome $y_{i,j}$ in $Y_i$ and the weights $\{W_i^C\}$ of the learning outcome $Y_i$ for comprehensive appraisal by the ratio method in Sec. III.*B*.

*Step 5:* Compute the attainment degree $B_i^k$ of the learning outcome $Y_i$ ($1 \le i \le M$) for student $k$ using following expression:

$$B_i^k = \sum_{j=1}^{N} W_j^i A_j^k. \quad (6)$$

*Step 6:* Compute the comprehensive appraisal value $C_k$ for a student $k$ is obtained as

$$C^k = \sum_{i=1}^{M} W_i^C B_i^k. \quad (7)$$

The Appraisal Method is a realistic method which can perform the PBL efficiently and systematically.

From this, knowledge/information, past experiences and know-how of the educators can be reflected directly into the process of PBL. Further the educators can make decision reasonably by recognizing the essence of the educational issue, while taking consideration of the information with inherent uncertainty for PBL. This leads to a rational judgment on the learning outcomes after careful consideration.

Further, in case of students' academic achievement isn't improved by using the Appraisal Method proposed above, we can also clear the reason why such results occurred.

## V. Illustrative Example

In this section, we clarify causal relationship between success factors and learning outcomes by multiple regression analysis. Moreover, we verify the usefulness of the analysis method shown in Sec. III and IV.

### A. Purpose of Questionnaire Survey

We quantitatively measure leaning effects of PBL and verify the analysis method.

### B. Survey Method

*(1) Class:* "Project and Management" as an optional course (2 modules per year) that is lectured to the freshman to senior students of Department of Business Administration and Information at Tokyo University of Science, Suwa.

*(2) Subjects:* A total of 62 students who are taking a course of "Project and Management" in Department of Business Administration and Information at Tokyo University of Science, Suwa (Breakdown of students: 8 fourth-year students, 41 third-year students, 5 second-year students, 8 first-year students, 44 male students and 18 female students).

*(3) Data collection method:* Questionnaire form on Web.

*(4) Survey date:* 21 January, 2016 (at the end of course).

*(5) Outline of class:* PBL class to acquire soft skills by tackling and solving the existing local problem with local people.

*(6) Analysis method:* R version 3.2.3.

### C. Results of Survey

In order to clarify the relationship between success factors and learning outcomes, we use the multiple linear regression analysis with the forward selection method. In this analysis, learning outcomes are the objective variable and success factors are the explanatory variable. We employ success factors as explanatory variable to minimize AIC (Akaike's Information Criterion) [17]. Table 6 shows the increment of contribution ratio when each factor added, the cumulative contribution ratio ($R^2$), the mean value ($\mu$), the standard deviation($\sigma$), a max variance inflation factor (VIF), the first quartile ($q_1$), the median ($q_2$), and the third quartile ($q_3$) of 46 valid answers. Effect value is defined as the sum of score of factor. The score is two point for factor with over 30% contribution ratio, and one point for the factor with less than 30% contribution ratio. It indicates that success factors with high effect value have influence on learning outcomes of PBL. $R^2$ value of almost learning outcomes has over 0.4 and VIF of all of learning outcomes has smaller than 10.0. These show that

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Looking at the mean value, we find that success factors are generally satisfied in this class. Especially, the evaluation on factors of "Utilize resource/On-campus Environment ($x_7$)", "Utilize resource /ICT ($x_9$)" and "Teachers' interaction/Individual ($x_3$)" are highly evaluated. As for the reason why these factors received high evaluations, our university has established a wireless LAN environment and many meeting spaces. In addition, teachers also participate in the project according to the operation manual. We find that learning outcomes are also generally improved as compared with before taking course. Especially, evaluations of ability of "Initiative ($y_{1,1}$)", "Flexibility ($y_{3,3}$)", and "Ability to apply rules and regulations ($y_{3,5}$)" are high. These results mean that students acquire the fundamental competency for working persons through the PBL course.

The learning outcome "Initiative ($y_{1,1}$)", which is the highest degree of acquisition by this PBL class, is related to satisfaction degree of success factors "Students' effort/group ($x_2$)", "Teachers' interaction/group ($x_4$)", "Utilize resource/ICT ($x_9$)", and "Utilize resource/ Fundamental Resource ($x_{10}$)". This means that it is possible to acquire higher level by sharing information among project members, collaboration among teachers, and utilizing ICT tools. Meanwhile, in order to raise the degree of acquisition of "Ability to deliver message ($y_{3,1}$)" which is the lowest acquisition level, it is necessary to operate to enrich the factors "Teachers' interaction/group ($x_4$)", "Utilize resource/ICT ($x_9$)".

The success factor with highest effect value is "Students' effort/a student ($x_1$)", and it is related to "Ability to work in a team ($Y_3$)", "execution skill", "planning skill", and "hard skill". In PBL, students acquire missing knowledge by tackling tasks with no clear answer, and by utilizing knowledge and skills according to themselves and surrounding circumstances. As the results, students acquire the fundamental competencies for working persons, such as the "Ability to work in a team ($Y_3$)".

**Table 6.**
**Relationship matrix and statics values.**

| | $y_{1,1}$ | $y_{1,2}$ | $y_{1,3}$ | $y_{2,1}$ | $y_{2,2}$ | $y_{2,3}$ | $y_{3,1}$ | $y_{3,2}$ | $y_{3,3}$ | $y_{3,4}$ | $y_{3,5}$ | $y_{3,6}$ | $y_{4,1}$ | effect value | $\mu$ | $\sigma$ | $q_1$ | $q_2$ | $q_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $x_1$ | 0 | 0 | 0.021 | 0 | 0.051 | 0.124 | 0 | 0.275 | 0.063 | 0.387 | 0.105 | 0.295 | 0.449 | 11 | 3.576 | 0.803 | 3.000 | 3.500 | 4.000 |
| $x_2$ | 0.082 | 0 | 0.087 | 0 | 0.087 | 0.297 | 0.084 | 0.04 | 0.035 | 0 | 0 | 0.087 | 0 | 8 | 3.726 | 0.674 | 3.200 | 3.400 | 4.200 |
| $x_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0.059 | 0 | 0 | 0 | 0 | 0.029 | 0.019 | 3 | 4.051 | 0.592 | 3.667 | 4.000 | 4.667 |
| $x_4$ | 0.498 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.277 | 0.096 | 0.412 | 0 | 0.102 | 7 | 4.043 | 0.988 | 3.000 | 4.000 | 4.000 |
| $x_5$ | 0 | 0 | 0.024 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4.109 | 0.795 | 3.500 | 4.000 | 4.000 |
| $x_6$ | 0 | 0 | 0 | 0.061 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0.047 | 0.039 | 0 | 4 | 4.109 | 0.795 | 3.000 | 4.000 | 4.000 |
| $x_7$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.130 | 0.806 | 4.000 | 4.000 | 5.000 |
| $x_8$ | 0 | 0 | 0 | 0 | 0.045 | 0 | 0 | 0 | 0.027 | 0 | 0 | 0 | 0 | 2 | 3.674 | 1.012 | 3.000 | 3.000 | 4.000 |
| $x_9$ | 0.044 | 0.437 | 0.416 | 0.441 | 0.429 | 0 | 0.269 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 3.739 | 0.773 | 4.000 | 4.500 | 5.000 |
| $x_{10}$ | 0.023 | 0 | 0 | 0.048 | 0 | 0 | 0 | 0 | 0.078 | 0 | 0 | 0 | 0 | 3 | 3.696 | 0.963 | 3.000 | 3.000 | 4.000 |
| $x_{11}$ | 0 | 0.058 | 0 | 0 | 0.023 | 0 | 0 | 0 | 0 | 0 | 0 | 0.026 | 0 | 3 | 3.797 | 0.704 | 3.000 | 3.333 | 4.000 |
| $R^2$ | 0.647 | 0.494 | 0.548 | 0.550 | 0.635 | 0.421 | 0.412 | 0.315 | 0.481 | 0.512 | 0.564 | 0.476 | 0.570 | | | | | | |
| $\mu$ | 4.054 | 3.696 | 3.717 | 3.685 | 3.522 | 3.717 | 3.196 | 3.620 | 4.022 | 3.793 | 3.946 | 3.783 | 3.978 | | | | | | |
| $\sigma$ | 0.762 | 0.853 | 0.841 | 0.865 | 0.900 | 0.911 | 1.003 | 0.902 | 0.767 | 0.834 | 0.932 | 0.867 | 0.830 | | | | | | |
| VIF | 3.833 | 1.195 | 1.889 | 1.529 | 2.278 | 1.130 | 1.972 | 1.130 | 2.694 | 1.421 | 1.421 | 2.453 | 1.974 | | | | | | |

*D. Compute Appraisal Value*

We calculate appraisal value of learning outcomes for each student by using the Appraisal Method. In order to decide the weights using the ratio method, we set the degrees of importance for classifications of learning outcomes $y_{i,j}$ as $f_{1,2}^1 = 0.7$, $f_{2,3}^1 = 0.4$, $f_{1,2}^2 = 0.6$, $f_{2,3}^2 = 0.6$, $f_{1,2}^3 = 0.6$, $f_{2,3}^3 = 0.5$, $f_{3,4}^3 = 0.5$, $f_{4,5}^3 = 0.4$, and $f_{5,6}^3 = 0.3$. Moreover, the degrees of importance for learning outcomes $Y_i$ are set as $f_{1,2}^C = 0.5$, and $f_{2,3}^C = 0.6$.

For instance, computing the weights $\{W_j^1\}$, one obtains $W_1^1 = 0.483$, $W_2^1 = 0.207$, and $W_3^1 = 0.310$.

From similar calculation, appraisal values of learning outcomes for each student are shown in Table 8. We also show the role of student in the project and score of this class in Table 8. The score is 100 point out and it is graded by the report submission status, attendance status, and willingness to learn (subject such as attitude in presentation).

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The student No.46 has not scored because he/she abandoned the course. The mean value ($\mu$) and standard deviation ($\sigma$) are computed excluding No.46.

Comparing appraisal value of soft skill with the score, the correlation coefficient is 0.364. This means that there is a weak correlation. More detailed analysis shows that the correlation coefficient is -0.212 for a group of students with a role such as a leader. This cause is that the proportion of acquisition of soft skills in the score is decreased since willingness to learn is improved by playing a role and reflected in the score. Typical cases are student No.2, 5, and 8. Although the comprehensive appraisal value of them are almost $\sigma$ (or more) smaller than $\mu$, the scores of them have over the mean value. This shows that they are evaluated by willingness to learn and attitude of learning, not by acquisition of soft skills. On the other hand, the correlation coefficient is 0.541 for a group of students who have no role. This means that there is a correlation between the acquisition of soft skills and the score. In this group, the comprehensive appraisal value and the score are in good agreement. These results show that it is effective to evaluate the degree of acquisition of soft skills by the Appraisal Method.

**Table 8.**
**Appraisal value.**

| student | role | *Y*1 | *Y*2 | *Y*3 | soft skill | score |
|---|---|---|---|---|---|---|
| 1 | leader | 0.146 | 0.389 | 0.342 | 0.293 | 71 |
| 2 | leader | 0.372 | 0.061 | 0.333 | 0.255 | 81 |
| 3 | leader | 0.730 | 0.641 | 0.911 | 0.761 | 70.2 |
| 4 | leader | 0.378 | 0.098 | 0.533 | 0.336 | 72 |
| 5 | leader | 0.022 | 0.041 | 0.038 | 0.033 | 75 |
| 6 | leader | 0.633 | 0.316 | 0.555 | 0.501 | 78 |
| 7 | sub leader | 0.527 | 0.451 | 0.876 | 0.618 | 74 |
| 8 | sub leader | 0.020 | 0.187 | 0.470 | 0.226 | 76 |
| 9 | sub leader | 0.774 | 0.754 | 0.956 | 0.828 | 68.5 |
| 10 | sub leader | 0.537 | 0.361 | 0.471 | 0.457 | 68.9 |
| 11 | sub leader | 0.511 | 0.443 | 0.872 | 0.608 | 73 |
| 12 | sub leader | 0.512 | 0.352 | 0.448 | 0.437 | 77 |
| 13 | sub leader | 0.413 | 0.131 | 0.722 | 0.422 | 79 |
| 14 | treasurer | 0.507 | 0.301 | 0.432 | 0.413 | 77 |
| 15 | treasurer | 0.485 | 0.231 | 0.390 | 0.368 | 69 |
| 16 | treasurer | 0.527 | 0.451 | 0.895 | 0.624 | 77 |
| 17 | treasurer | 0.728 | 0.661 | 0.901 | 0.764 | 77 |
| 18 | recorder | 0.904 | 0.785 | 0.887 | 0.859 | 70 |
| 19 | recorder | 0.489 | 0.386 | 0.844 | 0.573 | 74 |
| 20 | recorder | 0.711 | 0.542 | 0.665 | 0.639 | 83 |
| 21 | none | 0.038 | 0.102 | 0.059 | 0.066 | 44 |
| 22 | none | 0.498 | 0.328 | 0.436 | 0.421 | 83 |
| 23 | none | 0.372 | 0.024 | 0.307 | 0.234 | 69 |
| 24 | none | 0.749 | 0.721 | 0.922 | 0.797 | 81 |
| 25 | none | 0.774 | 0.754 | 0.947 | 0.825 | 74 |
| 26 | none | 0.014 | 0.037 | 0.035 | 0.029 | 54 |
| 27 | none | 0.708 | 0.560 | 0.881 | 0.717 | 76 |
| 28 | none | 0.537 | 0.385 | 0.492 | 0.471 | 78 |
| 29 | none | 0.050 | 0.212 | 0.283 | 0.181 | 73 |
| 30 | none | 0.488 | 0.342 | 0.814 | 0.548 | 68 |
| 31 | none | 0.549 | 0.508 | 0.913 | 0.656 | 64 |
| 32 | none | 0.716 | 0.575 | 0.707 | 0.666 | 81 |
| 33 | none | 0.397 | 0.057 | 0.333 | 0.262 | 65.2 |
| 34 | none | 0.014 | 0.000 | 0.000 | 0.005 | 70 |
| 35 | none | 0.543 | 0.446 | 0.702 | 0.564 | 74 |
| 36 | none | 0.549 | 0.508 | 0.913 | 0.656 | 69 |
| 37 | none | 0.518 | 0.389 | 0.629 | 0.512 | 72 |
| 38 | none | 0.461 | 0.244 | 0.777 | 0.494 | 64 |
| 39 | none | 0.652 | 0.348 | 0.425 | 0.475 | 78 |
| 40 | none | 0.956 | 0.887 | 0.963 | 0.935 | 73 |
| 41 | none | 0.083 | 0.159 | 0.296 | 0.179 | 65 |
| 42 | none | 0.527 | 0.451 | 0.876 | 0.618 | 68 |
| 43 | none | 0.466 | 0.330 | 0.835 | 0.544 | 72 |
| 44 | none | 0.730 | 0.641 | 0.920 | 0.764 | 62 |
| 45 | none | 0.036 | 0.094 | 0.054 | 0.061 | 51 |
| 46 | none | 0.089 | 0.257 | 0.524 | 0.290 | - |
| $\mu$ | - | 0.466 | 0.368 | 0.600 | 0.478 | 71.53 |
| $\sigma$ | - | 0.251 | 0.230 | 0.297 | 0.244 | 7.828 |

## VI. Conclusions

We have studied to clarify the relationship between success factors and learning outcomes of PBL and to construct the Appraisal Method with Fuzziness to quantify student learning outcomes.

For that purpose, we have created the relationship matrix based on structured success factors and learning outcomes of PBL and clarified the relationship between success factors and learning outcomes by multiple regression analysis. In addition, we have devised a method to quantitatively evaluate learning outcomes for each student by Fuzzy numbers and the ratio method. These methods have shown that it is possible to achieve the educational goal of PBL by encouraging student's individual and group effort and utilizing ICT tools in PBL.

We have shown that learning evaluation for each student by Fuzzy numbers and the ratio method can effectively evaluate the educational effects by quantifying experience and strategy of teachers by Fuzzy theory and considering the weight uniquely calculated by the ratio method. Comparing appraisal value of soft skill with the score of PBL class, the correlation coefficient has been 0.541 for a group of students who have no role in a PBL class.

In the future, we would like to analyze the data such as PBL course practiced at other universities to confirm this research. Based on the findings obtained from this research, we plan to construct an ICT system to support PBL course, and to construct a system that automatically manages learning outcomes from project management.

## REFERENCES

[1] Aruga, S., Ozaki, T. and Hirose, H. (2015). Analysis of Success Factors and Learning Outcomes in Project-Based Learning, Research report of JSET conferences, pp.155-160.

[2] Ozaki, T. et al. (2016). Quantitative Analysis Method of Success Factors and Learning Effects in Project-Based Learning, 2016 International Academic Business Conference, 2016 International Education Conference & 2016 International Science Education Conference Proceedings.

[3] Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. Learning and instruction, 13(5), pp.533-568.

[4] Ministry of Economy, Trade and Industry. (2006). Study group on fundamental Competencies for working persons - Interim Report -, Ministry of Economy, Trade and Industry. [Japanese]

[5] Ministry of Economy, Trade and Industry. (2007). Developing and accessing of fundamental competencies for working persons, Practical Project Management Association, Tokyo. [Japanese]

[6] Azer, S. A. (2005). Challenges facing PBL tutors: 12 tips for successful group facilitation. Medical Teacher, 27(8), pp.676–681.

[7] Higher Education Development Center, Mie University. (2007). Problem-Based Learning Workshop Manual, Higher Education Development Center, Mie. [Japanese]

[8] Kawaijuku Educational Institution. (2010). Guidebook for Fundamental Competencies for Working Persons, Asahi Shimbun Publications Inc. [Japanese]

[9] Ryukoku University Centre for Local Collaborations. (2012). Experimental Survey on Local Problem Solution Using University's Cultivation of Human Resources, Ryukoku University Centre for Local Collaborations, Kyoto. [Japanese]

[10] Project Management Institute. (2014). A Guide to the Project Management Body of Knowledge (PMBOK® Guide), 5th edition, Project Management Institute.

[11] Snyder, C., Kamei, K. and Shimizu, K. (2014). A User's Manual to the PMBOK Guide, 5th Edition, Kajima Institute Publishing Co., Ltd., Tokyo. [Japanese]

[12] Van Rooij, S. W. (2009). Scaffolding project-based learning with the project management body of knowledge (PMBOK®). Computers & Education, 52(1), 210-219.

[13] Delbecq, A.L., and Vandecq Ven A.H. (1971). A Group Process Model for Problem Identification and Program Planning, Journal of Applied Behavioral Science VII, pp.466-91.

[14] Nikkei Human Resources, Inc. (2013). Learning and Employment Book. Nikkei Human Resources, Inc. [Japanese]

[15] Zadeh, L.A. (1965), Fuzzy Sets, Information and Control Vol.8, pp.338-358.

[16] Amagasa, M. (2013), Performance Measurement System for Value Improvement of Science, Handbook of Industrial and System Engineering-Second Edition, CRC Press Publisher (London, New York), pp.51-67.

[17] Akaike, H., (1973), Information theory and an extension of the maximum likelihood principle, Proceedings of the 2nd International Symposium on Information Theory, Petrov, B. N., and Caski, F. (eds.), Akadimiai Kiado, Budapest, pp.267-281.