Relation between Combinations of Personal Characteristic Types and Educational Effectiveness for a Controlled Project-based Learning Course

Yusuke Sunaga, Hironori Washizaki, Katsuhiko Kakehi, Yoshiaki Fukazawa, Shoso Yamato, and Masashi Okubo

Abstract— To improve practical IT education, many Japanese universities are implementing project-based learning (PBL). Although a previous study examined the relationship between educational effectiveness and the scatter of personal characteristics, the relationship between educational effectiveness and the combination of personal characteristics in a team, which is important to optimize the team composition for PBL, has yet to be examined. Herein we use the Five Factor & Stress theory to measure personal characteristics and classify students enrolled in a PBL class at Waseda University into four types – leadership, management, tugboat, and anchor. Then knowledge and skills questionnaires are used to measure educational effectiveness. The results show that educational effectiveness is highest when a team consists of management and anchor types without leadership types. The results are preliminary because the practical usefulness of our results is limited as the experiment of the paper targeted only one PBL course of one university. For that reason, we need to collect data from other PBL course at same or other university.

Index Terms— Education, Software Engineering, Personality, Team Setting

1 Introduction

BECAUSE software engineering is a creative process, learning with other students is beneficial [21]. To improve practical IT education, many Japanese universities are implementing project-based learning (PBL) in which students acquire expertise, knowledge, and skills by participating in a group project with a strict deadline. PBL is recognized as an effective study method not only in information systems but also in various engineering domains [1].

In a PBL class, each student becomes a member of a team, and they participate in a group project. Because projects are affected by various factors, many researchers have examined the relationship between projects and personality [11]. For example, it has previously been shown that a moderately diverse team where members have different personalities reduces risks when developing software-intensive business systems [2]. In software engineering, personality impacts performance and attitude [4] [5]. Moreover, teams composed of complementary members exhibit increased productivity in other businesses [3]. Other studies have targeted classes or projects at a university [11], and examined the relationship between project success or the final product and personality. However, our research focuses on the relationship between educational effectiveness and personality. We think this relationship is important for PBL at the university level because we believe that the act of learning is important for students.

In the field of education, a study has examined the relationship between teams composed of different personalities and academic performance in a pair-programming course [6] according to the Five Factor Model (FFM) [7], which is used to measure personality. However, research on the relationship between education effectiveness and personality has yet to be investigated for university projects. Therefore, university teachers do not know the optimum team composition, and the educational effectiveness of teamwork in a group project may not be maximized for university students. Hence, our research focuses on this problem.

Previously we investigated the relationship between team construct and educational effectiveness via a limited preliminary study on select factors in the Five Factor & Stress (FFS) theory as personal characteristics [8] [9]. Our results indicated that the scatter of personal characteristics and educational effectiveness are related. However, we did

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not examine the impact of each student's personal characteristic in a team on educational effectiveness because the previous study focused on the overall factors of educational effectiveness.

Herein we aim to determine the combination of FFS types that yields the highest educational effectiveness for a course based on controlled PBL because this information can be used to determine what behaviors affect educational effectiveness in a PBL class. Below are the research questions this study aims to address:

RQ1) Do students have different personal characteristics according to FFS theory? We investigated whether all FFS types are represented in the course.

RQ2) What FFS characteristics result in a high educational effectiveness at the individual level? We researched whether personal characteristics affect individual educational effectiveness.

RQ3) What combinations of FFS theory characteristics result in a high educational effectiveness at the team level? We researched whether the combination of personal characteristics influences a team's educational effectiveness.

This paper makes the following contributions:

- FFS personal characteristics and educational effectiveness are not significantly related for an individual.
- A certain team composition in accordance with the FFS theory leads to a high educational effectiveness in a practical course.

The results are preliminary because the dataset, the environment of the paper and practical usefulness of our results is limited as the experiment of the paper targeted only one PBL course of one university. For that reason, we need to collect data from other PBL course at same or other university.

The remainder of this paper is organized as follows. Section 2 discusses related works, while Section 3 presents the background. Section 4 describes our experiment. Sections 5 and 6 present and analyze our results, respectively. Finally, Section 7 concludes the paper.

2 Related Works

Previous research has quantified personal characteristics and analyzed the relationship between the scatter of personal characteristics in a team and educational effectiveness [8] [9]. In this study, we research the types of personal characteristics and analyze the relationship between different combinations of personal characteristics and educational effectiveness.

Many different methods have been used to measure personality [6] [11], including the FFM and the Myers-Briggs Type Indicator (MBTI). The FFM quantifies personality, whereas the MBTI classifies personality. Another study analyzed the personality type of each team member with the goal of determining the member most suited for the role of project manager [13]. Due to our objectives, we use the FFS theory to measure personality because FFS theory are suitable for the goal of our study.

Other studies have researched the relationship between personality or product quality or performance [17] [18] [19]. However, it is possible that product quality and performance are related with other factors (e.g., original skills). In our study, we measure the educational effectiveness in a course by having students complete questionnaires before and after the course. This method should remove the influence of the students' original skills, allowing the relationship between personality and educational effectiveness to directly be assessed.

L. F. Capretz and F. Ahmed mapped personality on the main stage of the software life cycle [16] to determine their relationship. On the other hand, the domain of our research is the initial stage of the software life cycle.

Teamwork in self-managing agile teams working on a Scrum project has been investigated [14] using Dickinson and McIntyre's teamwork model. The teams were observed as they worked on actual Scrum projects in a company for an extended period of time. In our research, we use the FFS theory and examine a five-day university course.

Cheng and Beaumont analyzed the effectiveness of communication tools used by students in a PBL environment [15]. Although we did not examine communication tools directly, observations of the classroom and reading the students' learning journals indicate that they use a number of communication tools. Cheng and Beaumont examined a distributed-PBL course, whereas we examined a controlled-PBL course.

3 Background

Because data about each student's educational effectiveness and personality are necessary, we employed a knowledge and skills questionnaire to measure each student and team's educational effectiveness. Additionally, we used the FFS theory to measure each student's personality.

3.1 Educational Effectiveness

Often a university course is assessed by the quality of the products obtained during the course, subsequent questionnaires, and examinations. However, these measurement methods do not take the students' knowledge or skills prior to the course into account. Educational effectiveness is a measure of knowledge or skills acquired in a class and not a measure of student performance. Although a team comprised of highly skilled people may result in a high team performance, it is unclear if the knowledge and skills are learned in the class.

To quantitatively measure the improvement in knowledge and skills by taking the course, we asked the students to complete the same questionnaire before and after the practical course. The questionnaire consisted of 28 questions (19 basic human skills questions and 9 specific skills questions) that refer to the Information-technology Promotion Agency (IPA) common career skill framework [10]. This framework is based on the Skills Framework for the Information Age (SFIA) [22] and is the standard IT framework in Japan. We selected items from the IPA common career skill framework that we expected the students to acquire in this class. The students assessed themselves on a scale of 0 to 5, while the educational effective was expressed on a scale of –140 to 140.

To acquire and provide software-intensive business systems, both basic human skills (Table 1) and specific knowledge and skills for software-intensive business systems development (Table 2) are required. According to the IPA common career skill framework, human skills necessary for teamwork include communication, presentation, and planning skills. This study also uses the following terms:

- Ibef: Individual result of the knowledge and skills questionnaire before the class.
- Iaft: Individual result of the knowledge and skill questionnaire after the class.
- Idif: Difference in the individual results before and after the class, which is expressed as

$$Idif = Iaft - Ibef \qquad (1)$$

- Tmed: Median of Idif's for students on the same team.

TABLE 1
QUESTIONNAIRE TO MEASURE BASIC HUMAN SKILLS

Knowledge and Skills
Q1. Planning
Q2. Giving a presentation
Q3. Presenting
Q4. Communicating
Q5. Practical speaking
Q6. Asking relevant questions
Q7. Sharing information with the team
Q8. Applying problem-solving methods
Q9. Being independent
Q10. Involving others
Q11. Setting goal and actions
Q12. Analyzing the present situation and revealing goals or problems
Q13. Revealing processes for problem-solving
Q14. Being innovative
Q15. Clearly sharing ideas
Q16. Listening to others' ideas
Q17. Understanding different idea or situation
Q18. Understanding the relationship between people or matter
Q19. Illustrating for explanation

TABLE 2
QUESTIONNAIRE TO MEASURE SPECIFIC SKILLS

Knowledge and Skills
Q20. Requirements analysis
Q21. Requirements definition
Q.22 Functional design
Q.23 Discussion of business processes
Q.24 Project planning
Q.25 Project management
Q.26 Development process
Q27. User interface development
Q28. Database development

For example, assume that a team has four members – A, B, C, and D, who have Iaft's of 10, 5, 1, 4, and Ibef's of 5, 4, 4, 2, respectively. Then Idif's are 5, 1, -3, 2, and Tmed is 1.5.

3.2 Five Factor & Stress (FFS) Theory

In studies on the relationship between personal characteristics and performance or educational effectiveness, the FFM is generally used to measure human personality. However, the FFM does not consider personal characteristics or role on a team. Because the effect of students' behavior on educational effectiveness has yet to be elucidated and our research targets a PBL course, which is group work, the FFM is not apposite in our research. Other major models to categorize personal characteristics are the MBTI [11] and Belbin's team role model [12]. The MBTI can categorize 16 types, while Belbin's team role model can categorize 9 types. However, neither model is employed because our research target teams composed of 4 to 6 students, and both models categorize too many types not considered in our research.

We chose the FFS theory to classify the students because it is designed to optimize teams and the FFS personal characteristics indicate the behavior in a team, whereas the personal characteristic of the FFM simply indicate human personality. Therefore, the FFS theory is better suited to this study than the FFM because our goal is to elucidate the effect of student behavior on teamwork.

The FFS theory maps personal characteristics in a two-dimensional graph where the X-axis (Y-axis) ranges from receptive to condensable (preservative to diffusible) (Fig. 1). A receptive person is accepting of new knowledge and skills, while a condensable person imposes his or her own knowledge and skills on others. A diffusible person is assertive, whereas a preservative person is reserved. The numerical values of X and Y range from –20 to 20. The fifth factor is discriminative, which separates internal and external situations. Because this factor is not related to our research, it is excluded.

To determine the impact of behavior on educational effectiveness in a PBL class, students were classified into four types: leadership, tugboat, management, and anchor (Table 3). The characteristics of the four types are the

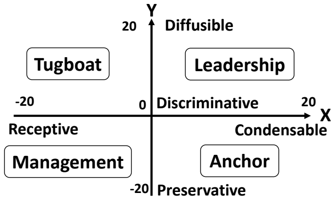

Fig. 1. Two-dimensional graph used in the FFS theory

TABLE 3
QUALIFICATIONS AND CHARACTERISTICS OF THE FOUR FFS TYPES

Type	Qualification	Characteristic
Leadership	X≧0 and Y>0	Aggressive, progressive, and good at changing
Tugboat	X<0 and Y>0	Good at realizing ideas
Management	X<0 and Y≦0	Good at revising and improving the present situation, and maintaining
Anchor	X≧0 and Y≦0	Good at maintaining the present situation

expected action of the team role, but the actual action is unknown until the team is constructed.

4 DESIGN OF THE EXPERIMENT

We analyzed the data from a class at Waseda University called "Fundamentals of Information Systems Development". This course, which teaches management skills for software-intensive business system development projects from the viewpoint of the initial stage of system development (e.g., requirement analysis and architectural design) by working on a realistic project in a classroom setting (controlled PBL), divides the students into teams composed of four to six members.

To collect data for our research, the students completed two different types of questionnaires: knowledge and skills questionnaires and one based on the FFS theory. The former measures educational effectiveness, and each student completed it twice (before and after the course), while the latter is used to categorize the students into the FFS four personality types. To maintain the integrity of our research, obviously insincere data about educational effectiveness were removed [e.g., if the same grade was checked in both (before and after) questionnaires].

Over the course of our five-year study (2011 – 2015), 173 students (25 in 2011, 17 in 2012, 39 in 2013, 64 in 2014, and 28 in 2015) participated. These students were divided into 36 teams (6 in 2011, 4 in 2012, 8 in 2013, 12 in 2014, and 6 in 2015). Of the 173 students, 167 provided valid knowledge and skills questionnaires, resulting in 31 valid teams.

5 ANALYSIS

We collected data for five years (2011–2015). Below is a brief explanation of our data and how the results were analyzed.

5.1 Data for Educational Effectiveness

The educational effectiveness data was analyzed from several perspectives:

・Individual educational effectiveness, which is the sum of basic human skills and specific skills, was assessed as the difference between the before and after knowledge and skills questionnaire results.

・Team educational effectiveness of basic human skills is the median individual educational effectiveness of basic human skills by team.

・Team educational effectiveness of specific skills is the median individual educational effectiveness of specific skills by team.

・Team educational effectiveness is the median individual educational effectiveness by team.

Figure 3 shows the histogram of the individual educational effectiveness by student. Because the students' educational effectiveness was scattered by a normal distribution, we used the Kolmogorov-Smirnov test to verify whether the histogram is a normal distribution. The p value of 0.1824 (> 0.05) confirms that the histogram is a normal distribution.

5.2 Data of Personal Characteristics

The personal characteristics were divided as follows: 18 students (leadership), 68 (management), 22 (tugboat), and 65 (anchor). Over the four years, the students were divided into 36 teams. After removing invalid data where students did not take the knowledge and skills questionnaire seriously, the number of teams was reduced to 31, and the students were divided as follows: 17 (leadership), 66 (management), 20 (tugboat), and 64 (anchors) (Fig. 2).

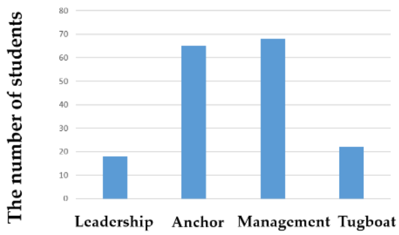

Fig. 2. Histogram of the number of students

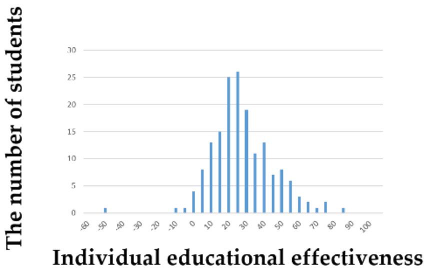

Fig. 3. Histogram of the educational effectiveness

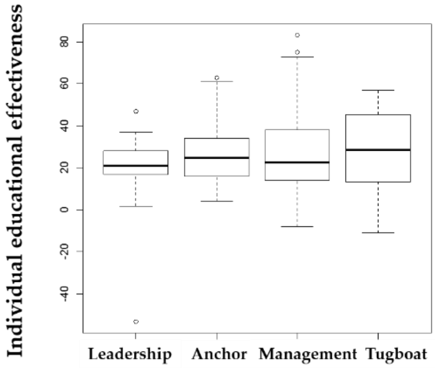

Fig. 4. Boxplot between the FFS type and individual educational effectiveness

5.3 Relationship between Personality and Individual Educational Effectiveness

Figure 4 shows the boxplot between the FFS type and educational effectiveness. For multiple comparisons, we used the one-way analysis of variance [23] because the aim is to determine the relationship between personality and individual educational effectiveness. A p value of 0.438 (> 0.05) makes it difficult to confirm if there is a significant difference in educational effectiveness by FFS type.

5.4 Relationship between Personality and Team Educational Effectiveness

Table 4 shows the nine different team compositions. Figure 5 shows the boxplot of the relationship between the FFS team composition and team educational effectiveness. However, a boxplot cannot be used to determine this relationship due to the small sample size. Thus, we used a regression tree to determine which combination has the best educational effectiveness by R and statistics software. A regression tree divides data into nodes and then determines the best node. Unfortunately we had insufficient data to create a reliable regression tree. Thus, we used the F-test and the t-test to confirm the precision of the regression tree.

Figures 6 – 8 show the regression trees of team educational effectiveness of basic human skills, team educational effectiveness of specific skills, and overall team educational effectiveness, respectively. The score of each node in the tree indicates the average score of the team education effectiveness of each team included in each node. It is possible that the best score is 140 as all of the teams have a node at 140. The highest score (15.241) of the team educational effectiveness of human basic skills occurs when the management node~~s~~ is true. However, when the leadership node is false, but the tugboat node~~s~~ is true, the highest score for the educational effectiveness of specific skills is 13.1. Moreover, the highest score (26.469) for educational effectiveness is achieved when the leadership node is false, but the management and tugboat nodes are true.

These results suggest that the educational effectiveness is higher in teams without a leadership node. For the educational effectiveness of basic human skills, teams containing management types are more effective. However, the role of other types on the educational effectiveness of basic human skills is unclear. The results from the regression tree of team educational effectiveness of specific skills suggest that teams consisting of tugboat types without leadership types provide the best educational effectiveness. The relationship between the management and anchor types and educational effectiveness is unclear.

A regression tree requires a lot of data to provide significant results, but our data is limited. Because there is insufficient data to create a regression tree, we divided the 31 teams into two groups from the results of each layer in Figs. 6 – 8. Table 5 shows which node is the most precise in each regression tree (Figs. 6 – 8) for the t-test. Because the most significant difference in Fig. 6 occurs for teams consisting of management types (29 teams), these teams were one group, and the remaining teams comprised the other group (2 teams). Because the p value from the F-test is 0.435, we conducted a t-test from the results of the F-test, which results in a p value of 0.242 (> 0.1). The p value makes it difficult to confirm if there is a significant difference in the educational effectiveness of basic human skills by team composition.

Similarly, the data was divided into two groups using the results in Fig. 7. One group contained the team with most significant difference (10 teams with tugboat types without leadership types) and the other contained the rest (21 teams). The p value from the F-test is 0.400. Thus, we conducted the t-test from the result of the F-test, and the p value is 0.056 (< 0.1). The p value confirms that there is a significant difference in the educational effectiveness of specific skills by team composition.

The data was also analyzed in the same fashion using the results in Fig. 8. The most significant group contained management and anchor types without leadership types (16 teams), while the rest of the teams were in the other group (15 teams). Because the p value obtained from the F-test is 0.050, we conducted the t-test from the result of the F-test, which gives a p value of 0.117 (> 0.1). The p value makes it difficult to confirm if there is a significant difference in the educational effectiveness by team composition.

6 Discussion

The previous section shows the data and results of our experiment. In addition to examining the RQs proposed in the Introduction, here we explain how to apply our findings.

TABLE 4
TEAMS COMPOSITIONS IN THE CLASS FROM 2011 TO 2015

No.	Leader-ship (L)	Anchor (A)	Manage-ment (M)	Tugboat (T)	Number of teams
1		✓	✓	✓	7
2		✓	✓		9
3			✓	✓	2
4	✓	✓	✓		4
5	✓		✓	✓	1
6	✓		✓		2
7		✓		✓	1
8	✓	✓	✓	✓	4
9		✓			1

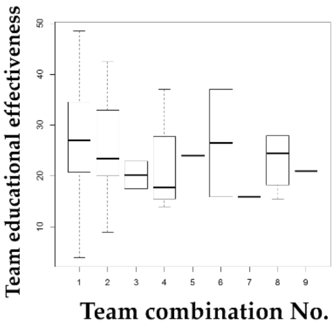

Fig. 5. Boxplot of the team composition and team educational effectiveness

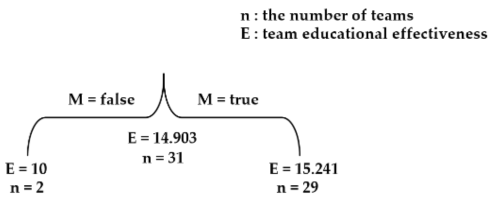

Fig. 6. Regression tree of the team educational effectiveness of basic human skills

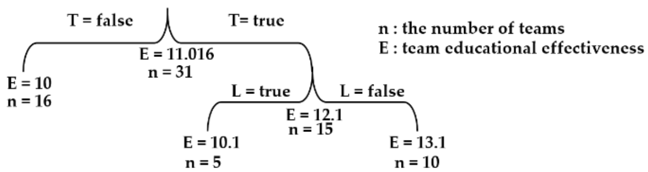

Fig. 7. Regression tree of the team educational effectiveness of specific skills

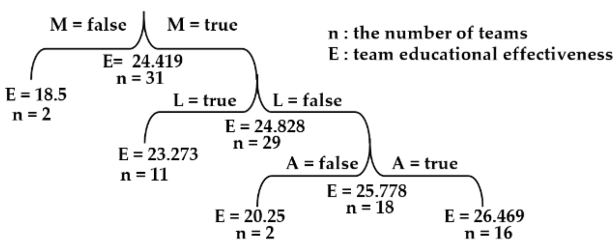

Fig. 8. Regression tree of the team educational effectiveness

TABLE 5
PRECISION OF EACH COMBINATION

		Median		p value	
		Target nodes	Others	F-test	t-test
Team educational effectiveness of basic human skills	with M	14	10	0.435	0.242
Team educational effectiveness of specific skills	with T	11	9	0.219	0.088
	with T and without L	10.75	9	0.400	0.056
Team educational effectiveness	with M	23.5	18.5	0.272	0.195
	with M and without L	23.5	21	0.112	0.188
	with M and A, without L	25.25	21	0.050	0.117

6.1 Do Students Have Different Personal Characteristics According to FFS Theory? (RQ1)

The personal characteristics were divided as follows: 17 (leadership), 66 (management), 20 (tugboat), and 64 (anchors) (Fig. 2). All FFS types enroll in the course (Fig. 2), but the distribution in uneven; more management and anchor types enroll in the course than leadership and tugboat types. We consider that the number of students enrolled in the class is sufficient to include all FFS types. The results may indicate a general trend in Japanese personal characteristics, which may differ in other countries. Moreover, not all teams are optimal due to deviations in the characteristics of the students.

6.2 What FFS Characteristics Result in a High Educational Effectiveness at the Individual Level? (RQ2)

For multiple comparisons, we analyzed the variance. The p value is 0.438 (> 0.05). Figure 4 shows the relationship between FFS type and individual educational effectiveness. Educational effectiveness is not related to the FFS type of the student, indicating that personal characteristics are not related to learning at the individual level. We consider the reason that there is not the relationship between FFS personality and educational effectiveness. This may be because learning in PBL courses involves working in groups. Additionally, the FFS types indicate human behaviors in a team. Consequently, the human behavior in a team is not related to individual educational effectiveness.

6.3 What Combinations of FFS Theory Characteristics Result in a High Educational Effectiveness at the Team Level? (RQ3)

The highest educational effectiveness is achieved when a team is composed of management and anchor types without leadership types (Table 5) (The p value is 0.117).

The highest educational effectiveness of basic human skills is achieved when a team is composed of management types (The p value is 0.242). The highest educational effectiveness of specific is achieved when a team is composed of tugboat types without leadership types (The p value is 0.056). In the Fundamentals of Information Systems Development course, students develop a system solution for a fictitious company where the course instructor sets the problem.

We consider that the content of a class and the characteristic of each FFS type are related. FFS management type students are good at improving the present situation. Tugboat type students can find new approaches, while anchor type students are good at maintaining the present situation by preserving knowledge in a team. These three types are well suited to this course because the students must improve a company from the present situation.

On the other hand, leadership type students are good at changing the present situation. Because the class involves minimal transformations, the strengths of leadership type students are not utilized. Consequently, teams consisting of management types without leadership types are the most effective. If students created the initial ideas, then it is likely that leadership type students would realize a high educational effectiveness.

6.4 Threats to Validity

One threat to internal validity is insincere responses because the knowledge and skills questionnaire and the FFS questionnaire are self-check forms. In addition, we currently cannot confirm the precision of the regression tree (Figs. 6 – 8) due to the small data size. Moreover, this study found and analyzed 9 of the 15 possible combinations for team composition. It is possible that this affected our results. Some combinations appear multiple times. However, ~~even if~~ for the same combination, it is possible that a different composition ratio will affect the results (e.g., 2 Managements and 4 Tugboats, or 4 Managements and 2 Tugboats). However, the impact is unknown. Hence, future studies should include other combinations and a larger dataset. Additionally, it is possible that the students were biased when they answered the after questionnaire on educational effectiveness because it was identical to the before questionnaire.

A threat to external validity is that we cannot guarantee that our results are applicable to other similar practical lectures due to the insufficient data. However, the lectures and courses under examination were developed in collaboration with the IPA as part of a national effort; thus, the results should be similar for equivalent lectures and courses offered at other universities or companies.

6.5 How to Use These Findings

This research assists university teachers by revealing the optimum team composition for a PBL course. The findings indicate that teams for a controlled-PBL course on software intensive system development should be formed by classifying students using the FFS theory and then creating teams with management types without leadership types. However, if a team contains leadership types, the team should also include management types, and either the teacher or a teaching assistant should carefully observe teams with management types. It is possible that other team combinations or additional data may produce different results because only 9 of the 15 possible combinations were observed in this study.

7 Conclusion

We researched the relationship between educational effectiveness of a team in a controlled-PBL class and the personal characteristics of the team members, which were categorized by the FFS theory. Our study targeted students in a controlled-PBL class at Waseda University using knowledge and skills questionnaires. To maximize educational effectiveness, teams should consist of management and anchor types without leadership types. However, if a PBL course teaches basic human skills, teams should be composed of management types, whereas teams should include management types, but if teaching specific skills, teams should contain tugboat types without leadership types.

In the future, we plan to target classes where teams contain many members using different methods such as the MBTI [11] and Belbin's team role model [12] to categorize personal characteristics. We also plan to implement special software to analyze the course [20] as well as verify whether the results are applicable to other classes. Moreover, we need to increase the sample size for a more precise analysis. Finally, because the knowledge and skills questionnaire is a self-check form, the responses may be insincere. For internal validation, we plan to test to students or use the products developed in the course.

Acknowledgment

We would like to thank Shota Inaga, Yusuke Yoshida, and the members of the Washizaki Lab for supporting Fundamentals of Information Systems Development.

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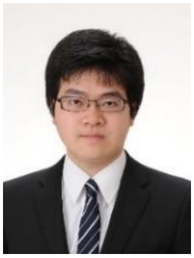

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