The Impacts of Personal Characteristic on Educational Effectiveness in controlled-Project Based Learning on Software Intensive Systems Development

Yusuke Yamada[1], Shota Inaga[1], Hironori Washizaki[1], Katsuhiko Kakehi[1], Yoshiaki Fukazawa[1], Shoso Yamato[2], Masashi Okubo[3], Teruhiko Kume[3], Manabu Tamaki[3]

[1]Waseda University, Tokyo, Japan, [2]University of Tsukuba, Ibaraki, Japan, [3]NEC Learning, Ltd., Tokyo, Japan,

[1] *ms08zerosaki@akane.waseda.jp, ztkyki-is@asagi.waseda.jp, washizaki@waseda.jp, kakehi@waseda.jp, fukazawa@waseda.jp,*

[2] *yamatos@cs.tsukuba.ac.jp,* [3] *m-okubo@bu.jp.nec.com, t-kume@cd.jp.nec.com, m-tamaki@ak.jp.nec.com*

Abstract

In practical courses on software-intensive business systems, students work in teams to acquire practical skills in systems acquisition and provisioning. However, we do not yet have an established method to determine the optimal team composition to achieve maximum educational effectiveness. In this study, we quantitatively and qualitatively investigate how the personal characteristics and the learning process of team members affect educational effectiveness by examining a university course in which students work in teams on a realistic project in a classroom setting. We use the Five Factors and Stress (FFS) theory and the modified grounded theory approach (M-GTA) to measure the personal characteristics and identify the learning process of each team member. Additionally, we compare the learning process which a team to have high educational effectiveness have with the one which a team to have low educational effectiveness have. As a result, we find that it is better for a team to have members with different personal characteristic as defined by FFS theory in order for the students to acquire more knowledge and skills through the course. Additionally, teams that focus on a smaller portion of the learning process acquire more knowledge and skills. We expect our findings to be applicable to increasing the educational effectiveness of other similar practical courses.

1. Introduction

In order 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 project with a strict deadline. PBL is recognized as an effective study method not only in information systems but also in various engineering domains [11]. We analyze a course entitled "Fundamentals of Information Systems Development," which is offered at two Japanese governmental bodies (MEXT and IPA) and two IT companies (NEC and NEC Learning) with Waseda University in cooperation. This course teaches the management of software-intensive business systems development projects from the viewpoint of the provider. Students primarily learn about upper processes, such as requirements analysis and architectural design through working on a realistic project in a classroom setting (controlled-PBL). The course meets three times a day for five days. The number of students that took this course was 26 in 2011, 17 in 2012, and 39 in 2013. Students are divided some teams, and teams of four to five students were formed randomly regardless of personal characteristics. The number of teams formed was 6, 4, and 8 for 2011, 2012, and 2013,

respectively.

It has been previously shown that a moderately diverse team where members have different personalities leads to reduced risk in developing software-intensive business systems [1]. Moreover, in other businesses, teams consisting not of random members but of complementary members were found to exhibit increased productivity [2]. As for same practical courses as this time, we conducted a limited preliminary study on few factors in Five Factors and Stress (FFS) theory as personal characteristics [13], but there have been no studies involving almost all factors in FFS theory, nor any studies on the optimal team composition to achieve maximum educational effectiveness from the viewpoint of these factors.

Our goal is to shed light on the ideal education process for a course based on controlled-PBL. Although educators understand the student expectations of a controlled-PBL course, they tend to rely on tried-and-true methods and not consider the student experience as much, especially because the relationship between the education process and the educational effectiveness is unclear.

In this study, we measure the students' knowledge before and after the course and their personal characteristics independent of experience in actual business, and analyze the relationships between them. We also analyze the relationship between a student's learning process and his or her knowledge before and after the course. We list our research questions below.

RQ1) What are the common characteristics of the teams in which high educational effectiveness was achieved?

RQ2) What is the learning process that the students experience during the course, and how is the process perceived by the students?

RQ3) What is the learning process for teams in which high educational effectiveness was achieved?

The contributions of this paper are as follows.

● We discovered a team composition for practical courses that can lead to high educational effectiveness by using FFS theory. This contribution is derived by collecting data for three years in same course.

● We determined the students' learning process in a practical course by using Modified Grounded Theory Approach (M-GTA).

● We defined the relationship between learning process and educational effectiveness.

The remainder of this paper organized as follow. First, we provide problems of analyzing the course in Section 2. In Section 3, we indicate a framework which solve the problems. We propose result of analysis in Section 4. We discuss related work in section 5. Finally, we conclude our work in Section 6.

2. Problem of analyzing educational effectiveness in practical course

As mentioned above, the most effective team composition in a practical course on software-intensive business systems development in a university setting has not yet been determined clearly. Here we list four problems, P1 through P4, that need to be addressed to clearly define educational effectiveness.

P1) Obscurity of educational effectiveness: In many cases, the educational effectiveness of a university course is measured by the quality of the products obtained during the course, and subsequent questionnaire and examination results. However, this method of measurement does not take into account the students' knowledge or skills prior to taking the course.

P2) Quantitative measurement of the education process: In this study, we cannot make a quantitative measurement of the education process throughout the course because the process can only be measured once each time the course is administered. Therefore, we make a

qualitative measurement of the education process.
P3) Difficulty in quantifying personal characteristics: To elucidate the influence of the compositional characteristics of a team on educational effectiveness, it is desirable to quantitatively measure both the compositional characteristics and educational effectiveness, and to analyze the relationship between them. To determine the compositional characteristics of a team, it is necessary to measure each member's personal characteristics quantitatively. However, to the best of our knowledge, no studies of the various personal characteristics of a university student without any actual business experience have been reported.
P4) Difficulty in determining the learning process: There is no established method to determine the learning process of students participating in a course. It is a challenge to collect meaningful quantitative data that can be translated into the learning process of the students. Therefore, qualitative data should be obtained to determine the students' ideas in the course.

3. Influence analysis framework for team composition

To solve the above-mentioned problems, we design a framework for influence analysis based on solutions S1 through S4 described below. The overall structure of the framework is shown in Figure 1. We asked all the students to keep a learning journal during the course, and had them fill out a questionnaire to evaluate their knowledge and skills before and after the course, as well as a FFS questionnaire. (Details of each of the above are provided later in this paper.) These were then used to evaluate the educational effectiveness of the course on each student, and to determine the students' learning process and their personal characteristics. Our primary focus is the quantitative analysis of the relationship between educational effectiveness and personal characteristics. We complement the quantitative analysis by examining it qualitatively from various angles.

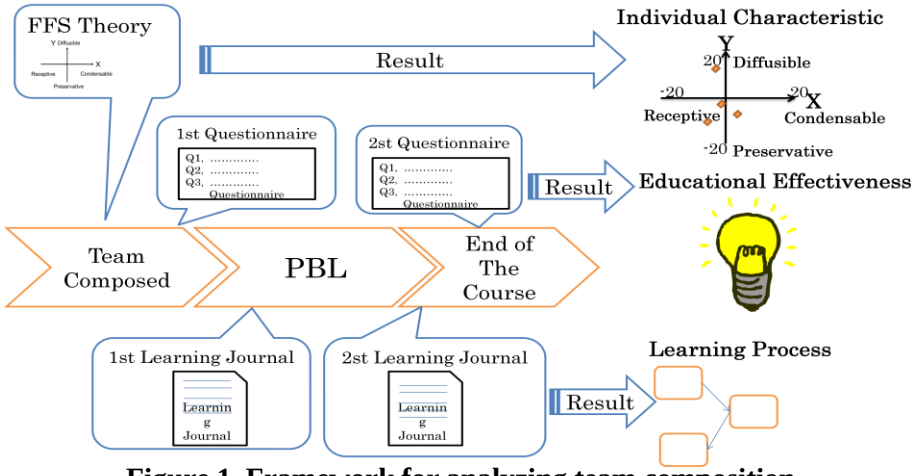

Figure 1. Framework for analyzing team composition

S1) Questionnaire evaluation of knowledge and skills before and after the practical course: We asked the students to fill out the same questionnaire before and after the practical course to quantitatively measure the improvement in their knowledge and skills by taking the course, thus solving problem P1. The questionnaire consists of about 40 questions that refer to the educational goal and common career skill framework of the lecture [4]. We had the students assess themselves at six stages. In the business of acquiring and providing software-intensive business systems, both basic human skills and specific knowledge and skills for software-intensive business systems development are required.
S2) Qualitative analysis using the Modified Grounded Theory Approach (M-GTA): M-GTA is a method of qualitative analysis [8]. By using M-GTA, analysts can discover the process of their research subject, which can then be used for related works. M-GTA consists of four steps. First, the analyst must decide on a research theme and an analysis theme. Second, the

analyst collects data by asking a set of questions to the test subjects related to the analysis theme, for example, in the form of interviews. Third, the analyst extracts common issues from the collected data as concepts described in short phrases, and makes an interpretation of the relationship among the concepts. To remove arbitrariness, the analyst makes some concepts during comparing concepts with many similar concepts and opposite concepts. Finally, the analyst creates categories, which are groups of similar concepts. Through this process of forming concepts and categories, the analyst can gain an understanding of the analysis theme. In this study, we use M-GTA because we want to find characteristics that are common to all of the individual learning processes of the students, and that make use of our research. The KJ method is another popular qualitative analysis method, but we do not use this method because it relies on intuitive thinking processes [10].

S3) Quantification of personal characteristics using the Five Factors and Stress (FFS) theory: The Herrmann model [5] and FFS theory [2] can be used to quantify the personal characteristics of university students with no business experience. We chose FFS theory for this study because the practical course only meets for a limited time, and personal characteristics can be quantified by the students' responses to just 30 questions using FFS theory. For example, students are asked if they say things as they come to mind, and if they get tired easily. FFS theory maps a person's personality onto a two-dimensional graph where the X axis ranges from receptive to condensable and the Y axis ranges from preservative to diffusible (Figure 2). 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. We use standard deviations of X and Y to quantify the compositional characteristics of a team, thus solving P3. Fifth factor of FFS theory is discriminative. A person discriminative separates inside and outside situation. We do not use this factor because we consider this factor do not relate our research. A sample plot of the member characteristics of a team is shown in Figure 2. We see that all points have similar Y values, or that all team members are preservative to a similar degree. We show Five factor, definition, and keyword in FFS theory at Table 1.

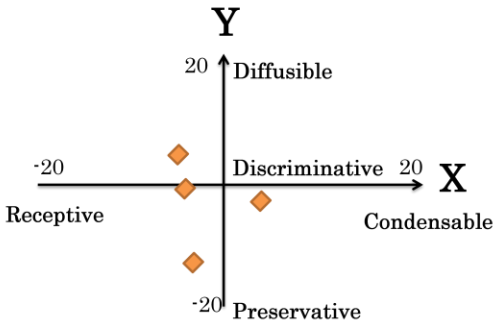

Figure 2. Two-dimensional graph used in FFS theory

S4) Learning journals as data for M-GTA: In general, data for M-GTA are obtained through interviews. However, there were too many students in the practical course to be able to interview them all within a reasonable timeframe, and we did not want to take extra time from the students outside of regular school hours. Moreover, the cost of recording a conversation log of all students and reading through them all would have been extremely high. Therefore, we asked the students to keep a learning journal in which they were specifically asked to write down their learning goals, what they learned, notice and review, and matter and team that you do not know for each session of the course. The students were asked to write the learning journal in their own words. We decided on this method because the time it takes to write a journal entry should be shorter than an interview, and it should not burden the students

much because the list of items that they need to write in the journal is short. In addition, the students will be able to introspect by writing the journal entries.

Table 1. Five factors, definition, and keywords in FFS theory

The factor of FFS	Definition	Keywords
Condensable	To impose his or her own knowledge and skills on others	leading, authority, dominant, moral, ideal, exclusive, responsible, critical
Receptive	To accept of new knowledge and skills	generous, reseptive, protective, sympathetic, affectionate, friendly, affirmative
Discriminative	To separate inside and outside situation	mathematical, rational, logical, realistic, analytical, inference, probable
Diffusible	To be self-assertive	unrestrained, diplomatic, frank, creative, bold, wild, optimistic, ambitious
Preservative	To cooperate with those around people	introverted, cooperative, passive, discreet, sensitive, methodical, obedient

4. Analysis of the influence of team composition

We use FFS theory and the results of a questionnaire given before and after the practical course to evaluate the changes in the students' knowledge and skills to analyze the influence of team composition. We studied the practical course each time it was offered from 2011 to 2013 at Waseda University. Learning journals were used instead of questionnaires for one offering of the course in 2013. The procedure and results are described below.

4.1. Object

We use some metrics and conduct a statistical analysis to investigate the relationship between personal characteristics and educational effectiveness. The notations used for the analysis are listed below.

- σx (σy): A team's standard deviation of the value of personal characteristic X (Y) obtained by FFS theory.
- Kbef: A team's average score of the knowledge and skills questionnaire before the course. .
- Kaft: A team's average score of the knowledge and skills questionnaire after the course.
- Kdif: A team's average score difference of the knowledge and skill questionnaire before and after the course; Kdif=Kaft-Kbef.

4.2. Analytic method

In this study, we ask the students to fill out the same questionnaire regarding their knowledge and skills before and after the practical course, and use the score difference to quantify the educational effectiveness.

We measure each member's personal characteristics by the FFS theory [2]. We can see that for this team, all team members have fairly different condensable or receptive values (X).

To obtain qualitative data for M-GTA, we asked all students taking the course in 2013 to keep a learning journal. We analyze the learning journals to determine the students' learning process. To check the validity of our analysis, we asked two random students about their learning process. If we find some revisions in the learning process, we judge whether the

revisions are valid by consulting the learning journal data. We compare the learning process with the learning journals of some students.

4.3. Analysis results

The following research questions are answered through our analysis results.

RQ1) What are the common characteristics of the teams in which high educational effectiveness was achieved?

We expect the team with the largest scatter in personal characteristics to acquire more knowledge and skills as a team because the team members can complement each other with their different talents. To confirm this expectation, we divide σx and σy into two groups by using their median and compare the two groups. In order to evaluate these two groups, we conduct the two-sample F-test and evaluate whether the variances of the two groups are equal or not. After evaluating the variances of two groups, we conduct the two-sample t-test and evaluate the p-value.

This method leads to significant results when we analyze the relationship between σx and Kdif. We did not have sufficient data to find a definitive relationship between σy and Kdif. We consider that σy do not relate the course.

We show the scatter diagram and how the points are divided into two groups using the median of σx in Figure 3. Group A contains the points with values of σx smaller than the median σx value, and Group B contains the points with larger σx values. Each group contains data for 9 teams. The p-value obtained from the F-test was 0.27, so we conducted the t-test for equal means and the p-value became 0.03 (<0.05). The boxplot of these two groups is shown in Figure 4.

From Figure 4, we can see that the median Kdif value of group B is higher than that of group A, which tells us that it is preferable to form teams with members who are different in how condensable or receptive they are for the students to acquire more knowledge and skills through the course. This matches our expectation. In a team with members of diverse characteristics, each member has different strengths and they can learn from each other as they work together. As a result, they can acquire more knowledge and skills compared to students in more homogenous teams. Indeed, the team represented in Figure 6 with a high σx value has a bigger Kdif value compared to that of the team represented in Figure 5.

RQ2) What is the learning process that the students experience during the course, and how is the process perceived by the students?

We show a diagram of the learning process of the students that we obtained through our qualitative analysis in Figure 7. The steps in the learning process are detailed below.

- Step 1: Prior to the start of the course, the students develop a general learning motive, such as wanting to obtain the knowledge and skills related to becoming a software engineer. The students then set more specific learning goals on what they want to get out of the five-day course based on their preconceived image of the course. Their goal may be to improve their communication skills to better convey their ideas and to better understand the ideas of others, or to acquire the expert knowledge and skills required to accomplish certain tasks.
- Step 2: At the beginning of each session, the instructor introduces the tasks that the students must accomplish during the session. This constitutes the first learning experience of the students for the day, and they adjust their learning goals accordingly. They then obtain an initial understanding of how to accomplish the given tasks, and start working in teams. Teamwork can involve discussions with team members, role sharing, helping each other out, and information sharing.

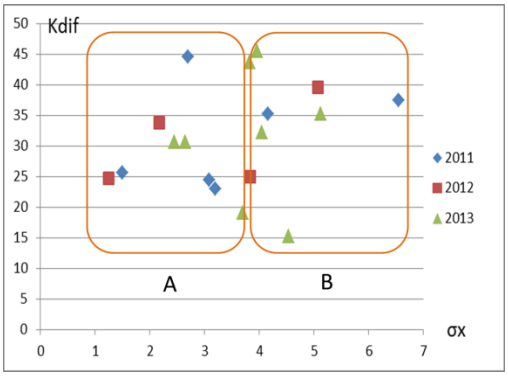

Figure 3. Scatter diagram of σx and Kdif for student teams that participated in the practical course between 2011 and 2013

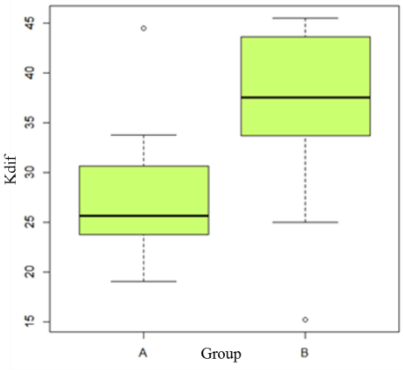

Figure 4. Boxplot of groups A and B

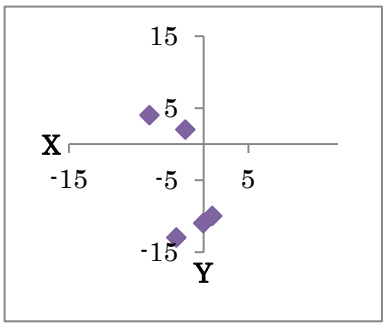

Figure 5. Scatter diagram of a team with low σx and low Kdif

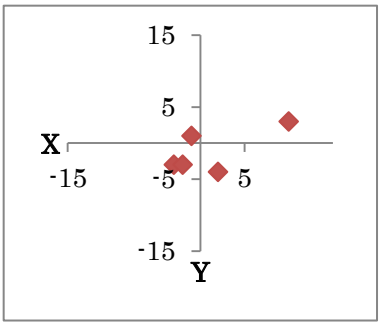

Figure 6. Scatter diagram of a team with high σx and high Kdif

● Step 3: As the students continue to work in teams, they advance their understanding of how to accomplish the given tasks. Specifically, they discover what knowledge or skills they are lacking as individuals and as a team to accomplish the given tasks, obtain an understanding of how to acquire the necessary knowledge or skills, and act on their understanding as they work in teams. This then leads back to the discovery of other weaknesses. This cycle of discovering weaknesses, figuring out ways to overcome the weaknesses, and taking action continues on throughout the course as the students work in teams to accomplish the given tasks. In this way, both individual and team weaknesses are overcome.

● Step 4: The students acquire some skills and specialized knowledge as they try to overcome their weaknesses and accomplish the tasks given to them.

● Step 5: At the end of each session, the students introspect on their team, the tasks that they worked to accomplish, and on themselves to improve their learning experience for the next session.

RQ3) What is the learning process for teams in which high educational effectiveness was achieved?

We pick up two teams. One team has low σx and Kdif (Figure5). Other team has high σx and Kdif (Figure6). Our results show that the teams that wrote about a smaller number of the learning process components as shown in Figure 7 in their learning journals achieved higher Kdif values, which is true to our expectations. Students who are aware of fewer learning

process components focus more intently on these components, allowing them to acquire deeper knowledge or achieve higher proficiency in skills related to those components compared to students who are aware of many learning process components. Despite the fact that not all of the learning process components were mentioned in all of the learning journals, we believe that all the teams went through each of the learning process components because otherwise they would not have been able to accomplish their given tasks. We shown the items by writing dotted underline that the team in Figure 5 only has, the items by writing underline that the team in Figure 6 only has, and the items by writing double underline that two teams have.

We conclude from our studies that in order to achieve high educational effectiveness, teams should consist of students with varying values of x as defined by FFS theory, and students should be taught to work on their given tasks one by one.

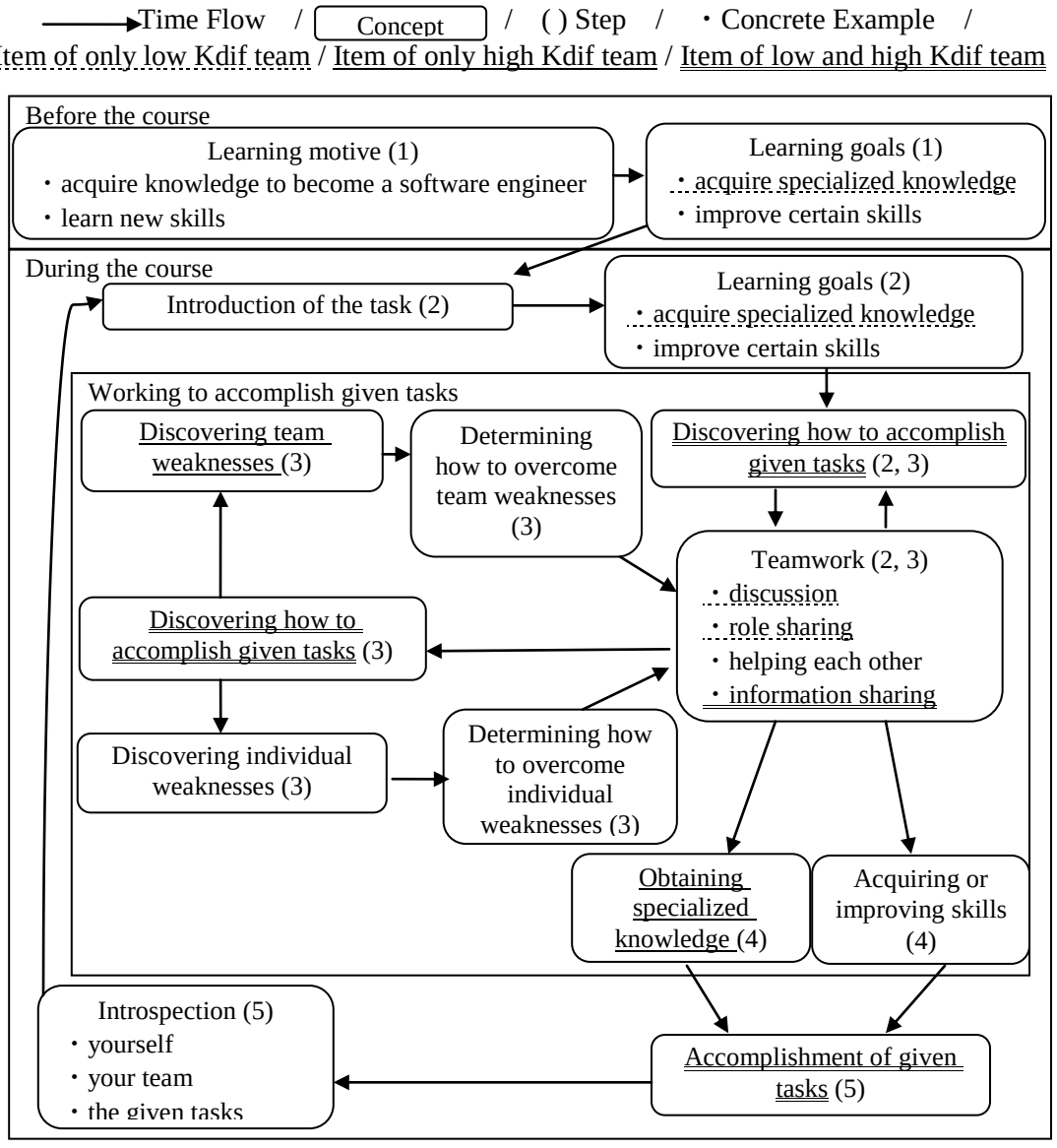

Figure 7. Diagram of the student learning process during the course

4.4. Summary of findings

We find that if we form a team with members who are different in how condensable or receptive they are, the team acquires more basic knowledge and skills through the course compared to a team with members who are condensable or receptive to a similar degree. This is because team members with different personal characteristics can contribute different strengths, and they can discover new perspectives from each other through these they work together on exercises.

We also determine the learning process of how the students acquire knowledge and skills through this course (Figure 7). We compare the learning process with the students' learning journal entries, and find that higher educational effectiveness is achieved when students focus on topics one by one as a team rather than discussing many things at once. Because all the teams are allotted the same amount of time for the exercises, the students can learn skills and concepts more deeply by being aware of only a small number of components of the learning process than by being aware of many.

4.5. Threats to validity

The knowledge and skills questionnaire evaluations are based on self-evaluation. Therefore, the response may not accurately reflect the students' actual knowledge and skills. The learning journal may also not be an accurate representation of the students' thoughts. These are possible threats to internal validity. A threat to external validity is that we cannot guarantee that our results can be applied to other similar practical lectures because there we do not have enough data. However, the lectures and courses under examination were developed in collaboration with IPA as part of a national effort, so the results will most likely be similar for the equivalent lectures and courses offered in other universities or companies.

5. Related work

The effects that human personality attributes may have on the effectiveness of pair programming has been investigated previously [7], but the focus of our paper is team-based activity in a classroom setting. Moreover, the previous study uses the Five-Factor Model [15] to investigate personal characteristics, whereas we use FFS theory.

A study has been conducted to analyze the personality type of each team member with the goal of determining the member most suited for the role as project manager [6]. Our study is not intended for use in electing an individual for a managerial role, and only examines the directive variation of an individual as a team member. Additionally, while the previous study characterizes individuals by determining how similar they are to the ideal project manager, we use FFS theory to measure personal characteristics.

Another study investigated teamwork in self-managing agile teams working on a Scrum project [9]. While the authors of this study use Dickinson and McIntyre's teamwork model and follow teams as they work on an actual Scrum project in a company for an extended period of time, we use 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 [12]. We did not examine communication tools, but we noticed through observations of the classroom and reading learning journals that students use a number of communication tools. Cheng and Beaumont examined a distributed PBL course, but we examined a controlled PBL course.

Rocha and Stroulia studied teamwork in a software-engineering course using grounded theory, based on email exchanges, questionnaires, and interviews [14]. In contrast, we used M-GTA based on learning journals written by every student to analyze the learning process.

6. Conclusion

We investigated the relationship between personal characteristics of team members and educational effectiveness, and determined the learning process of the students as they participated in the course. We also investigated the relationship between how a team approaches multiple tasks and educational effectiveness. Our analysis of the results clearly shows that variations in the team members' personal characteristics affect educational effectiveness. Moreover, high educational effectiveness is achieved when tasks are approached one by one and careful consideration is given to each task. For future work, we will also take measures to eliminate the threats mentioned in Section 4, focus more on individual performance rather than team performance, and use different quantification methods such as the Herrmann model [5] to quantify personal characteristics. In addition, we will elucidate the issues of controlled PBL by analyzing the teaching methods used with the goal of proposing new methods to improve the educational effectiveness of courses involving controlled PBL.

References

[1] G. Klein, J.J. Jiang, and D.B. Tesch, "Wanted: Project Teams with a Blend of IS Professional Orientations", Communications of the ACM, 2002, Vol. 45, No. 6, pp. 81-87.

[2] T. Furuno, "Measuring Corporate Intellectual Assets: FFS Theory Organizational Audits", OECD Conference on Intellectual Assets Based Management, 2006.

[3] Y. Matsuzawa, J. Oshima, "Learners' Use of SNA–Based Discourse Analysis as a Self–Assessment Tool for Collaboration, International Journal of Organisational Design and Engineering, 2012, Vol. 2, No. 4, pp. 362-379.

[4] Ministry of Economy, Trade and Industry & Information-Technology Promotion Agency, Japan (IPA), "Common career/ skill framework", 2012, http://www.ipa.go.jp/english/humandev/reference.html.

[5] N. Herrmann N, The Whole Brain Business Book, McGraw-Hill, New York, 1996.

[6] K. Shirakawa, S. Yamamoto, and R. Chiba, "Optimal Team Formation for Software Development Exercise", Proceedings of the 9th WSEAS international conference on Applications of computer engineering, 2010.

[7] N. Salleh, E. Mendes, and J. Grundy. 2009. An Empirical Study of Effects of Personality in Pair Programming using the Five-Factor Model. Empirical Software Engineering and Measurement, ESEM 2009. pp. 214-225.

[8] Y. Nagayama, M. Hasegawa, "Nursing care process for releasing psychiatric inpatients from long-term seclusion in Japan: Modified grounded theory approach", Nursing and Health Sciences, Blackwell Publishing Asia Pty Ltd, Yamaguchi, 2012.

[9] N. B. Moe, T. Dingsoyr, and T. Dyba, "A teamwork model for understanding an agile team: A case study of a Scrum project", Information and Software Technology, ELSEVIER,Trondheim, 2010, pp. 480-491.

[10] K. Shimura, "Compare and Contrast of Grounded Theory and KJ Method", Hirosaki University Social Welfare Research Bulletin, Hirosaki University Social Welfare, Hirosaki, 2005, pp. 46-57.

[11] R. Graham, UK Approaches to Engineering Project-Based Learning, Bernard M. Gordon-MIT Engineering Leadership Program, Building Engineering Leaders, Cambridge, 2010, pp. 1-48.

[12] C. S. Cheng, C. Beaumont, "Evaluating The Effectiveness Of ICT To Support Globally Distributed PBL Teams", ITiCSE '04 Proceedings of the 9th annual SIGCSE conference on Innovation and technology in computer science education, ACM, New York, 2004, pp. 47-51.

[13] S. Inaga, H. Washizaki, et al, "Team Characteristics for Maximizing the Educational Effectiveness of Practical Lectures on Software Intensive Systems Development", 26th IEEE-CS Conference on Software Engineering Education and Training. CSEE&T 2013, 2013.

[14] F. Rocha, E. Stroulia, "Understanding Individual Contribution and Collaboration in Student Software Teams", 26th IEEE-CS Conference on Software Engineering Education and Training. CSEE&T 2013, 2013.

[15] R.R. McCrae, R. R. and O. P. John, "An Introduction to the Five-Factor model and its application", J. of Personality vol. 60(2), 1992, pp. 175-215.