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Learning Effectiveness of Team Discussions in Various Software Engineering Education Courses

Masashi Shuto, Hironori Washizaki, Katsuhiko Kakehi, Yoshiaki Fukazawa
Waseda University
Tokyo, Japan
masashisk@asagi.waseda.jp, {washizaki, kakehi, fukazawa}@waseda.jp

Shoso Yamato
Ehime University
Ehime, Japan
yamatos@cs.ehime-u.ac.jp

Masashi Okubo
NEC Management Partner
Tokyo, Japan
m-okubo@bu.jp.nec.com

***Abstract*—Students working in teams to complete software tasks is an effective method to learn necessary skills. Previously we examined the educational effectiveness as a function of personal characteristics, but the findings were inconclusive. Because we hypothesize that team discussions impact learning and are related to educational effectiveness, this study investigates the influence of team discussions on learning effectiveness in various types of software engineering education courses. Students' responses to questionnaires about how much students contribute to discussions indicate that learning effectiveness and the number of remarks during a discussion are related. Additionally, upon comparing two learning courses (a system development course and a IT management course), two antithetical results are elucidated. We expect that this research will help improve the effectiveness of educators leading student team discussions.**

***Keywords*— project-based learning; software engineering education; communication; coordination;**

I. Introduction

Many universities employ project-based learning (PBL) so that students acquire and practice technical skills. PBL differs from traditional classroom lectures because students in a PBL course work in teams to solve problems in actual projects. Many studies have denoted its utility [1] [11]. Recently, Sunaga et al. studied the impact of personal characteristics, which were determined by the Five Factor and Stress (FFS) theory, on educational effectiveness in controlled PBL on software intensive systems development [2]. The composition of the team members' personal characteristics clearly affects educational effectiveness. Our research indicates that learning effectiveness improves as the diversity of the personal characteristics with regard to leadership on a team increases. However, why variations in personal characteristics influence educational effectiveness remain unclear.

Both the software industry and academia have recognized the importance of teamwork as a driver of success in software projects [14]. Hoeg and Gemuenden reported that the variables directly affecting teamwork in software development include: communication, coordination, balance of member contributions, mutual support, effort, and team cohesion [9]. To improve the effectiveness of educators, this paper focuses on team (group) discussions in PBL courses because they should encompass these variables and elucidate their relations.

In this study, we measured the number of remarks during group discussions. Remarks spanned from sharing or acquiring the knowledge and skills of software engineering or team management, or correcting the wrong knowledge and skill (e.g., "If you need any help, I can teach you the knowledge of IT strategy.", "I don't have enough skill about requirements definition. Do you have it?", and "It is mistaken. From the viewpoint of…"). This study focuses on the following research questions (RQs):

RQ1) Is the number of remarks related to learning effectiveness?

RQ2) Does the PBL course format affect the relationship between the number of remarks and learning effectiveness?

To investigate the above questions, we analyzed two actual university academic courses entitled "Systems Development Project" and "IT Management Project." In these courses, students worked in teams on a real project in a classroom setting (controlled PBL). These courses have been analyzed for several years to survey the impacts of personal characteristics on learning effectiveness. Herein we discuss the results from a questionnaire administered after each day of a five-day course.

This paper makes the following contributions:

- Learning effectiveness is not significantly correlated with the number of individual remarks in controlled PBL lecture courses, indicating that future research should focus on the remarks of the team as a whole.
- The ideal style of discussion for a control PBL lecture course depends on the format of the course. When the main format is a lecture followed by team discussions, active discussions enhance students' learning effectiveness. On the other hand, active discussions decrease learning effectiveness in other formats.
- Sub-dividing students' remarks do not provide valuable information using questionnaires.

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The remainder of this paper organized as follows. First, Section 2 explains the relevant expertise about learning effectiveness and team discussions. Section 3 describes our research method. Sections 4 and 5 report and evaluate the results, respectively. Section 6 discusses related works. Finally, Section 7 concludes this paper.

II. BACKGROUND

We asked the students to answer two types of questionnaires: one about learning effectiveness and the other about the number of remarks.

A. Learning effectiveness

Learning effectiveness is the improvement in knowledge and skills as defined by the Information-technology Promotion Agency (IPA) common career skill framework based on the Skills Framework for the Information Age (SFIA) and is the standard IT framework in Japan [4] [5]. To measure this quantitatively, we asked the students to answer the same questionnaire before and after the courses on a six-point scale. This questionnaire contained 28 questions in the Systems Development Project and 40 questions in the IT Management Project. Table I shows that the topic for each question in the Systems Development Project. We defined the learning effectiveness as the improvement in the questionnaire results according to the difference in the before and after questionnaires. The mean of the team members' learning effectiveness is used as the learning effectiveness of the team.

B. Number of Remarks

In this research, we used questionnaires to determine the number of remarks. In the future, we plan to develop an appropriate method to observe and quantify the team discussions without questionnaires. (It should be noted that data-mining is too time consuming to be practical. For example, this work required transcribing about 40 hours of video.)

The questionnaires were administered at the end of each day. To reduce the burden on students, each question was assessed on a four-point scale. Students answered three questions:

1. How satisfied are you with the number of remarks in your team?

2. How many remarks about software engineering or team management knowledge and skills did you make today?

3. How many remarks about software engineering or team management knowledge and skills did each of your team members make today?

We summed each student's daily response in the self-evaluation, and used that number to define that the mean per student for (2). For (3), we used the median of other-members' daily evaluations to determine the number of remarks. In the actual questionnaire, remarks are divided into three types as described in Section 6.

III. METHOD

To gather data, we analyzed two actual academic courses entitled, "Systems Development Project" and "IT Management Project." These are offered at two Japanese governmental bodies (MEXT and IPA) and two IT companies (NEC and NEC Learning) in cooperation with Waseda University. The former course teaches management of software-intensive business systems development projects from the viewpoint of the provider. Students primarily learn about upper processes (e.g., requirements analysis and architectural design) by working on a real project in a classroom setting. The latter course teaches the knowledge and skills of IT management

TABLE I. QUESTIONNAIRE TO MEASURE KNOWLEDGE AND SKILLS IN THE SYSTEMS DEVELOPMENT PROJECT

No	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

No	Knowledge and skills
Q15	Clearly sharing ideas
Q16	Listening to others' ideas
Q17	Understanding different ideas or situations
Q18	Understanding the relationship between people or matter
Q19	Illustrating as an explanation
Q20	Requirements analysis
Q21	Requirements definition
Q22	Functional design
Q23	Discussion of business processes
Q24	Project planning
Q25	Project management
Q26	Development process
Q27	User interface development
Q28	Database development

from the viewpoint of the IT section personnel. Students primarily learn about knowledge and techniques to develop management strategy, IT strategy, etc. from an experienced guest lecturer. These academic courses were targeted to junior or senior of undergraduate students, announced by the syllabus, and held on the campus of Nisi-Waseda. Both courses met for five days. Each day involved three 90-minute sessions. The Systems Development Project, which was given from 9/14 – 9/18, 2015, had 28 students divided into 6 teams. The IT Management Project, which occurred from 9/7 –9/11, 2015, had 23 students divided into 5 teams. Each team had four or five students.

Figure 1 overviews our method. Based on the students' responses, 26 students (5 teams) provided valid responses for "Systems Development Project" and 22 students (4 teams) provided valid responses for "IT Management Project".

IV. Results

A. Individual Evaluation

Table II shows the correlation between learning effectiveness and individual evaluation for both courses. Neither course has a strong correlation.

B. Team Evaluation

Table III shows the correlation between the team evaluation and learning effectiveness for both courses. The learning effectiveness is strongly correlated to the number of remarks in team communication and the dispersion of the other-evaluation of remarks. (The p values are 0.010 and 0.047, respectively). In contrast, the mean of the other-evaluation has the highest correlation with learning effectiveness (p value is 0.097) in the IT Management Project. Although the IT Management Project does not have a very strong correlation, learning effectiveness is negatively correlated with the number of remarks.

V. Discussion

A. Relation of Learning Effectiveness and the Number of Remarks (RQ1)

As expected, the learning effectiveness is strongly correlated with the remarks of a team in the Systems Development Project, indicating that student teams learn more effectively through lively discussions. Additionally, the learning effectiveness is correlated with the dispersion of the other-evaluation of remarks, indicating that all students benefit from a lively discussion even if their contribution is small.

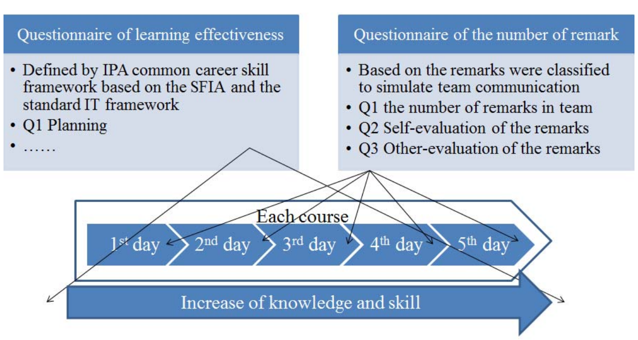

Fig. 1. Schematic of our research method

Figure 2 shows the individual learning effectiveness for the students belonging to the high/low dispersion of the other-evaluation, where circles, triangles, crosses, x marks, and squares denote students belonging to the team with the highest, second, third, fourth, and lowest learning effectiveness, respectively. Teams with a higher learning effectiveness have more dispersed other-evaluations. This may be because a skillful and active student improves the learning effectiveness of the team. If there are skillful and active students in the team, they have high other-evaluation and other students have low other-evaluation. If not, all team members have similar other-evaluations. On the other hand, the learning effectiveness may be negatively correlated with remarks in the in the IT Management Project, suggesting that an appropriate amount of time must be allotted to team discussions in order to achieve a high learning effectiveness. Figure 3 shows a boxplot of team learning effectiveness. Team A has a slightly higher learning effectiveness. In the future, we plan to refine the team type to optimize learning effectiveness via discussions by course format.

B. Difference in Educational Effectiveness by Course Format (RQ2)

The two courses yielded two opposing conclusions, which may be due to the differences in the lecture style. In the IT Management Project, the students had three 1.5-hour sessions per day, which were organized as follows: Session 1 was a lecture. Session 2 was a team discussion on a project, and

TABLE II. Correlation between individual evaluation and learning effectiveness

Course	Data	Cor. value	p value
Systems Development Project	Self-evaluation of remarks	-0.005	0.979
	Other-evaluation of remarks	-0.161	0.430
IT Management Project	Self-evaluation of remarks	-0.131	0.560
	Other-evaluation of remarks	-0.083	0.710

TABLE III. Correlation between team evaluation and learning effectiveness

Course	Data	Cor. value	p value
Systems Development Project	The number of remark in team communication	0.958	0.010
	Mean of self-evaluation of remark	0.395	0.509
	Mean of other-evaluation of remark	-0.257	0.675
	Dispersion of self-evaluation of remark	-0.160	0.796
	Dispersion of other-evaluation of remark	0.882	0.047
IT Management Project	The number of remark in team communication	-0.667	0.333
	Mean of self-evaluation of remark	-0.809	0.190
	Mean of other-evaluation of remark	-0.486	0.513
	Dispersion of self-evaluation of remark	-0.902	0.097
	Dispersion of other-evaluation of remark	-0.113	0.886

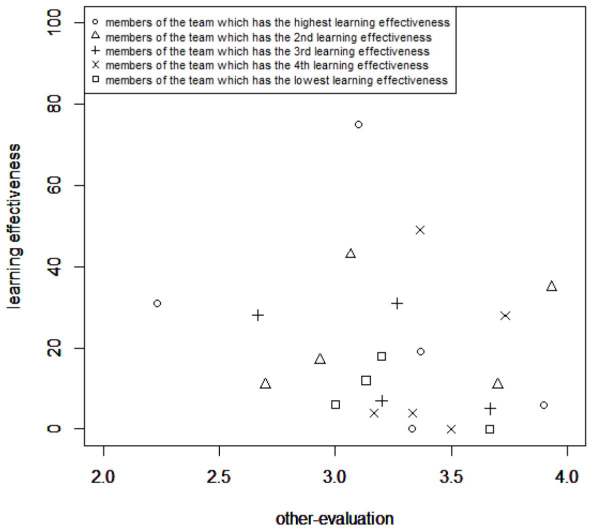

Fig. 2. Learning effectiveness and other-evaluations of the individual students by team in the Systems Development Project

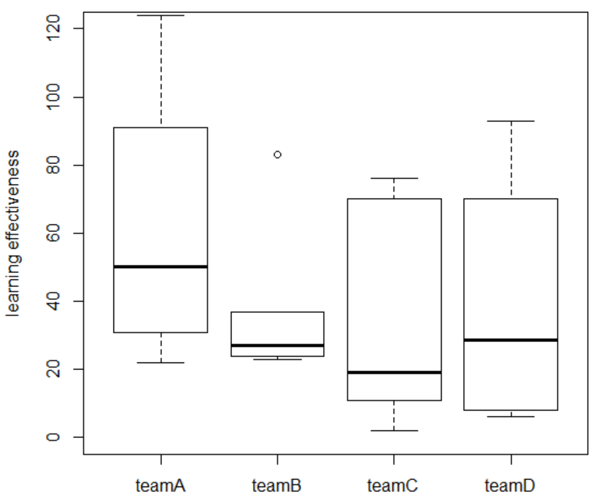

Fig. 3. Boxplot of team learning effectiveness in the IT Management Project

Session 3 teams presented their findings to the class. Team discussions were held in only Session 2, and the schedule was very firm. On the other hand, the Systems Development Project involved a simulated project and a presentation from a guest lecturer, extending the team discussion time. These results suggest that if adequate time is devoted to team discussions, discussions can positively impact learning effectiveness (System Development Project). Otherwise, discussions cannot positively impact learning effectiveness (IT Management Proect). Hence, the format of the discussion time of a class influences the relationship between the number of remarks and the educational effectiveness.

C. Threats to Validity

This research data were acquired using questionnaires, which were subjectively answered by students. Thus, spurious estimations and insincere responses are the threats to the internal validity. To resolve this, more quantitative methods that do no burden educators and students are necessary. Another threat to the internal validity is sample dataset. Because the dataset is small, it currently impossible to verify whether the results are time specific or universal. In the future, additional data should be acquired and analyzed.

One threat to the external validity is that we do not have sufficient evidence to apply these results to other FFS similar practical lectures. However, the courses used in this research have been developed as the part of a nationwide effort in collaboration with the IPA. Therefore, we deduce that similar courses should yield comparable findings. Another threat to the external validity is the scarcity of data. We gathered data from 28 students in the System Development Project and 23 students in the IT Management Project. These data volumes are insufficient to make universal conclusions. Thus, we need to acquire more data to confirm the universality of our results.

VI. Related Work

A. Five Factor and Stress Theory (FFS)

Because software projects are affected by various factors, many researchers have examined the relationship between a project and personality [15] [16]. We have previously studied the influence of personal characteristics on educational effectiveness in a control PBL lecture course called "Systems Development Project", where personal characteristics were quantitatively expressed by FFS theory [2] [6] [7]. FFS theory maps a person's personality onto a two-dimensional graph where the X-axis ranges from receptive to condensable, while the Y-axis ranges from preservative to diffusible. 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. Teams with a larger dispersion on the X-axis have higher learning effectiveness [2]. This finding may be applicable to the findings here; that is, a receptive (condensable) person delivers many (few) ideas in a discussion.

B. Types of Remarks

There are two communication types: phenotype and genotype [8]. Phenotypes are viewable elements (e.g., uttered words or performance verb), whereas genotypes are non-viewable elements (e.g., theoretic reasons or physiological mechanisms for specific phenotype elements). Genotypes can be subdivided into three types. The first type is own cognition or inferences of other's cognition and psychological state. The second type is helping other's cognition or inference. The last one is correcting other's cognition or inference. In our research, we asked the students to answer question (2) in the questionnaire for each genotype. Students' responses were similar for each genotype. Very few students answered with a specific number of remarks for only one particular genotype. Therefore, if a student delivers many ideas for his cognition or inferences of other's cognition and psychological state, he or she tends to deliver many ideas to help other's cognition or inference and correction other's cognition or inference.

C. Variables Affecting Teamwork

Some software engineering researchers have emphasized the importance of teamwork in the software industry [12], [13].

Hoeg and Gemuenden stated that communication, coordination, balance of member contributions, mutual support, effort, and team cohesion are variables that directly affect teamwork [9]. In our research, we focused on the number of remarks designed to include these variables. In the future, we plan to determine a method to gather data for each variable.

D. *ThinkeLet*

ThinkLet is the smallest unit of intellectual capital required to create a repeatable predictable pattern of thinking among people working toward a goal, and might serve a useful pattern language for reasoning toward a goal [10]. ThinkLet can address the challenge of transferring teamwork skills to future software engineers in a reasonable way [3]. Although previous research has confirmed the utility of ThinkLet, ThinkLet helps address problems with the current state of a team. Our research focuses on establishing teams with a high learning effectiveness.

VII. CONCLUSION

We examined the relation between team discussions and learning effectiveness in two software engineering education courses. The questionnaires indicate that the number of remarks and educational effectiveness are correlated when sufficient time is allotted for team discussions. In the Systems Development Project, which mainly employs team discussions, students have a higher educational effectiveness when the discussion is lively. In contrast, the IT Management Project, which does not emphasize team discussions, the discussions are not correlated to learning effectiveness. Therefore, when the lecture course allots adequate time for team discussions, discussions can positively impact learning effectiveness.

In the future, we plan to acquire more data to confirm the universality of our results. In addition, we plan to devise a method to quantify the discussions and learning effectiveness in an effort to eliminate subjective evaluations. Quantification methods include data-mining and actually employing the products developed in the course.

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