A Study on Interactive Educational and Learning Communication in Consideration of Simultaneity and Heterogeneity for Improving the Quality of Education

Shumpei Kurosumi and Michiko Tsubaki

***Abstract*—Recently, researchers have studied the education on the basis of the concept of the service science and analysed its educational effectiveness in consideration of the simultaneity and heterogeneity that characterise the services. However, it is very difficult for the teacher to design the constitution of the classes when taking into account the heterogeneity of students' learning because the education given by the teacher and the learning of the students occur simultaneously. The previous study showed that improving the satisfaction and the learning outcomes of students at the same time is quite challenging. To increase the degree of student satisfaction, it is important that the teacher and students create and develop mutual understanding through effective communication. On the other hand, for the students' learning effects to improve, they themselves have to develop their learning styles. Once both goals are achieved, the improvement in education and learning is to be expected. In this study, we analysed in detail the educational effectiveness of improving the lessons and the learning behaviours of students based on educational and learning communication after the midterm educational survey. We divided the students into six groups, according to their learning outcomes. Through the analysis, we could grasp the relationship between the learning styles of the students, educational improvements, and learning outcomes. Furthermore, we could determine which factors are effective for students in all groups and which are effective with the trade-off resulting from the communication between one teacher and many students.**

***Index Terms*—Analysis according to learning outcomes, educational improvement, effectiveness for students in all groups and with the trade-off, heterogeneity, interactive educational and learning communication, simultaneity.**

I. Introduction

Recently, researchers have studied education on the basis of the concept of service science as studied by [1]-[4] and analysed its educational effectiveness in consideration of the simultaneity and heterogeneity that characterise the services ([5]). The evaluation of educational quality has reached a turning point. As indicated by reference [6], great importance has been placed on the validity and reliability of qualitative evaluations in traditional education assessments. However, universities have entered the age of "fourth- generation evaluation" or "responsive constructivist evaluation," wherein students are also required to do evaluations. Given this background, many studies have been performed on the enhancement of student satisfaction with educational quality.

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A dominant concept of "fourth-generation evaluation" is to produce joint interpretations by students and teachers, enhance such joint interpretations through lectures and enable more refined lectures [7]. However, it is very difficult for the teacher to design the constitution of the classes when taking into account the heterogeneity of students' learning because the education given by the teacher and the learning of students occur simultaneously. In the field of pedagogy, [8]-[10] observed that the effects of teaching methods, contents, and materials differ according to students' abilities and aptitude. Reference [2] proposed the model, suggesting that it is not the class form designed by the teacher or attitude of the students but their learning style that brings about a large improvement in learning outcomes. See Fig. 1. Reference [3] showed that improving the satisfaction and the learning outcomes of students at the same time is quite challenging. To increase the degree of student satisfaction, it is important that the teacher and students create and develop mutual understanding through effective communication ([11]). On the other hand, for the students' learning effects to improve, they themselves have to develop their learning styles. Once both goals are achieved, the improvement in education and learning is to be expected.

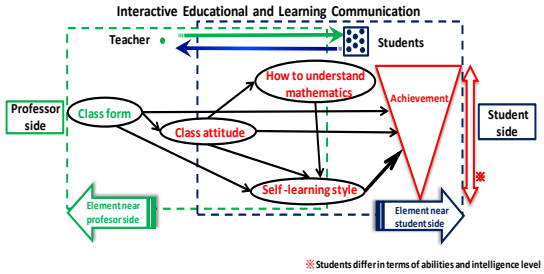

Fig. 1. Lecture model with a simultaneous and heterogeneous structure.

Reference [12] proposed a method for analysing the effectiveness of education according to student type. Reference [12] classified students by their personal characteristics and analysed differences in educational and learning effects by type.

In this study, we analyse in detail the educational effectiveness of improving the lessons and the learning behaviours of students based on educational and learning communication after the midterm educational survey. We divided the students into six groups, according to their learning outcomes. Through the analysis, we can grasp the relationship between the learning styles of the students, educational improvements, and learning outcomes. Furthermore, we can determine which factors are effective for students in all groups and which are effective with the

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trade-off resulting from the communication between one teacher and many students.

II. Subjects and Investigative Method of the Study

In this study, the subjects of the midterm educational survey for the first half the course (communication from the teacher to students) were 93 second-year students attending the lecture course 'Probability and Statistics' in the Department of Intelligence Mechanical Engineering, Faculty of Informatics and Engineering, at the University of Electro-Communications in 2011. The number of usable responses was 78. The survey was conducted to elicit free descriptive answers. The descriptive survey question items, which were created with [13]'s detailed review of qualitative research surveys, are shown in Table I.

TABLE I: Descriptive Question Items of the Midterm Survey

Question No.	Question Contents
1	What is your ideal lesson type? Please answer according to your experiences of good and bad lessons up to the present. You can use your experiences at both junior high and high school.
2	Please write about the positioning of this lesson in relation to the many subjects in your department.
3	What kind of lesson content did you think that you would study in this course, after you read the syllabus and attended the first lecture, including the guidance? Furthermore, how did you think that you could use and apply this knowledge in the future?
4	What do you think your teacher wants you to learn during this course?
5	What do you need to obtain in order to be satisfied by the course?
6	Please describe your learning style. What kind of learning activities do you usually carry out? What kind of learning activities do you carry out before examinations?
7	What do you think both the students and the teacher should do in order to improve learning and teaching satisfaction?

Then, the teacher examined the improvements of the lessons based on answers of Question 5 and 7 (communication from students to the teacher) in Table I, and improved the quality of education based on the educational and learning communications from the teacher to students in the latter half of the course. Table II and Table III shows the specific items improved.

TABLE II: Items of Improvement to the Teaching Method

Improved items	The number of the requests
1. The teacher explained the educational intention.	10
2. Since there is no opportunity to practise analysing real data after the class, the teacher used exercises in which the students encounter and analyse real data.	7
3. The teacher employed group tasks, in order to help students develop a deeper understanding of the lesson contents by working together.	7
4. The teacher distributed printed handouts that described the theories in detail.	24
5. The teacher wrote printed handouts that contained not brief but detailed answers for the exercise problems.	14
6. The teacher returned copies of the midterm examinations, after they had been marked, in response to students' requests to know their scores and review their performance.	2
7. The teacher made the students take the root of learning by correcting their mistakes in the midterm examination, and he/she also wants students to develop the ability to apply their knowledge, by solving exercise problems that are similar but not identical to those encountered in the midterm test	2
8. Since there is no opportunity to practise analysing real data after this class, the teacher distributed handouts about performing the t-test method with EXCEL.	7
9. The teacher changed from writing in yellow chalk, which cannot be seen from the back of a large classroom, to white chalk, within a border of yellow.	15
10. The teacher paused to explain what they were writing.	4
11. The teacher observed time strictly, in consideration of the start of the 5th period.	4
12. The teacher submitted a request for there to be more reference books in the library.	2

TABLE III: The Questionnaire Items of the Final Survey

(1) Did you think that the teacher tried to explain the educational intention?
(2) Did you think that students collected and analysed real data?
(3) Did you think that your understanding was significantly enhanced by means of thehandouts about contents of statistics?
(4) Did you think that you tried to understand and learn more independently by using the printed handouts you had received?
(5) What do you think about the detail of the printed handouts about the maximum likelihood method?
(6) The teacher was asked to explain the test statistics on which t-distribution was based on the occasions when the data followed normal distribution. The teacher wrote a printed handout to answer this question. What do you think of it?
(7) Do you think your understanding was improved and expanded by solving similar problems?
(8) Did you refer to other sources when you solved the similar problems?
(9) Do you think your understanding was enhanced by group work?
(10) Do you think you do not need the handout, because you will search for the information by yourself when you are in the third and fourth years?
(11) Do you think that educational and learning communication is improved by using IT technology or the electronic blackboard?
(12) Do you think that the use of clicker would be effective for your understanding ?
(13) The teacher improved the teaching behaviour, based on your opinions. Did you change your learning behaviour?

III. Analysis of the Effectiveness of the Improvement of the Class Based on Educational and Learning Communication

A. The Overall Educational and Learning Effectiveness of the Class

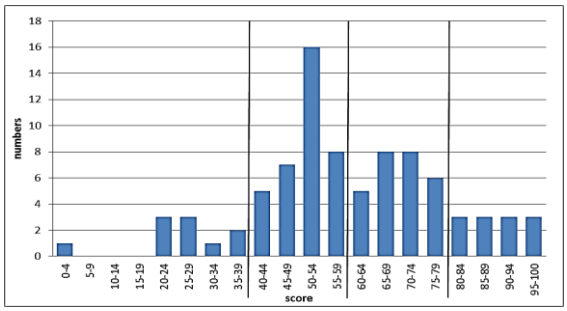

Fig. 2. Distribution of scores of the midterm exam.

To analyse the improvement of education and learning, we examine the changes in the scores from the midterm exam to the final exam. Fig. 2 shows the distribution of the scores of the midterm exam and Fig. 3, that of the final exam. The comparison between Fig. 2 and Fig. 3 shows that the number of students with 0–39 points decreased from 9 to 7, while the

number of students with 80–100 points doubled from 12 to 24. The mode of score distribution of the midterm exam is the 50–54 points interval, while that of the final exam shifted to right and is thus higher than that of the midterm exam. Therefore, on the whole, we consider that educational and learning activities improved during the period between the midterm and final exams.

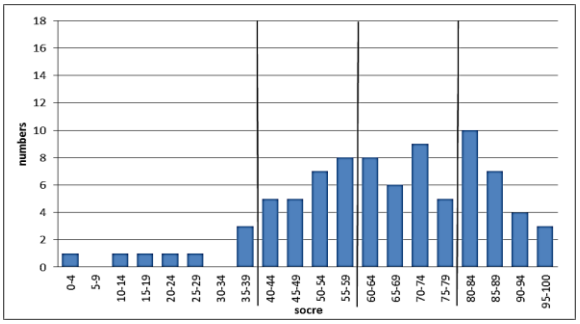

Fig. 3. Distribution of scores of the final exam.

TABLE IV: RESULTS OF THE T-TEST ON THE DIFFERENCE BETWEEN THE MEAN SCORES OF THE MIDTERM AND FINAL EXAMS

	The midterm exam	The final exam
Average	59.3452	64.9167
Variance	367.9878	361.6436
Number of students	78	78
Pooled variance	364.8157	
Difference between the two mean scores in the hypothesis	0	
Degree of freedom	166	
T-test statistics	-1.8904	
P-value of the one-sided test	0.0302	
Critical value of the one-sided test	1.6541	
P-value of the two-sided test	0.0604	
Critical value of the two-sided test	1.9744	

We found that the average score in the midterm exam (59.4 points) increased 5.5 points in the final exam (64.9 points). We used a one-sided t-test on the difference between the mean scores of the midterm and final exams. A significant difference between the mean scores of the two exams was demonstrated (with a significant level of 5%) as a result of the test (see Table IV).

In order to analyse in detail how each item of improvement affected each group, we classified the students based on their learning outcomes.

Analysis of the effectiveness of learning behaviour, we used Welch's test to examine the difference between the mean of the student groups who increased their learning outcomes and the mean of the student groups who decreased their learning outcomes with regard to the items related to the student's learning behaviour in the final survey and reports in class. The tested items are as follows:

- The score obtained for the report in which the student solved problems similar to those which he/she could not solve in the midterm exam (total possible score = 10 points)
- The score obtained for ordinary reports (total possible score = 10 points)
- Survey item 7: 'Do you think your understanding was improved and expanded by solving problems similar to those which you could not solve in the midterm test?' (Not improved ⇔ Improved, 5-point scale)
- Survey item 8: 'Did you refer to other sources when you solved the similar problems?' (Only the textbook ⇔ Yes, other references, 5-point scale)
- Survey item 9: 'Do you think your understanding was enhanced by group work?' (Ineffective ⇔ Very effective, 5-point scale)
- Survey item 13: 'Did you change you're learning behaviour?' (No change ⇔ Significant change, 5-point scale)

The mean, variance, and standard deviation of the scores and the test results (p-value) are shown in Table V. Here, a one-sided test is performed, and the items marked * represent those for which a significant difference between the two groups was demonstrated (with significance level 5%) as a result of the test.

TABLE V: RESULTS OF WELCH'S TEST CONDUCTED FOR THE DATA REGARDING LEARNING BEHAVIOUR

	The score for the report in which students solved problems similar to those in the midterm exam (maximum score = 10 points)	The score for ordinary reports (maximum score = 10 points)	Survey item 7: 'Do you think your understanding was improved and expanded by solving problems similar to those in the midterm test?' (Not improved ⇔ Improved, 5-point scale)	Survey item 8: 'Did you refer to other sources when you solved the similar problems?' (Only the textbook⇔Yes, other references, 5-point scale)	Survey item 9: 'Do you think your understanding is enhanced by group work?' (Ineffective⇔Very effective, 5-point scale)	Survey item 13: 'Did you change your learning behaviour?' (No change ⇔ Significant change, 5-point scale)
Mean (the groups who increased their learning outcomes)	8.292	8.667	3.688	2.229	3.063	3.063
Mean (the groups who decreased their learning outcomes)	6.857	8.357	3.750	2.107	3.286	2.857
Variance (the groups who increased their learning outcomes)	9.707	3.389	1.340	1.885	1.600	1.017
Variance (the groups who decreased their learning outcomes)	13.480	4.872	0.830	1.524	1.347	1.122
Standard deviation (the groups who increased their learning outcomes)	3.116	1.841	1.158	1.373	1.265	1.008
Standard deviation (the groups who decreased their learning outcomes)	3.671	2.207	0.911	1.235	1.161	1.059
P-value of t-test	0.047	0.270	0.399	0.348	0.222	0.209
5% level significance	*					

As the Table shows, the only significant difference between the groups whose learning outcomes increased and those whose learning outcomes decreased appeared with regard to one item: 'the points obtained for the report in which the student solved problems similar to those which he/she could not solve in the midterm exam'. That is, the score obtained in this report by the student groups whose learning outcomes increased, was higher. This suggests that receiving back a midterm exam and writing reports about problems similar to those which the student had been unable to solve previously contributed to their understanding of the course.

IV. Analysis of the Effectiveness of the According to Groups that Are Defined by Changed Learning Outcomes

A. Classification of Students into the Six Groups According to Their Changed Learning Outcomes

The teacher improved many points of the class during the midterm and the final examination, as described in chapter 2.

To analyse in detail the learning effects of these improvements for the students whose learning outcomes improved and worsened respectively, we classified students into the following 6 groups, using 60 points which is the criterion for acquiring credits as the datum point.

1) Group 1 is composed of students who obtained more than 60 points in the midterm and the final exam, and increased their score (17 students)
2) Group 2 is composed of students who obtained fewer than 60 points in the midterm exam, but more than 60 points in the final exam (19 students)
3) Group 3 is composed of students who obtained fewer than 60 points in the midterm and final exam, but increased their score (10 students)
4) Group 4 is composed of students who obtained more than 60 points in the midterm and final exam, but decreased their score (10 students)
5) Group 5 is composed of students who obtained more than 60 points in the midterm exam, but fewer than 60 points in the final exam (19 students)
6) Group 6 is composed of students who obtained fewer than 60 points in the midterm and final exam, and decreased their score (6 students)

The average scores for each of the 6 groups are plotted in Fig. 4.

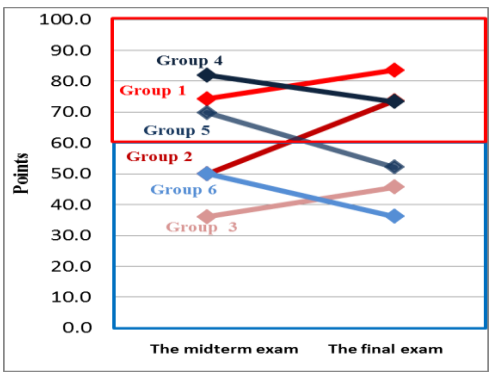

Fig. 4. Plotted averages for each of the 6 groups, classified by changes in test scores.

The average score of the 17 students classified as Group 1 increased by 9.4 points, from 74.2 points in the midterm exam, to 83.6 points in the final exam. As the students already achieved the pass mark in the midterm exam, and further improved their score in the final exam, they are considered excellent students who can successfully respond to changes in the teaching methods.

The average score of the 19 students classified as Group 2 increased by 23.7 points, from 50.0 points in the midterm exam, to 73.7 points in the final exam. Although these students did not achieve the pass mark at the stage of the midterm exam, their score in the final exam increased, and they are therefore considered to be students who can successfully respond to changes in the teaching methods and enhance their learning outcomes.

The average score of the 10 students classified as Group 3 increased by 9.6 points, from 36.0 points in the midterm exam, to 45.6 points in the final exam. These students did not achieve the pass mark either in the midterm or the final exam. In spite of their improvement, we consider that they were unable to deal with the learning content from the beginning.

The average score of the 10 students classified as Group 4 decreased by 8.6 points, from 82.0 points in the midterm exam, to 73.4 points in the final exam. Since these students achieved the pass mark in both the midterm and final exam, they have no problem in terms of acquiring credits. However, we need to analyse the negative influence caused by the changes to teaching and learning activities.

The average score of the 8 students classified as Group 5 decreased by 17.8 points, from 69.9 points in the midterm exam, to 52.1 points in the final exam. Despite achieving the pass mark in the midterm exam, the students' outcomes decreased in the final exam. We must examine the negative influence caused to this group by the changes to teaching and learning activities.

The average score of the 6 students classified as Group 6 decreased 13.8 points, from 50.0 points in the midterm exam, to 36.2 points in the final exam. These students did not achieve the pass mark in the midterm exam, and their outcomes were even lower in the final exam. These are the students who were unable to cope with the learning content from the beginning, and furthermore were unable to successfully change their learning as the teaching activities evolved.

Considering that the average score in the midterm exam for both group 2 and group 6 was 50.0 points, it is crucial to explore why the average score of group 2 rose by 23.7 points to 73.7 points in the final exam, while the average score of group 6 decreased by 13.8 points to 36.2 points in the final exam.

B. Investigations of the Educational Effects for Students in All Groups and the Trade-Off Effects

In order to investigate the effective items for all 6 groups and the items with the trade-off, we present the correlation coefficient table between the scores of the midterm exam, the final exam, and 18 variables in Table VI: the scores of the midterm and final exam, the score of the reports about problems similar to those which the student could not solve in the midterm exam, the score of the ordinary reports, responses

to items (1)-(13) in the final survey. Below, we examine these elements in detail.

In the correlation coefficient table, we present a correlation coefficient of more than 0.5 with a light red background and a red number, a correlation coefficient of more than 0.8 with a dark red background and the solid-white number, a correlation coefficient of less than -0.5 with a light blue background and a blue number, and a correlation coefficient of less than -0.8 with a blue background and a solid-white number. Trade-off is said that an item is effective for some groups; the item is not effective for the other groups.

TABLE VI: CORRELATION COEFFICIENT TABLE OF 6 GROUPS

	The midterm exam			The final exam		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
	Group 4	Group 5	Group 6	Group 4	Group 5	Group 6
The score of the midterm exam	1.00	1.00	1.00	0.67	-0.08	0.72
	1.00	1.00	1.00	0.79	0.50	0.96
The score of the final exam	0.67	-0.08	0.72	1.00	1.00	1.00
	0.79	0.50	0.96	1.00	1.00	1.00
The score of the report in which students solve problems similar to those in the midterm exam	0.05	-0.15	0.29	0.28	0.39	0.57
	0.05	0.25	0.97	0.11	0.47	0.93
The score of the ordinary reports	0.10	0.15	0.47	0.46	0.16	0.27
	0.08	0.70	0.62	0.47	0.29	0.64
(1) Educational intention	-0.04	-0.25	0.05	-0.16	0.01	0.06
	0.70	0.07	-0.28	0.66	-0.18	-0.25
(2) Collecting and analysing real data	-0.43	-0.19	0.28	-0.29	0.50	0.30
	0.85	-0.32	0.21	0.83	-0.46	0.07
(3) Printed handouts explaining of theories in detail	-0.03	-0.25	-0.25	-0.25	-0.04	-0.14
	0.89	-0.31	-0.04	0.69	-0.34	0.07
(4)-1 Understanding the contents printed handouts	-0.25	-0.32	0.13	-0.49	0.31	0.43
	0.82	-0.15	-0.04	0.70	-0.08	0.07
(4)-2 Learning the contents of printed handouts	0.06	-0.29	0.06	-0.37	0.12	0.45
	0.84	-0.24	-0.18	0.81	-0.55	0.02
(5) Printed handouts explaining the maximum likelihood method in detail	0.38	-0.22	-0.20	0.19	0.34	0.18
	-0.13	-0.02	0.10	-0.03	-0.30	0.32
(6) Printed handouts of t-distribution	-0.16	-0.34	0.06	-0.34	0.36	0.01
	0.75	-0.26	-0.27	0.54	0.30	-0.04
(7) The report in which students solved problems similar to those which they could not solved in the midterm exam	0.00	-0.21	-0.45	-0.10	0.42	-0.07
	-0.30	-0.60	0.21	-0.27	-0.36	0.07
(8) Other sources	-0.17	-0.03	-0.42	-0.44	0.00	0.00
	-0.43	0.08	-0.21	-0.56	-0.06	-0.29
(9) Group work	0.04	-0.30	0.40	0.12	0.01	-0.06
	0.78	-0.15	0.00	0.81	-0.14	-0.03
(10) Printed handouts describing tests conducted by Excel	-0.13	-0.16	-0.01	-0.19	0.30	0.02
	0.66	0.32	-0.12	0.51	-0.29	-0.07
(11) IT technology and the media board	-0.36	-0.55	-0.42	-0.20	0.21	0.06
	0.69	-0.64	0.14	0.48	-0.72	-0.05
(12) Clicker	-0.12	0.07	0.11	0.02	0.19	0.52
	-0.01	-0.03	0.50	-0.35	-0.14	0.64
(13) Changes in learning behavior	-0.08	0.18	0.04	-0.17	0.19	0.41
	0.82	0.00	0.78	0.71	0.00	0.71

1) Investigation of factors with educational effects on students in all groups

According to Table 6, our investigation revealed that the correlations between the score of the report in which students solved problems similar to those they could not solve in the midterm exam and the final exam score were positive for all groups. When we examined these correlations in detail, we discovered first that the correlations in group 3 and 6 were particularly high, and then that students with low scores for the report also obtained low scores in the final exam.

We also discovered that the correlations between the score for the ordinary reports and both the midterm and the final exam scores were positive in all groups. When we examined there in detail, the correlation coefficient between the scores obtained for the ordinary reports and the midterm exam was higher in groups 3 and 5, while the correlation coefficient between the report's score and the final exam score is higher in groups 1 and 4. It turned out that the students who were able to obtain consistently high marks in the tests also received high scores in their reports, because they made a substantial effort toward the report, in preparation for the final exam.

In conclusion, therefore, we determine that it is effective for students to complete reports in which they solve problems similar to those encountered in tests, along with other reports, because these prove useful for all groups.

2) Investigation of factors with a trade-off for student groups

Except for the items indicated in section B-a, no other items of educational improvement had positive or negative correlations with the final exam scores of all groups.

We examined '(5) the detailed printed handouts explaining the maximum likelihood method'. The correlation between this item and the final exam score was positive in groups 1, 2, 3, and 6 but negative in groups 4 and 5. Therefore, we found that the students who made an effort to understand the contents of the detailed printed handouts enhanced their learning effectiveness. In contrast, those who did not try to understand the contents and simply memorised them had lower final exam scores. The correlation in group 6, whose final exam scores decreased, was also positive because the detailed printed handouts restrained the decrease in their grades. Therefore, we concluded that the essential understanding of '(5) the detailed printed handouts explaining the maximum likelihood method' enhanced the students' effective leaning.

The correlation coefficient between the final exam score and the item '(13) change in learning behaviour (The teacher improved the teaching behaviour, based on your opinions. Did you change your learning behaviour?)' was negative only in group 1; it was positive in the other five groups. We found that the students in group 1 had developed learning styles for themselves but those in the other groups did not. We considered also that the students of the other five groups wanted to change their learning behaviour and improve their effective learning efficiency.

Furthermore, the correlation coefficients between the final exam score and the items '(2) collecting and analysing real data', '(4)-1 understanding the contents of printed handouts', and '(4)-2 learning the contents of printed handouts' were positive in groups 2, 3, 4, and 6 but negative in groups 1 and 5. The reason is the students in group 1 had established their learning styles, while those in group 5 did not try to learn more positively. Thus, we found that correlations in groups 1 and 5 were negative.

V. CONCLUSION

In this study, we analysed in detail the educational effectiveness of the improvement of the lessons and learning behavior, by dividing the students into 6 groups according to learning outcomes

We analyse in detail which factors are effective for students in all groups and which are effective with the trade-off resulting from the improvement of the education based on the educational and learning communications between one

teacher and many students. In this study, we showed the correlation coefficient table of 18 variables which are the scores of midterm exam and final exam, the score of the reports about the similar problem of the midterm exam, the score of the ordinary reports, responses of items (1)-(13) at the final survey, and examined the elements of it in detail.

As a result, we determine that it is effective for students to complete reports in which they solve problems similar to those encountered in tests, along with other reports, because these proved useful for all groups.

Also, the students in group 2 considerably increased their score in the final exam. The items that had high correlations with the final exam score were question item (2) (collecting and analyzing real data), (4)-1, 2, (5), (6) and (10) (the question items related to printed handouts), and (7) (the report in which students solved problems similar to those which they could not solved in the midterm exam). Our result revealed that the students were conscious of the relationship between these improvements and the growth of their score.

There were no the improvement items of having positive or negative high correlations with the final exam's scores in all groups except for the reports of solving the similar problems of the test, and the other reports. Then, we need to continue examining in more detail in the future, or, we need to continue considering with the communicative technique with one teacher and many students.

In a future study, we are going to examine in closer detail the nature of the skillful educational and learning communications with one teacher and many students, with regard to each student group, by adopting the viewpoint of the communicology or educational psychology.

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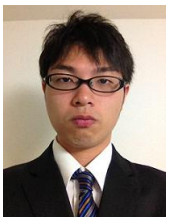

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