The effect of differentiated instruction on student mathematical communication ability

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Abstract. This study aims to analyze: (a) mathematical communication ability of students before and after learning with Different Instruction; (b) difference between students' mathematical communication ability using Differentiated Instruction and conventional learning. The research method used in this study is a quantitative research. 70 Junior High School students of the 8th graders, participate in this study. The first class sample is learning with Differentiated Instruction approach and the second class with the conventional learning. Data obtained using research instruments consisting of pre-test and post-test. Based on the results of data processing, it was obtained: (a) the mean achievement of communication ability of the student of Differentiated Instruction class is 77.37 in the medium level and the student of conventional class (75.87) in the medium level too; (b) to improve students' mathematical communication ability, Differentiated Instruction approach is better to use. From the data that has been obtained, the effect of Differentiated Instruction is to improve students' mathematical communication ability.

1. Introduction
The development of science and technology is now increasingly rapid, the demands of an increasingly complex world of education require students to have the ability to understand, reason, solve problems, and communicate them. The Indonesian education system has the principle of character education. According to Arie Budhiman, an expert staff of Ministry of Education and Culture in the field of character development, strengthening character education in schools must be able to foster the character of students to be able to think critically, creatively, be able to communicate, and collaborate, who are able to compete in the 21st century students in the 21st century called 4C, namely Critical Thinking and Problem Solving (critical thinking and problem solving), Creativity (creativity), Communication Ability (communication ability), and Ability to Work Collaboratively (the ability to work together) [1]. The National Council of Teachers of Mathematics (NCTM) stimulates that there are five abilities students must possess through mathematics learning and include high order mathematical thinking, namely (1) problem solving (2) reasoning and proof (reasoning and proofing), (3) communication (communication), (4) connection (connection) and (5) representation [2].

Lack of a learning process that supports the creation of students' thinking abilities, especially mathematical communication ability is one of the factors that make student can’t develop enough in their mathematics learning. This is in line with the opinion of Vygotsky who argues that knowledge construction occurs through a process of social interaction with other people who are more understanding and understand the knowledge [3]. This is in line with Bell's opinion which states that
choosing the right teaching strategy and setting up the learning environment has a significant influence on the success of children's mathematics learning, children's talents, willingness to learn, children's interests, material presentation, personal and teacher attitudes, learning atmosphere, teacher competence, as well as outside conditions [4]. From this opinion, it shows that student differences are important to consider in the learning process in the classroom. Therefore, to increase it required an instructional strategy that can accommodate differences of students, so that students can get better learning potential compared to using the conventional learning. As stated by Peterson that in teaching and learning activities, if the elements of diversity of students are observed, it will make students more successful [5].

The relation of extrinsic rewards to individual differences is of critical importance. In the classroom, extrinsic incentives are often intended to motivate the least attentive students or those who typically perform poorly; however, the rewards are typically applied to the entire classroom or even the entire school population, as in many reading incentive programs. The hidden costs become most apparent when they are applied to these larger groups where individual differences in interest, performance, and ability are ignored [6]. The same thing suggested by Sumarmo that in mathematics learning requires a change of view to create a conducive learning atmosphere, from serving students as a whole towards serving students according to students' interests, strengths, hopes, and needs [7]. According to Henningsen & Stein to develop students' mathematical abilities, the learning environment must be arranged so that students can be actively involved in useful mathematical activities [8]. Learning that involves students actively is often done through group learning activities, with group activities will familiarize students to be able to communicate actively in learning.

The learning strategy that can answer the issue of student differences is the Differentiated Instruction (DI) approach. Learning mathematics must be built by the social constructivist paradigm for the teaching and learning process in which active students learn as Vygotsky has stated. According to Tomlinson, DI is a learning that is tailored to the needs of students who aim to maximize the potential of each student [9]. DI can be likened to a prescription from a doctor. The doctor will prescribe the patient according to the dosage required by the patient. The appropriate dose will be able to cure the patient from his illness. From these opinions can be analyzed that DI is designed so that all students can learn in the way they have in accordance with the potential of students. As Bao stated if children don't learn the way we teach them, then we teach them the way they learn [10]. It is in accordance with Good's opinion that DI is a learning that emphasizes the initial conditions of students were learning plans that pay attention to the readiness, interests, and profile of student learning [9]. DI provides more opportunities for students to explore all the potential they have in understanding mathematics. Differentiation can be defined as an approach to teaching in which teachers proactively modify curricula, teaching methods, resources, learning activities, and student products to address the diverse needs of individual students and small groups of students to maximize the learning opportunity for each student in a classroom [11]. So this learning was divided to small groups of students. Through grouping, students will easily interact with their friends. Small groups make the intensity of expressing the opinions of each student will be higher so that it will provide a great opportunity to develop the ability of mathematical communication. For this reason, we need to divide the group into learning so that each student in the group can learn from each other and work together to create enjoyable learning. From the DI process, the learning stage with worksheets and presenting them is indicated to be one of the factors that causes students' mathematical communication ability to improve. The group learning process with friends who have the same learning style makes it possible to discuss and in the presentation stage of their worksheets, there are visual, auditory and kinesthetic groups that enable students to practice their mathematical communication ability.

A previous study from Hapsari mention that students expect mathematical instruction to be easy to understand, fun, not in a hurry, and not too serious [12]. In this research we given treatment in the form of differentiated worksheets based on learning styles. Applying instructions that are divided into mathematical instructions is not easy. Teacher must master various knowledge, assess students continuously, and plan teaching well though wasting time [12]. In this research, it already planned with
conventional learning and the difference is in worksheet, the worksheet is different for every learning style and already discussed with 2 lecturers before. Based on this background, the author wants to look for differences in students' mathematical communication ability through mathematical tests using the right indicators and given treatment in the form of differentiated worksheets based on learning styles for the experimental class and conventional learning for the control class.

2. Method
This research employs a quantitative method started with collected the students’ learning profiles by their learning style and pre-test to know their ability first before learning. The next step was implemented the differentiated instruction in the experiment class and conventional learning in control class to learn polyhedra materials and then examined the students’ answer from exam. The types of exam are 5 essay questions about mathematical communication ability that are in accordance with the indicators. The indicators were: Roomberg, et al. propose indicators of mathematical communication ability, namely: (1) express mathematical ideas verbally, written, and describe them visually; (2) understanding, interpreting, and evaluating mathematical ideas presented both verbally, written and visually; (3) use terms, notations, and mathematical structures to present various ideas, describe various relationships and model various situations [13]. 70 Junior High School students of the 8th graders, participate in this study. The two samples had the same characteristics: they finished grade VII, in which they had studied figure and inequalities in one variable in its first semester. This study aims to look for differences in the value of pre-test, post-test and n-gain mathematical communication ability of students using Differentiated Instruction approach and with conventional learning which seems to be traditional and common in Indonesia. Differences test use independent sample t-test if the data is normal and homogeneous, independent sample t’-test if the data is normal but not homogeneous and uses Mann-Whitney if the data is not normal. First, researchers wanted to know the difference in pre-test scores from both classes. Second, the researchers wanted to know the difference in post test scores from the two classes. Third, the researchers wanted to know the difference in n-gain scores of the two classes to determine the differences in the increase of the two classes.

3. Results and discussion
This part presents the results test difference test communication mathematical students before, after and the increase between approach Differentiated Instruction and conventional learning. To ensure that these questions are well-used in research, the questions were tested first. The test was tested in a IX class grade to look for validity, reliability, level of difficulty and power of difference questions. After being analysed, the questions were prepared to be a matter of pre-test. Then the question was used in pre-test and post-test to analyze students’ mathematical communication ability in polyhedra material. The treatment was carried out 4 times to the differentiated instruction class. At the first meeting, students were given pre-test and also given a learning style test for the experimental class. The aim is to group students into what they were learning so that the appropriate worksheet was given. Descriptive statistical analysis of students’ mathematical communication ability before learning obtained from pre-test data, after learning obtained from post test data, for improvement obtained by n-gain data in the DI and CL classes can be seen in the following table.

| Table 1. Pre-test, Post-test and N-Gain descriptive statistics data. |
|---------------------------------|----------------|----------------|
| **Pre-Test DI**                 | **Descriptive** | **Statistic**  |
| Mean                            | 33.88          | 1.722          |
| Std. Deviation                  | 10.889         |
| **Pre-Test CL**                 | **Descriptive** | **Statistic**  |
| Mean                            | 33.88          | 1.259          |
| Std. Deviation                  | 7.965          |
| **Post-Test DI**                | **Descriptive** | **Statistic**  |
| Mean                            | 77.38          | 1.869          |
| Std. Deviation                  | 11.821         |
Table 1. Cont.

| Post-Test | Mean | Std. Deviation |
|-----------|------|----------------|
| CL        | 75.88| 11.485         |
| N-Gain DI | 0.63994| 0.0357513 |
| N-Gain CL | 0.631725| 0.0275876 |

From the table, it can be seen that the pre-test results of the two classes have the same mean value but the DI class has a larger standard deviation which means the data varies or spreads more from the average while the CL class is more homogeneous. The post-test results of DI classes are smaller than CL class and the DI class has a larger standard deviation which means the data varies or spreads more from the average while the CL class is more homogeneous. The n-gain results of DI classes is bigger than CL class and the DI class has a larger standard deviation which means the data varies or spreads more from the average while the CL class is more homogeneous. But because the data cannot be concluded only from descriptive, it is necessary to do a difference test using the difference mean or mean rank test.

To do a difference test, we tested difference of mean or mean rank value of the pre-test, post-test and n-gain. First we tested for normality and homogeneity. If both data are normal and homogeneous then you can use the independent sample t-test. But if the data is not normal then use the Mann-Whitney test to see if there are differences from the DI class and the CL class.

To process the data pre-test, the hypothesis used is \( H_0 \) = There are no significant differences early mathematical communication ability between students who use Differentiated Instruction and conventional learning. Basis for a decision as follows:

- If \( \text{Sig.} \geq 0.05 \) then \( H_0 \) is accepted.
- If \( \text{Sig.} < 0.05 \) then \( H_0 \) is rejected.

After tested normality both data turned out not normally distributed, so test continued using the Mann-Whitney test to see the difference students’ mathematical communication ability.

Table 2. Test results for differences in student pre-test.

| Test Statistics\( ^a \)         |                  |
|--------------------------------|------------------|
| Pre-test                       |                  |
| Mann-Whitney U                 | 658.000          |
| Asymp. Sig. (1-tailed)         | .153             |

From the table it can be seen that the \( \text{Sig.} \geq 0.05 \) so that \( H_0 \) is received. The conclusion is that there is no difference in pre-test scores from the two classes. So the comparison of the increase can be calculated because it has no difference.

In addition to the pre-test, a learning style test was also conducted for the experimental class. Produced 9 people have kinesthetic learning styles, 9 people have audio learning styles and 18 people have visual learning styles. The difference in treatment of the experimental class lies in the provision of student worksheets. In the experimental class, a learning style test had been given then the students were grouped with students who had the same learning style and worked on the worksheets together. Where as in the OL class students explain the material according to what the teacher usually does. The student's first action is given a worksheet relating to the properties of polyhedra. The treatment of the two students is also given a worksheet about the polyhedra. Moreover, third treatment of students was given a worksheet about the surface area of polyhedra. And the final treatment of students is given work holiday related to the volume of polyhedra. At the last meeting, post-test was carried out to find out student achievement in polyhedra material after being treated.
And next difference test is from posttest value. From the results of these tests it turns out that the data is also abnormal so the Mann-Whitney test is used to see the difference in achievement. With the hypothesis $H_0 = \text{There is no significant difference in the achievement of mathematical communication ability between students using Differentiated Instruction learning and conventional learning on the basis of the same decision-making as in pre-test testing.}$ Achievement of mathematical communication ability of students with learning Differentiated Instruction after the Mann-Whitney test, the results are listed in the following table:

Table 3. Test results for differences in student post-test.

| Test Statistics$^a$ | Post-Test |
|---------------------|-----------|
| Mann-Whitney U      | 555.000   |
| Asymp. Sig. (2-tailed) | .017     |

From the table, it can be seen that the value of Sig. < 0.05 so that $H_0$ is rejected. The conclusion is that there are differences in post-test scores from both classes. So the comparison of the increase can be calculated because the post-test score has a difference.

From the results of the pre-test and post-test, the increase will be sought whether there is a difference or not and the higher from these two classes in the increase. The data used are data n-gain from the results of the pre-test and post-test that have been carried out with the hypothesis $H_0 = \text{There are no significant differences in the increase in mathematical communication ability between students using Differentiated Instruction learning and the conventional learning and } H_1 = \text{Increasing students' mathematical communication ability which uses Differentiated Instruction learning is better than the conventional learning.}$ The principle of decision-making is the same as in testing pre-test and post-test. The data were tested for normality and homogeneity and the results were not normal. Then the Mann-Whitney test is used to see the difference in improvement. After the Mann-Whitney test, the results are listed in the following table:

Table 4. Testing results differences in students' mathematical communication ability.

| Test Statistics$^a$ | N-Gain |
|---------------------|--------|
| Mann-Whitney U      | 354.5  |
| Asymp. Sig. (1-tailed) | .004   |

The table shows that the Sig. < 0.05 so that $H_0$ rejected. The conclusion is an increase in students' mathematical communication using Differentiated Instruction learning better than those using conventional learning. So it can be concluded that learning using Differentiated Instruction can produce better communication ability than the conventional class.

According to these statistical data, students who are involved with mathematics learning become engage voluntarily after giving assignments that are appropriate to their respective learning styles. McAdamis and Christensen also stated that learning differences increase motivation and enthusiasm of students in learning [14,15]. Students are not enthusiastic and bored when receiving explanation of the teacher about the material they understand. One of the success factors maybe because the group learning process with friends who have the same learning style makes it possible to discuss with their friends. It happens because with group learning with the same learning style, they can ask their group friends and can discuss so they can understand better. Then the presence of visual, auditory and kinesthetic groups enable students to train their mathematical communication ability. Work becomes easier and they can socialize and work together at the same time. This is in line with what Butler & Luwe suggests that effective differentiated learning will work in group [9]. Through grouping, students will easily interact with their friends. This is a power that helps them overcome and solve the instructions.
4. Conclusion
From the results of the data, it has answered the research question. The conclusions are achieving mathematical communication of students between classes using Differentiated Instruction learning with conventional learning has a difference. And then the improvement of students' mathematical communication between classes using Differentiated Instruction learning with conventional learning has a difference and obtained that the results test students who use Differentiated Instruction learning is better from students who use learning conventional. So, the effect from Differentiated Instruction is to improve students' mathematical communication ability.

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