

Analysis of Improving Students' Physics Conceptual Understanding through Discovery Learning Models Supported by Multi-representation: Measurement Topic

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ABSTRACT

This study aimed to analyze students' conceptual understanding by using a multi-representation assisted discovery learning model in measurement. This research was conducted in Public High School 1 Kendari. This research is a quasi-experimental study using a one-group pre-post test design. The research method consisted of a conceptual comprehension test using a caliper and a screw micrometer in an essay in the form of a multi-representational test on long measurements. The analysis showed an increase in conceptual understanding between the pre-test and post-test with an average pre-test score of 16.24 (SD = 14) and a post-test of 61.4 (SD = 21). These results indicate an increase in students' understanding of concepts after learning with an average N-gain increase of 0.5 (SD = 0.2) in the medium category. It also obtained the most significant increase in students' understanding of the indicators mentioned parts caliper and micrometer with an N-gain average of 0.6 in the medium category.

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I. Introduction

The role of multi representation in learning is an essential topic in educational research, and representation in physics learning plays an essential role in explaining natural phenomena. Students can understand well a topic learned is presented in a form that is easy to learn. In textbooks, the presentation of natural phenomena in physics usually expressed in the form of various representations such as text, diagrams, graphs, and mathematical equations, tables, charts, symbols, and this used to understand and study physics, as well as to convey the ideas and concepts it has [1-4].

Besides, representations help improve students' understanding of physics problems, create bridges between mathematics and verbal or text representations, and help students develop ideas that give mathematical symbols meaning [5]. Physics is a branch of science that studies matter and energy-related natural phenomena. By the interaction of different physical quantities, natural phenomena are created. Physics is a part of natural science with some elements [6,7]. Physics often involves modeling real-world physical phenomena using external

representations that range from concrete to abstract forms: pictures, diagrams, words, graphs, and equations [3], [8].

Given the importance of understanding physics's content by students, teachers, and students' concerns should always be logical mastery and student learning progress in physics. Students can see how their knowledge can be conveyed by reflecting on what is used in solving the problem. It will not be difficult for learners who already understand physics's meaning to communicate their understanding in the form of different representations [6]. Martaida et al. [9] reported that one of the problems in education, especially in science subjects, was the learning process's weakness. Students are less motivated to explore their information, but students ask to recall what the teacher has given them. Consequently, students can not solve the problems that occur, especially if the issue is related to the definition of science.

The learning system tends to approach mathematics to get stuck after the mathematical process without understanding physics concepts. Therefore, we need an

alternative learning model that can enable students to build their knowledge, one of which is the discovery learning model.

Discovery learning is a model for developing active student learning by finding out and investigating so that the results will last a long time in memory, not easily forgotten by students [10,11]. The advantage of the discovery model of learning is a learning process based on problem-solving [12]. With this model, students can be more intense in solving problems, making it useful for life in the future [13]. Besides, discovery learning focuses on solving a problem relevant to current developments required to think about society's problem-solving. Therefore, discovery-learning needs to be actualized in real life so that students can respond to more complex life problems. Ansori et al. [14], in their study, reported that implementing the discovery learning model can support students to think critically. Besides, applying the learning discovery made the children learn to think the analysis and try to solve the problems they face themselves [9], [15].

The combination of multi-perception based knowledge to students can optimize the role of discovery learning models. Multi representation is a model that re-represents the same concept in several different formats. Some representation types may be terms, images, diagrams, graphs, simulations of machines, and mathematical equations in physics. Multi-representation can help learners understand and construct a concept, solve problems, help solve problems, and help solve problems [16,17]. In developing knowledge of scientific concepts and processes, Setyandaru et al. [18] argue that developing science learning in schools requires understanding and connecting verbal, visual, and mathematical representations. In his research, Sunyono and Meristin [19] argued that multiple representation-based learning could enhance students' conceptual understanding of high school chemistry materials compared to discovery learning. Meanwhile, Altan and Eksi [20] reported using several representations to enhance learners' conceptual understanding of energy concepts, such as tables, data-meaning tables, conceptual change texts, concept maps, and analogies.

The solution proposed to solve this problem is to choose models, methods, techniques, or learning approaches with learning paradigms that emphasize students' superiority or behavior in response to different facts and science learning issues (student-centered learning). The exploratory learning model can accommodate all of these things. Discovery learning is a model that promotes the active participation of each student by prepared issues presented by the instructor to discover the concepts and values individually or in groups. According to the specified target, the teacher's task in this model is to direct students with a few roles in seeking concepts and principles.

To solve this issue solution proposed is to choose models, methods, strategies, or learning approaches of learning paradigms that emphasize students' dominance or action in learning in response to various facts and

problems of science learning (student-centered learning). A learning model that assumes that all these items can be accommodating is the learning model for exploration. Discovery learning is a model that facilitates each student's active involvement through the teacher's prepared questions to explore the concepts and values individually or in groups. In this model, the teacher's job is to direct students with a few roles to look for concepts and principles according to the goal defined.

Several researchers have studied the use of multi-representation based discovery learning models. Puspitasari et al. [21] reported that the guided discovery learning model accompanied by multi-representation student worksheets based on problem-solving could improve students' conceptual understanding. Meanwhile, Ummu et al. [22] argued that applying a multi-perception-based discovery learning model could improve students' conceptual understanding by a percentage of 90%.

However, based on the results of searches using google scholar, Eric, and ProQuest, it is still rare to explain in detail the use of multi-representation with the discovery learning model, especially on the topic of measurement. In this study, researchers focused on multi-perception on measuring instruments in the form of calipers. This selection is due to the lack of literature sources that examine multi-perception on several measuring instruments.

Therefore, researchers are interested in studying students' conceptual understanding through models of discovery learning supported by multiple representations from what has been mentioned. This study aims to analyze and provide an overview of students' conceptual understanding based on multi-representation with discovery learning models on measurement.

II. Theory Concept Understanding

Understanding is the keyword in the learning. According to Berns and Erickson [23], understanding is an absolute prerequisite for high cognitive abilities, application, analysis, synthesis, and evaluation in a learning domain. According to Amien [24], a concept is based on relevant experiences that can be generalized to form a concept.

Physics is a discipline that needs more comprehension than memorization, so the ability to use three principal points of physics, namely concepts, laws or principles, and theories, is the key to success in studying physics. In learning physics, the ability to conceptualize physics is an absolute requirement in achieving the success of learning physics. According to Bloom, the taxonomy of teaching objectives in the cognitive realm consists of six levels: remember, understand, apply, analyze, evaluate, and create. Competence is characterized by learners' ability to understand concepts, formulas, or facts to interpret and restate them with their own words. For example, tasks that fall under this skill summarize the subject matter,

clarify the fairy tale contents to one's own experience, and include examples of events similar to those mentioned by the instructor.

Discovery Learning

Discovery learning model of learning based on constructivist learning theories [25]. Learning is the active method of creating context, argument, dialogue, and physical experiences from constructivism. An assimilation process takes place and connects the experiences or knowledge that has been acquired [26].

In discovery learning, students are not given the concept in its final form, but students are encouraged to find the concept. Students build knowledge based on new information and data-sets they used to investigate learning [27]. Participation in finding concepts in learning gives students a more profound impression so that information is stored longer in students' memory. The process of exploring the concepts being taught also gives students the incentive to make more discoveries to improve their learning interest.

Syntax discovery learning consists of six phases as follows: (a). Stimulation, (b).the problem statement, (c). Data collection (d). Data processing, (e). Verification, and (f). Generalization.

Multi-representation

According to Ainsworth [28], a multi-representation learning environment's conceptual analysis shows three main functions of multi-representation used in learning situations to complement and build conceptual understanding. The first function is to use representations to obtain additional information or support existing and complementary cognitive processes. Secondly, the representation can be applied to restrict the interpretation of the possible. Recently, multi-representation can be used to encourage students to build a deeper understanding of the concept.

Sunyono and Meristin [19] concluded that multi-representation involves the importance of restating principles that have been taught in different forms and different acts and expressions, such as delivery by word of mouth, gestures, visuals. Therefore, multi-representation represents the physical processes in various ways; verbal, sketches, diagrams, graphs, and mathematical equations. There are several advantages of using the first representation; representation helps students understand the material as a visual aid to increase perceptual understanding. Second, the representation is a physical nature, bridging between verbal representations with mathematical representations. The representation of a physical nature helps facilitate students in moving from words into mathematical equations.

III. Method

This type of research includes experimental research. The research design was made in the form of a pretest-posttest one group design. The experiment was

conducted in Public High School 1 Kendari Class X_{MIPA} on measurement with 36 students. The research instrument consisted of a multi-representation test, as presented in Table 1.

Data collection techniques in the form of a written test and an indicator containing multiple representations, multi-representation based student competency achievement indicators with discovery learning models are presented in Table 2.

Data analysis techniques consisted of descriptive analysis and categorization and the students' understanding of statistical analysis in which there are test N-gain normalization [29]. Formula descriptive analysis presented in equation (1).

$$A = \frac{B}{C} \times 100\% \quad (1)$$

Symbol A is the total score obtained, B is the score obtained, and C is the maximum score.

IV. Results and Discussion

Understanding is a manifestation of a person's perception or viewpoint given a problem. An individual is said to understand whether the issues he faces may derive meaning from messages or clues [30]. Understanding representations is meaningful because information on a problem is often represented differently, such as providing visuals information [31-33]. Multi-representation understanding, namely, students' understanding of visual, verbal, mathematical, pictures, and graphics [34]. Students are expected to master various representations during learning, such as experimental results, conceptual results, formulas, images. It can be seen in Figure 1 that students are more focused on responding to the questions given.

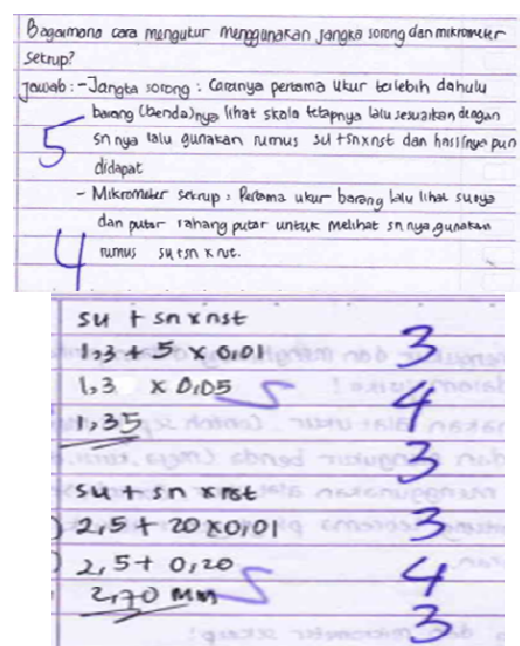


Figure 1. The results of the student's work

Table 1. The instrument of the student's multi-representation ability

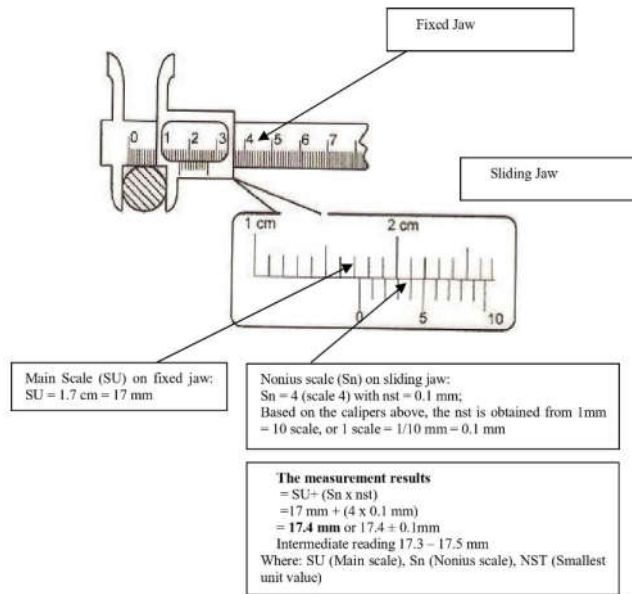
Caliper

Mathematical symbol representations The measurement results = $SU + (S_n \times NST)$

Text representation The measurement results on the Calipers are:

1. Viewed and read designation numbers on the main scale (the fixed jaw) adjacent or before zero on a Nonius scale (on a sliding jaw) as readings main scale
2. View and read the scale on the nonius scale, which is precisely in line with the scale on the fixed jaw and multiplied by the smallest unit value on the caliper used as the nonius scale reading. (of all the scales contained in the Nonius scale or on a sliding jaw, there is only one (1) scale that is aligned with the scale on the fixed jaw, scale readings in mm)
3. The measurement result is the sum of the main scale and the nonius scale.

Representation of Image Symbols



Micrometer

Text representation The measurement result on the screw micrometer is:

1. Viewed and read designation scale of the highest rates in the major scale (fixed jaw) near the jaw swivel as reading the main scale
2. View and read the scale on the rotary jaw, which is in line with the horizontal line (horizontal) on the fixed jaw and multiplied by NST (smallest unit value) on the micrometer screw, which is used as the Nonius Scale (SN) reading. Of all the scales contained in the rotary scale or on the rotary jaw, there is only one (1) scale that is entirely in line with the horizontal line on the fixed jaw, with the reading scale in mm.

The measurement results are the sum of the Main Scale and the Nonius Scale.

Mathematical symbol representations The measurement results = $SU + (S_n \times NST)$

Representation of Image Symbol

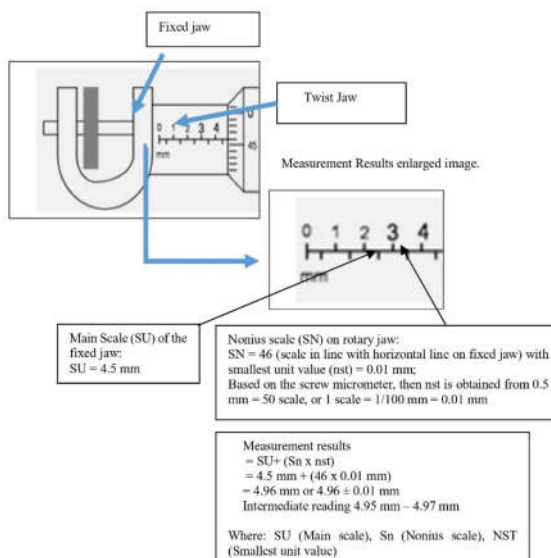


Table 2. A multi-representation based competency achievement indicator with a discovery learning model

No	Student Competency Achievement Indicators
1	Differences measure to calculate and provide an example
2	Named parts of the caliper
3	Named parts of the micrometer
4	The procedure used and the scale reading caliper
5	The procedure used and read the scale micrometer screw
6	Read the measurement of the length of an object using a caliper
7	The reading the results of measurement of the length of an object using a .micrometre

Applying multi-representation in the discovery learning model makes it easier for students to understand and question more about the questions given. The findings of the study can be seen as follows, based on the review of research data:

- a. The pre-test and post-test application of the discovery learning model assisted by multiple representations of the measurement topic are shown in Table 3.

Table 3. Pre and post-test results in the application of discovery learning model assisted by multi-representation

Test	Value			
	min	max	average	SD
Pre Test	2.9	55.7	16.3	13.9
Post Test	11.4	88.6	61.4	21.0
G	0.07	0.8	0.5	0.2

Note: G (N-gain normalization); SD (Standard Deviation)

It appears in Table 3 that the use of multi-representation-assisted discovery learning on the subject of measurement increased the comprehension of the measurement content by students from an average of 16.3 to 61.4. After the application model with an increase in N-gain (normalized gain) of 0.55, which is in the medium category. An increase in N-gain of 0.55 means that students in class X_{MIPA-4} experience an increase in learning outcomes by 55% from the difference between the student's pre-test average score and the ideal or maximum average (or 100) from the test on the topic of measurement.

In other words, the difference between the mean of the initial test and the ideal mean of the students class X_{MIPA-4} is 83.7 (from 100 - 16.3), and 55% of 83.7 is 46.04, or the average value of students after learning increases by 46.04 from the initial test so that the average test eventually to 62.3 (relative value equal to the value of post-test, differ only because of rounding).

Thus, learning multi-representation assisted discovery models can improve students' understanding of the topic of measurement with an average N-gain of 0.55. Suhandi and Wibowo [35] argued that multi-representation is one approach that is quite effective to use to instill an understanding of physics concepts. While, Utami et al. [36] reported that multi-representation

could improve students' conceptual understanding of physics education in the optical wave course with the N-gain value obtained is 0.69, which is in the medium category.

Therefore, the use of multi-representations with discovery learning models emphasizes qualitative analysis and the quantitative aspects. The emphasis on multi representation with discovery learning significantly assists students in explaining physical phenomena problem-solving.

- b. Total percentage of students (%) based on the N-gain category.

The distribution of categories for increasing understanding of concepts on the topic of measurement to students' numbers is shown in Table 4.

Table 4. Percentage of total students (%) based on N- gain category

Category	Total student (%)
High (N- Gain ≥ 0.7)	30.6
Medium ($0.3 \leq \text{N-gain} < 0.7$)	50.0
Low ($0 < \text{N-Gain} \leq 0.3$)	19.4

Table 4 shows that the increase in N-gain usually is distributed; It means that more students (50%) have a medium increase or as the gain category, in general, is 0.55, which is in the medium category. However, the number of students who have a high N-gain category is more significant than those in the low gain category.

- c. Description of the distribution of students' pre-test and post-test scores in terms of the aspect of competency achievement indicators on the topic of measurement.

The distribution of student understanding for measures of student competency achievement is shown in Table 5. The distribution of understanding of each indicator on the measurement subject is illustrated in Table 5. In general, based on this data, students had a poor understanding of all indicators before learning. The lowest indicator was using and reading the scale on the initial screw micrometer of 6.9. The extended measurement results using a caliper are also low on the indicator, and the micrometer parts of 10.7 and 11.6 are reported, respectively.

However, students calculate and offer marginally better examples than all other aspects of the distinction aspect. Students' comprehension improved after the learning process, with the highest average being 70.1 in terms of mentioning the caliper components and 67.4 in terms of saying the screw micrometer components. Compared to other aspects, namely 0.63, these two elements also had the most considerable N-Gain rise.

Table 5 shows that the distinguishing aspect of measuring by counting and giving examples has the lowest N-Gain increase of 0.48. It also appears that although the invention has been applying aided

instructional model representation, there are still students who do not understand the concept of the last four

indicators (even no value 0 both on the pre-test and post-test).

Table 5. The distribution of students' pre-test and final test scores in terms of N-gain for each indicator of student competency achievement

No	Student Competency Achievement Indicators	Pre Test				Post Test				N Gain
		min	max	Average	SD	min	max	Average	SD	
1	Differences measure to calculate and provide an example	12.5	43.8	26.2	10.2	21.9	93.8	61.8	17.5	0.4
2	Named parts of the caliper	0.0	66.7	19.2	25.8	25.0	100	70.1	14.6	0.6
3	Named parts of the micrometer	0.0	66.7	11.6	22.3	16.7	100	67.4	20.8	0.6
4	The procedure used and the scale reading caliper	0.0	50	20.8	19	0.0	100	62.5	26.7	0.5
5	The procedure used and read the scale micrometer screw	0.0	50	6.9	15.4	0.0	100	53.5	32.3	0.5
6	Read the measurement of the length of an object using a caliper	0.0	69.2	10.7	17.3	0.0	100	60.1	40.3	0.5
7	Reading the results of measurement of the length of an object using a micrometer	0.0	84.6	13.2	24.4	0.0	100	59.7	40.2	0.5

Teachers need to increase the awareness of students' multi-representation in different ways of presenting the knowledge to grasp an abstract topic that becomes tangible in all analysis areas [37]. One way to apply learning with multiple representations approach as the research results Widianingtiyas et al. [38] obtained a multi-representation approach can positively influence students' cognitive abilities, including low-level cognitive

and high-level cognitive. Understanding is a form of student cognition in the learning process.

d. Description of the success rate of mastery of the subject matter on the measurement topic

Table 6 and Table 7 shows the number of students based on mastery of the material for measurement subjects, both in the initial and final exams.

Table 6. The distribution number of students (%) each indicator of conceptual understanding in terms of the success rate of mastery of the material on the initial test (pre-test)

No	Level of success	Category	Indicator codes and number of students (%)						
			1	2	3	4	5	6	7
1	Mastering all topics/indicators of subject matter (100%)	Excellent	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	Most of them master the topic/indicators of the subject matter (76 % - 99 %)	Very good	0.0	0.0	0.0	0.0	0.0	0.0	5.6
3	Students master 60% - 75% of indicators/subject topic materials	Good	0.0	16.7	5.6	0.0	0.0	2.8	2.8
4	Students only master a small portion of the topic/topic indicator of the lesson (1% - 59%)	Lest	100	27.7	19.4	75	22.2	50	33.3
5	Students do not master the topic/indicator topic of the lesson (0%)	Not master	0	55.6	75	25	77.8	47.2	58.3

Indicator Information: (1) Differences measure to calculate and provide an example; (2) Named parts of the caliper; (3) Named parts of the micrometer; (4) The procedure used and the scale reading caliper; (5) The procedure used and read the scale micrometer screw; (6) Read the measurement of the length of an object using a caliper; (7) Reading the results of measurement of the length of an object using a micrometer

Table 7. The distribution number of students (%) each indicator of conceptual understanding in terms of the success rate of mastery of the material on the final test (post-test)

No	Level of success	Category	Indicator codes and number of students (%)						
			1	2	3	4	1	6	7
1	Mastering all topics/indicators of subject matter (100%)	Excellent	0.0	8.3	11.1	5.6	2.8	36.1	36.1
2	Most of them master the topic/ indicators of the subject matter (76 % - 99 %)	Very good	19.4	16.7	16.7	25.0	25.0	13.9	13.9
3	Students master 60% - 75% of indicators / subject topic materials	Good	30.6	69.4	55.5	36.1	25.0	5.6	2.8
4	Students only master a small portion of the topic/topic indicator of the lesson (1% - 59%)	Lest	50.0	5.6	16.7	25.0	27.8	38.8	36.1
5	Students do not master the topic/indicator topic of the lesson (0%)	Not master	0.0	0.0	0.0	8.3	19.4	5.6	11.1

Indicator Information: (1) Differences measure to calculate and provide an example; (2) Named parts of the caliper; (3) Named parts of the micrometer; (4) The procedure used and the scale reading caliper; (5) The procedure used and read the scale micrometer screw; (6) Read the measurement of the length of an object using a caliper; (7) Reading the results of measurement of the length of an object using a micrometer

It appears that of the 36 students, the level of comprehension of the students is still in the decent/minimum group below (the level of mastery of materials is below 76% for all indicators), based on Table 6 and Table 7 before learning. Besides, the indicator uses a micrometer to read the long measurement results. Even more than 50% of students do not master the content/subject matter on four indicators, namely, mentioning parts of the calipers, mentioning parts of the micrometer, procedures for using and reading the micrometer screw scale reading the length measurement using a screw micrometer.

More than 50% of the students had a degree of understanding of materials or indicators of more than 60% (good, excellent, and special categories) after learning, except for differentiating indicators calculated by counting and offering. For instance, no students met a particular category. Moreover, no more students are not mastering the content for the first three indicators after

learning. However, there are still students who are not mastering the material for the last four indicators.

It can be observed from this clarification that the implementation of the discovery learning model with multi representations can enhance the comprehension of each indicator in the measuring material by students. As explained, indicators mean N-gain on the subject calculation; all indicators have increased with an average N-gain between 0.48-0.63.

e. The relationship between initial knowledge and pre-test and post-test on measurement topics

The relationship between the original information gained from the basic understanding of physics assessments for class grouping when entering school to understand students on the subject of measurement is presented in Table 8.

Table 8. The relationship between students' initial ability levels with pre-test and post-test on the topic of measurement

No	Initial ability level	Average			
		TA	Pre-test	Posttest	N-gain
1	Groups of students with low abilities	37.5	13.2	62.8	0.57
2	Groups of students with medium abilities	41.4	17.2	58.0	0.52
3	Groups of students with high abilities	45.0	17.0	66.5	0.61
	Average total (N=36)	41.5	16.3	61.4	0.55
	Standard deviation total	2.8	13.9	21.0	0.21

Note: TA (Initial ability)

The mean comprehension of students on the measurement content tends to be compatible with their initial ability (TA) based on Table 8. In contrast, the pre-test has almost the same mean between students with modest abilities and elevated abilities. In the post-test performance, it can be shown that high-quality students have a higher increase in N-Gain (0.61) compared to the middle and low-quality student classes with an average N-Gain of 0.52 and 0.57, respectively.

The rise N-Gain of the high-capacity and low-capacity groups of students (0.61 and 0.57 respectively) can be shown from the data in Table 8 to be higher than the N-gain of the moderate-capable group (0.52). It implies that implementing the multi representation discovery learning model is appropriate for enhancing the comprehension of the measurement content by high-capacity students and low capacity.

These findings indicate that multi representation based learning is effective in increasing the conceptual understanding of students with "low" and "medium" initial abilities [19].

V. Conclusion

Based on the explanation of the study, it indicates that there is an improvement in the conceptual comprehension of students with a mean pre-test score of 16.2 (SD = 14) and post-test 61.4 (SD = 21) via the multi-representation aided discovery learning model on the subject of measurement between pre-test and post-test.

These results indicate that the concept is substantially improved with a boost in the un-normalized gain of 0.5 (SD = 0.2) and the intermediate category. By offering representational learning facilities, student communication can be generated, and students can help solve problems and better understand concepts. Moreover, with an average N-gain of 0.63, an improvement in understanding the principle on the subject of measurement, particularly on the indicators explaining the calipers' sections and the screw micrometers obtained.

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