Critical Thinking Skills (*CTS*) and Rigid Object Rotation (*ROR*) Concept Mastery Through Multiple-Based Representation (*MR*) in Mechanics Learning Using *GeoGebra* Software

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Abstract: This research examines critical thinking skills and concept mastery of the Rigid Object Rotation (ROR) in Mechanics learning in Physics education students. There are some computer programs in Mathematics learning used in Physics learning, e.g. *GeoGebra*. The subjects of this study were 21 students of third semester at one private university in Jakarta. This is a mixed method research with quantitative and qualitative triangulation. The data collection instruments were the tests results on the Rigid Object Rotation (ROR) multiple-based representation (MR) concept that corresponds to the concept of understanding by using revised Bloom's taxonomy and California Critical Thinking Test (CCTT) to evaluate critical thinking skills and Critical Thinking Disposition Inventory (CTDI) to measure students' critical thinking attitudes. The results show that the average rate of pre-tests was 44.38 and the average rate of post-test was 68.14 with percentage of N-Gain of 42.5 % for the mastery of ROR concept which shows improvement. The results of multiple representations (MR) analysis on students' worksheet (SW) using *GeoGebra* software for ROR were 61.7 % for verbal, 85.7 % for picture, 45.3 % for graph and 77.9 % for Mathematics which show considerable percentage. The results of the analysis on Critical Thinking Skills (CTS) was categorized as good as well as the improvement of ROR concept mastery using *GeoGebra* software was in good category.

1. Introduction

There are three basic things that students should have in Physics education are namely conceptual, analytical, and numerical aspects [18]. In Mechanics course, it requires a lots of understanding on abstract concepts. Teachers as the facilitators have responsibility to ensure these three concepts are mastered by the students. In this case, the lecturers should prepare a set of teaching materials, one of which is to prepare relevant learning media. The development of information and technology (IT) is one influential factor that can be utilized by the lecturers to support the learning process of Mechanics to facilitate the learning process and increase students' conceptual understanding as well as analytical and numerical abilities.

Regarding the students' ability, critical thinking as a mental process for analyzing or evaluating information should be part of consideration. The information can be obtained from observation, experience, common sense or communication like discussion [3]. Critical thinking is a mental activity to evaluate the truthfulness of a statement. In general, the evaluation ends with the decision to accept,

deny, or doubt the truthfulness of the statement in question [13]. The basic conception of critical thinking is to think correctly in obtaining relevant and reliable knowledge [19]. Critical thinking means thinking logically, reflectively, responsibly, and proficiently. From Steven's sense, someone who thinks critically is likely to determine the relevant information as the thinking process is accurate regarding the information so that it can be trusted, logical, and in conclusion, convincing, and can make responsible decisions. A person who thinks critically may provide logical analysis and draw reliable conclusions. Critical thinking is thinking process aimed at making rational decisions that are geared towards deciding whether to believe or do something [8].

From Ennis' definition on critical thinking, it can be concluded that critical thinking focuses into the sense of something full of consciousness and leads to certain purpose. The goal of critical thinking is to allow us taking decisions. Critical thinking activities consist of formulating, analyzing, solving problems, concluding and evaluating. In addition, Bloom classifies intellectual skills from simple to complex skills such as knowledge or recognition, comprehension, application, analysis, synthesis, and evaluation. The skill of analyzing, synthesizing, and evaluating on Bloom's taxonomy are categorized as higher level skills or Higher Order Thinking Skills (HOTS) [4]. The agreement obtained from the results of the workshops of the American Philosophical Association on components of intellectual skills required on critical thinking include interpretation, analysis, evaluation, inference, explanation, and self-regulation [7]. According to Ennis, critical thinking is a sensible and reflective thought focused on deciding what to believe or do. The indicators proposed by Ennis are namely formulating problems, giving arguments, performing observations, performing deductions, inducing induction, evaluating, deciding, and implementing [10].

The implementation of critical thinking skills depends on the students' cognitive style. Cognitive style is a way of the students to absorb information; some students are better to absorb information verbally, categorized as verbal learning, while other students are rather to absorb the information easier through drawing or mathematical learning. In dealing with such learning styles, such learning approach that may convey the materials in multiple representation is necessary [17]. Learning styles are classified into three styles, e.g. visual, auditorial, and kinesthetic styles. Of these three learning styles, there are individuals who tend to be in one style, while some others are able to perform all learning styles [6]. If the teacher's teaching strategy is appropriate with students' learning style, the lesson would be easily understood by the students [5]. Multiple representations and multimedia are believed to support learning process in many different ways [1]. Learning with multiple presentations (MR) is believed to be more effective at building students' mental models and understanding concepts compared to conventional learning approaches [21].

This study explores how the students utilized multiple representations (MR) including texts, graphs, symbols, rules, and formulas in solving mathematical problems; in addition, it deals with the multimedia system (*GeoGebra* software) can be used to support students in conducting multiple representations (MR). The study also intends to investigate the relationship between the students' critical thinking ability and concept mastery. Multiple representations (MR) are considered as teaching practices involving depictions, symbolizing, or representing a concept or process through different forms of representations [16]. Representations, such as diagrams, equations, drawings, models, animations, maps, tables, graphs, diagrams, and text are pervasive in the context of science. Representation is the right tool that helps students overcome difficulties, learn abstract concepts and build scientific knowledge [22]. By using multiple representations, it is believed to support students' deep understanding of the depiction of one representation to another (for example, from a concrete to an abstract, from simple to complex).

The abstract concept employed in this study is critical thinking skills related with rigid object rotation (ROR) materials, such as rigid body mass center, rotation of rigid fixed axis, moment of inertia, calculation moment of inertial rod, physical pendulum, momentum, the angle of the rigid object in the laminar motion, laminar motions as the example of the rigid object, the impulse and the collision involving the rigid object [9]. *GeoGebra* software is the computer program which can be used to facilitate the abstract concepts and build scientific knowledge. It is an alternative learning media which is appropriate to the development of the current era and can help in terms of delivering abstract material. *GeoGebra* is developed by Markus Hohenwarter in 2001. *GeoGebra* is a computer program (software) to teach Mathematical Geometry and Algebra [11]. *GeoGebra* main menu are, namely *File, Edit, View, Option, Tools, Windows,* and *Help* to draw geometry object CTS. There are a lots of abstract concepts

in the concept of physics on ROR material, and all of these abstract concepts can be solved by using images and graphs through *GeoGebra* software.

2. Method

The research was conducted at one private university in Jakarta, involving third year undergraduate students (N=21) as participants, started from December 2018 to January 2019. This is a mixed method research quantitative and qualitative triangulation approach. In this research, the implementation stage of research included treatment by applying multiple-based representation (MR) on Mechanics learning (treatment = O), pre-tests and post-test (X1, X2) of which the results after the treatment were to become the outcomes of learning understanding on the concept of ROR mechanics and the assessment of students' worksheets (SW) using critical thinking skills (CTS). The data of this study were obtained through tests results on understanding the concept of mechanics with five questions based on the indicators of understanding the concept stated in Bloom's theory [2]. The analysis students' critical thinking skill was by using California Critical Thinking Test (CCTT) in order to evaluate critical thinking skills and Critical Thinking Disposition Inventory (CTDI). The data analysis techniques in this study were conducted through N-Gain analysis, normality, and homogeneity [12]. Quantitative and qualitative analyses of test instruments included measurement of the validity rate of problems, reliability, and descriptive analyses.

3. Results and Discussion

Kinematics is often referred to as motion geometry, which means that the resolution of overall kinematic problems can be solved geometrically. *GeoGebra* is a dynamic mathematics application for Mathematics learning and science education at schools [15]. This application is developed by Markus Hohenwarter with his programmer team. By utilizing the software, students are believed to be fully engaged to build their own animations of object motion to indicate their conceptual understanding, and thus their analytical and numerical abilities can be improved. The ability to think critically can be developed through the Mathematics learning at schools or universities, which focuses on the system, structure, concepts, principles, and the strict relationships between one element and other elements [14]. Multiple Representations (MR) as the practice of re-presenting the same concept through various forms, which include verbal, visual, symbolic, graphic, and numerical modes to describe concepts at the macroscopic, microscopic, and symbolic levels [21].

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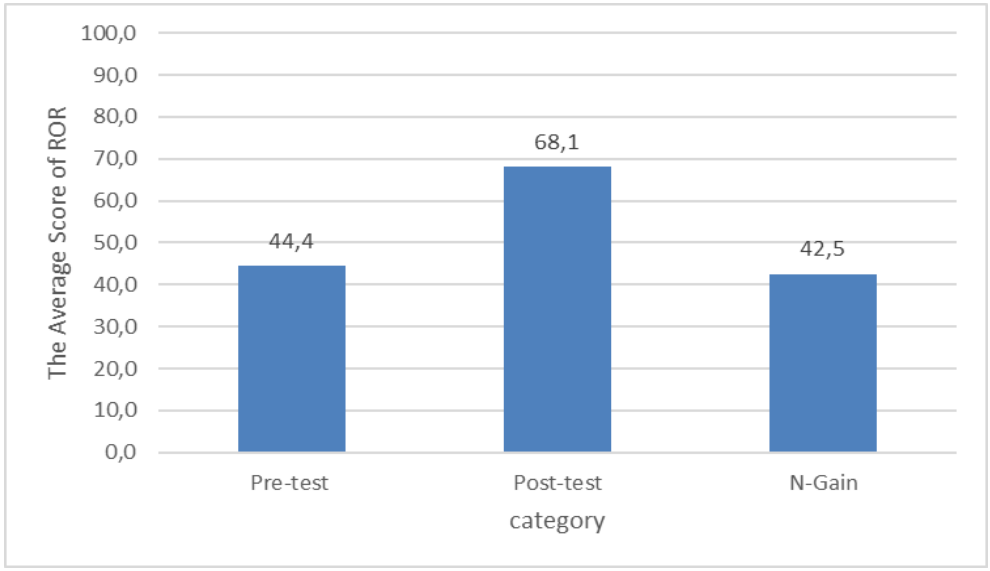

Figure 1. The Average Scores of Pre-Test and Post-Test with the Percentage of N-Gain 42.5 % on Mastering the ROR Concept

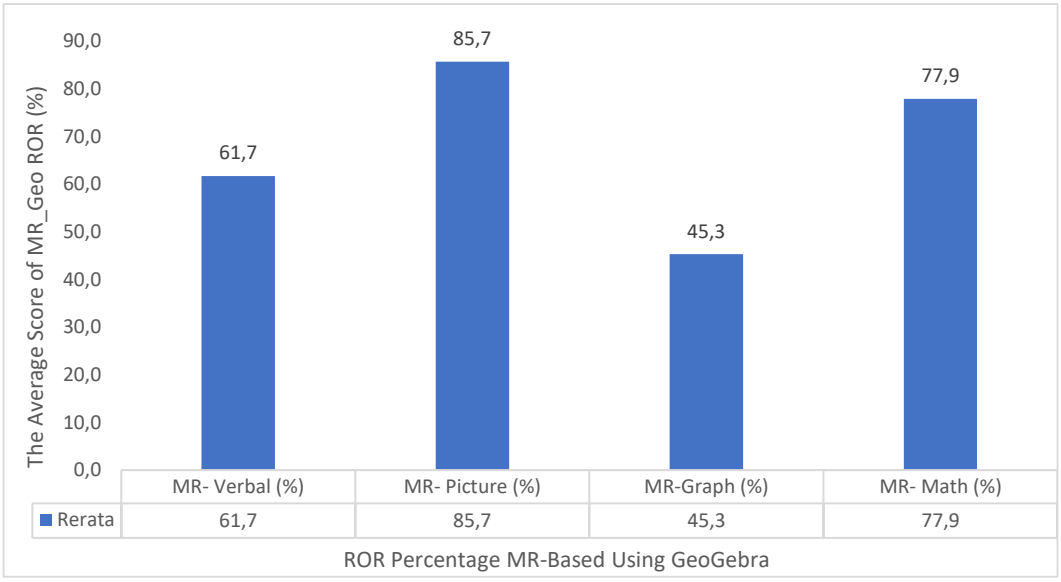

Figure 2. The Average Scores of Critical Thinking Skills and ROR Concept Mastery Based on MR Using *Geogebra* Software

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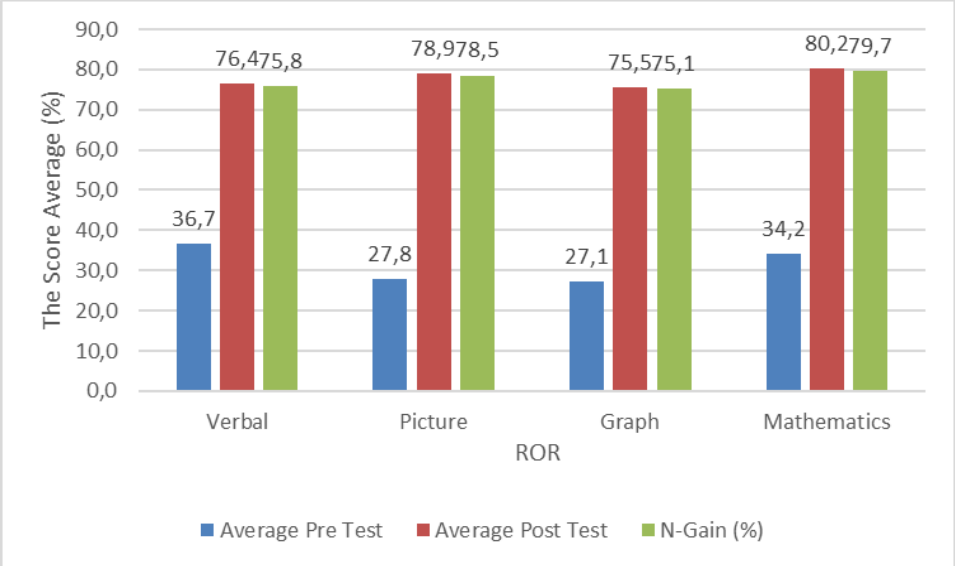

Figure 3. The Average Results of Employing Multiple Representation (MR) to ROR Concept Mastery by Using *Geogebra*

Figure 3 describes MR-based on the concept mastery and critical thinking skills by using *GeoGebra* software. It shows that the results of the concept mastery increases in the analysis of critical thinking skills for ROR concept, and the category was good as seen in the results of improvement before being given treatment namely without Students' Worksheet (SW), in which the results were low. The improvement levels show before and after the treatment, namely 36.7 % to 76.4 % for verbal, 27.8 % to 78.9 % for figures, 27.1 % to 75.5 % for graphs, and for mathematics the increase was from 34.2 % to 80.2 %. It can be seen that students' critical thinking skills have improved after being given treatment in filling MR-based worksheet using *GeoGebra* software.

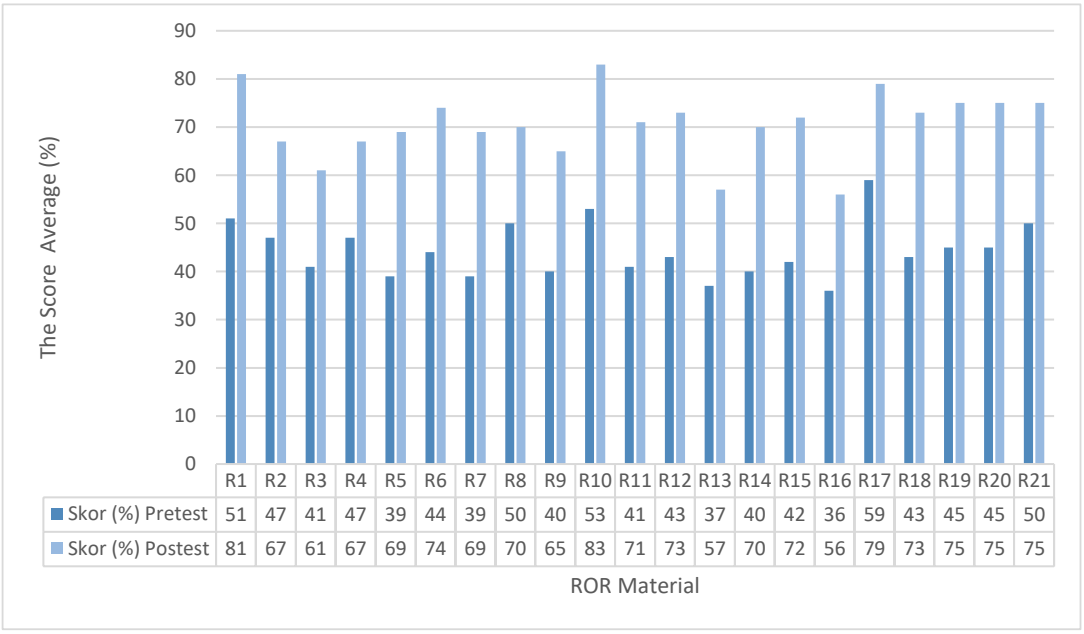

Figure 4. Analysis of Critical Thinking Skills (CTS) on Students' Worksheet (SW) for ROR Material

Figure 4 shows the results of the analysis of critical thinking skills (CTS) of the respondents (N=21). The analysis results show an average of 70.6 % in the medium category, with special annotation that there were 2 respondents obtaining less than 60 for the post-test scores. The average score of the pre-test score was 44.4 %, while the posttest was 70.6 %. There is a clear increase in students' understanding of the concept after using critical thinking skills on students' worksheet. There are seven sub-topics of the concepts covered in ROR material as outlined in the students' worksheet using MR-based critical thinking skills developed using *GeoGebra* software. The completion scores are categorized into good level.

4. Conclusion and Recommendation

The results of data analysis and discussion on understanding the basic concept of Mechanics of the students show that the critical thinking skills in learning mastery for the ROR material through Multiple Representation (MR) in Physics education have increased. In terms of concept mastery, it was categorized into good percentage, as well as the implementation of critical thinking skills which was considered as at the good category. As the limitations, this study can only be implemented in classical learning setting with sufficient Internet access supported with IT media. Thus, the learning of Mechanics subject through multiple-based representation approach could be effectively applied to the ROR concepts for the students majoring on Physics education. It is suggested that the implementation of multiple representation on Mechanics subject be used as the alternative learning approach of other courses. It is expected that future researchers would involve varied variables for similar context.

Acknowledgement

The author would like to thank all the students as the supportive team for data collection. In addition, the authors extend the appreciation and gratitude to BUDI-DN and LPDP as the sponsors and all respective parties who have big impact on the success and completion of this research. The authors expect positive criticism and suggestions.

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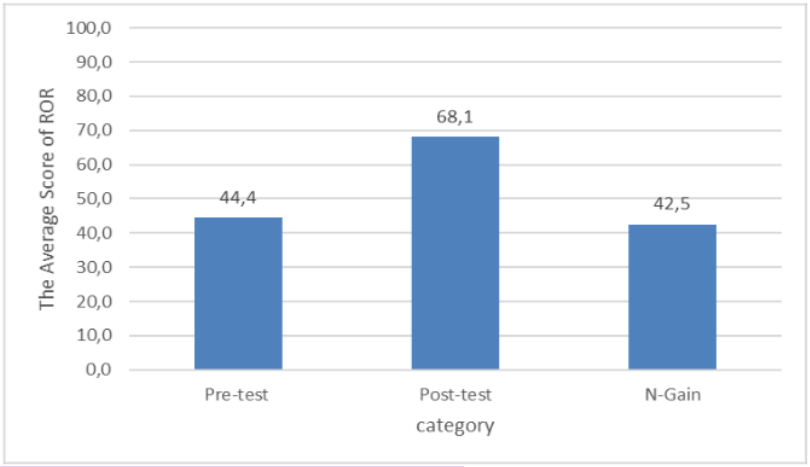

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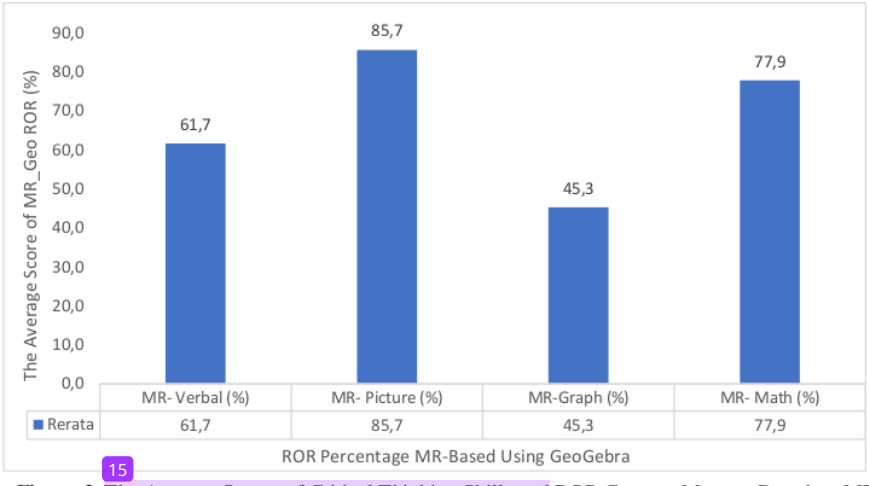

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In Figure 2, the results of the analysis of critical thinking skills and ROR concept mastery based on Multiple Representation (MR) using *GeoGebra* are respectively 61.7 % for verbal, 85.7 % for image, 45.3 % for chart and 77.9 % for math. These four representations were categorized into a good level, with the percentage ranged from 45 % to 90 %. This category indicates that the students are able to analyze the ROR concept verbally, images (visually) and mathematically. On the other hand, students' skill to analyze the graphics was categorized into lower (poor) category on understanding the materials; based on the entire sub-chapter, there have been changes, and they show increasing trend.

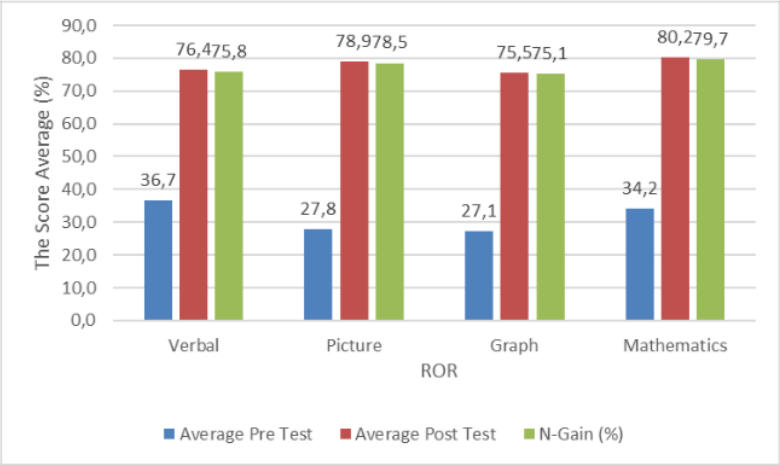

Figure 3. The Average Results of Employing Multiple Representation (MR) to ROR Concept Mastery by Using *Geogebra*

Figure 3 describes MR-based on the concept mastery and critical thinking skills by using *GeoGebra* software. It shows that the results of the concept mastery increases in the analysis of critical thinking skills for ROR concept, and the category was good as seen in the results of improvement before being given treatment namely without Students' Worksheet (SW), in which the results were low. The improvement levels show before and after the treatment, namely 36.7 % to 76.4 % for verbal, 27.8 % to 78.9 % 18 figures, 27.1 % to 75.5 % for graphs, and for mathematics the increase was from 34.2 % to 80.2 %. It can be seen that students' critical thinking skills have improved after being given treatment in filling MR-based worksheet using *GeoGebra* software.

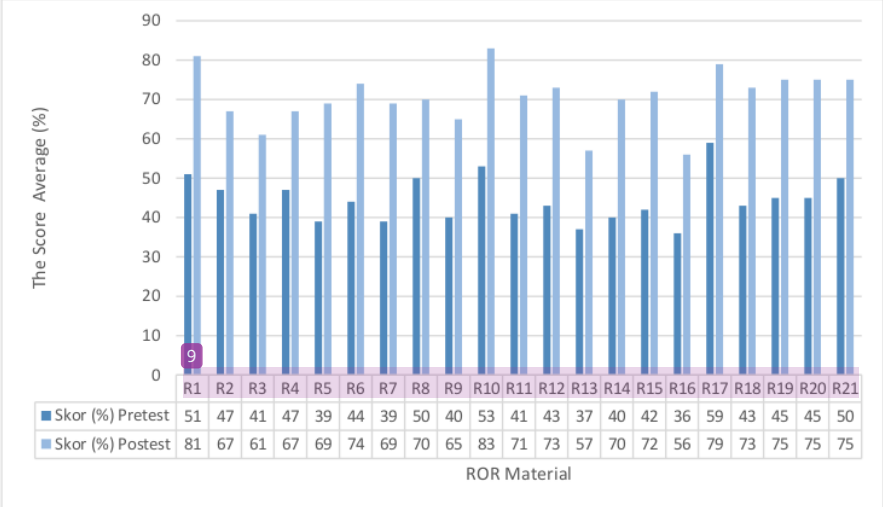

Figure 4. Analysis of Critical Thinking Skills (CTS) on Students' Worksheet (SW) for ROR Material

Figure 4 shows the results of the analysis of critical thinking skills (CTS) of the respondents (N=21). The analysis results show an average of 70.6 % in the medium category, with special annotation that there were 2 respondents obtaining less than 60 for the post-test scores. The average score of the pre-test score was 44.4 %, while the posttest was 70.6 %. There is a clear increase in students' understanding of the concept after using critical thinking skills on students' worksheet. There are seven sub-topics of the concepts covered in ROR material as outlined in the students' worksheet using MR-based critical thinking skills developed using *GeoGebra* software. The completion scores are categorized into good level.

Conclusion and Recommendation

The results of data analysis and discussion on understanding the basic concept of Mechanics of the students show that the critical thinking skills in learning mastery for the ROR material through Multiple Representation (MR) in Physics education have increased. In terms of concept mastery, it was categorized into good percentage, as well as the implementation of critical thinking skills which was considered as at the good category. As the limitations, this study can only be implemented in classical learning setting with sufficient Internet access supported with IT media. Thus, the learning of Mechanics subject through multiple-based representation approach could be effectively applied to the ROR concepts for the students majoring on Physics education. It is suggested that the implementation of multiple representation on Mechanics subject be used as the alternative learning approach of other courses. It is expected that future researchers would involve varied variables for similar context.

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