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Research Article

Effects of Multiple Representation in Student's Conceptual Understanding and Metacognitive Awareness in Mechanics

Mark Joseph F. Orillo, Voltaire M. Mistades

De La Salle University, Manila, Philippines

ORCID
Mark Joseph F. Orillo: https://orchid.org/0000-0002-2758-9949
Voltaire M. Mistades: https://orchid.org/0000-0002-2758-9949

Abstract.
Using a mixed-method design, the study investigated the effect of the use of multiple representations on 207 (106 male and 101 female) Grade 11 students' conceptual understanding and metacognitive awareness in learning concepts in physics (mechanics). There were five multiple representations (MRs) used in this study namely: (a) drawing/sketch, (b) free-body diagram/FBD, (c) description, (d) mathematical equation, and (e) concept map (Know - Want to know - Learn). These MRs were embedded in the teacher's lesson plan as a strategy for teaching and learning selected topics in Mechanics. All these MRs were used by the teacher to discuss each lesson, and by the students to understand and do the tasks given to them. The conceptual understanding of the students was measured by obtaining the mean scores from the formative test scores in the form of a 10-item quiz for the following topics - Kinematics, Laws of Motion, and Universal Law of Gravitation. The students' metacognitive awareness was measured using the 52-item metacognitive awareness inventory (MAI) questionnaire, given before and after the implementation of the teaching-learning intervention. Students' perceptions on the use of MRs were also gathered in the form of short responses to a 5-item questionnaire. Their responses to these questions were used to elaborate and explain the results in the subcategories of the MAI. Mean scores in the formative tests revealed that students obtained passing grades in all three quizzes. Results also showed that there was an increasing trend in the students' mean scores from Quiz 1 to Quiz 3. Paired t-test also showed that the increase in the students' scores moving from Quiz 1, Quiz 2, to Quiz 3 were significant at $p < 0.05$. The results of the Metacognitive Awareness Inventory (MAI) questionnaire revealed that a significant difference was observed, when comparing the students' profile scores before and after the implementation of the teaching-learning intervention. The use of multiple representations (MRs) made the students more aware of how they think about learn the physics concepts.

Keywords: multiple representation, conceptual understanding, metacognitive awareness

Corresponding Author: Mark Joseph F. Orillo; email: voltaire.mistades@ dlsu.edu.ph

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1. INTRODUCTION

The landscape of basic education in the Philippines has undergone a significant change with the introduction of the K to 12 curriculum in 2012. The K to 12 curriculum advocates the principle of spiral progression in learning. It gives emphasis to the development and mastery of prerequisite ideas and skills to equip the learner in the comprehension and application of more complex ideas. The progressive building of conceptual understanding plays a crucial part in the entire holistic transition of individual learners from basic to advanced learning [1].

In the same manner that conceptual understanding sets a vital function in the teaching-learning process, metacognitive awareness has importantly contributed to the development of a wide range of educational mechanisms, such as verbal articulation of information, verbal persuasion, verbal comprehension, reading comprehension, writing, language acquisition, attention, memory, problem solving, social cognition, and various types of self-instruction. Metacognitive awareness is defined as 'cognition about cognition or thinking about one's own thinking, including both processes and the products' [2]. Metacognitive awareness helps develop learners' control and self-regulation while engaged in learning [3].

While both constructs, conceptual understanding and metacognitive awareness, are known to be vital in the instructional settings, there remains a challenge to facilitate their development, more so, their sustained existence, among learners. Perhaps because these two are not easily achieved, and it takes the learner's initiative to maximize their worth. Nonetheless, the instructional composition of classroom learning should always focus on these two important constructs and the goal is to nourish these important mental facilities in any learning domain taught in the classroom.

Physics uses mathematical modeling to describe phenomena and to explain relations between variables. This explains why learning Physics necessarily include both the conversion of Physics modeling to mathematical modeling and the interpretation of mathematical models from a Physics' point of view. Acquisition of conceptual knowledge on the domain of Physics had been perceived by learners to be extremely challenging because it entails pragmatic problem solving, which are at times foreseen as incomprehensible or beyond the level of students' ability to understand [4]. This had been observed by the authors during class sessions, when students are unable to correlate the conceptual ideas with mathematical models. The same is true concerning the metacognitive strategies employed by these learners when attempting to comprehend concepts and applying them to word problem. The learners' use of metacognitive strategies, as observed in their performance level, remains low. Other research has reported similar observations [5, 6]. Thus, there is a need for teachers to include in their daily instructional plan, strategies on improving the conceptual knowledge and metacognitive awareness of learners.

The task to incorporate the development and sustenance of conceptual knowledge and engagement to metacognitive strategies among learners, can be facilitated by pedagogical strategies that include utilization of multiple representations. These may be in the form of pictures, words, graphs, diagrams, and equations. Mayer [7] has postulated that students learn better with a combination of words, pictures, and other representations. This is supported by the experimental study [8] as regards the effective utility of multiple representations in enhancing mental models to ensure that the right concept is reinforced. With the use of multiple representation approach, it was shown that student's mental model abilities have significantly increased. The study further showed that multiple representation facilitated the autonomous learning of students, who develop the freedom to think strategically and actively engage as they are able to keep track of their learning capabilities.

Learning Physics entails pragmatic problem solving and translation of conceptual ideas to mathematical models. Given these mental exercises evident in the learning of Physics, it is necessary to develop in learners the utility of metacognitive strategies as well as the building of basic and advanced conceptual knowledge. Following the arguments of Mayer [7] and of Haili, Maknun, and Siahaan [8] relative to the use of multiple representations, this research investigated how the teaching Physics concepts (Mechanics) through Multiple Representations (MRs) affected student's metacognitive awareness and conceptual understanding.

Specifically, the research was guided by the following questions: 1) What is the effect of the use of Multiple Representations in developing students' conceptual understanding? 2) What is the change in students' metacognitive awareness after using Multiple Representations in learning Physics concepts (Mechanics)? 3) What are the students' perceptions on the use of Multiple Representations in understanding Physics concepts (Mechanics)? .

2. RESEARCH method

This research followed a mixed method design in which both quantitative and qualitative data were gathered and analyzed to understand the research problem. The quantitative data were in the form of formative test scores and metacognitive awareness scores of the students; while the qualitative data was obtained from short response answers.

The participants in the study were two hundred and seven (207) Grade 11 students from a public Senior High School in Cavite, Philippines. The students were taking their Physics class. The topics during the implementation of the research include: Kinematics, Laws of Motion, and the Universal Law of Gravitation. The teaching – learning strategy utilized five forms of Multiple Representations, namely free-body diagram (FBD), sketching/drawing, description, mathematical equation, and conceptual map (Know – Want to know – Learned), which were embedded in the Physics teacher's lesson plan.

Prior to the implementation of the teaching – learning strategy, the students answered the Metacognitive Awareness Inventory (MAI) [9]. The MAI consists of the following sub-scales: declarative, procedural, conditional, planning, information management strategies, comprehension, debugging strategies, and evaluation. The students took around 30 minutes to finish answering the inventory. For each topic covered by the class session, a formative test (short quiz) was administered to the students. This is to determine their conceptual understanding. Each quiz was composed of ten (10) items, five true/false questions and five concept questions.

At the end of each class session, after using the Multiple Representations in solving the word problems, the students also answered the following open-ended questions:1) How did you find the word problems for this topic? 2) Which Multiple Representation helped you the most in solving the word problem? Why? 3) If you were not able to completely answer the word problem, how do you think you will re-do it? After implementing the teaching – learning strategy for the three topics mentioned above, the students again answered the Metacognitive Awareness Inventory (MAI). The quantitative data obtained from the Quizzes and the MAI scores were then statistically analyzed using Statistica 13.4 to determine if there is an improvement in students' conceptual understanding and metacognitive awareness

3. result and discussion

Mean scores of the students for each quiz. We see an increasing trend in the students' scores. Their familiarity with the use of several Multiple Representations have contributed to the students' conceptual understanding of the different topics.

Even though the qualitative responses showed that majority of the students perceived the lesson as being difficult, they also reported that the use of the Multiple

Table 1: Mean scores of the students in quiz 1, 2, and 3.

Quiz Number	Topic	Mean Score	Paired Differences
1	Kinematics	6.56	[a]
2	Newton's Laws of Motion	7.59	[b]
3	Universal Law of Gravitation	8.57	

[a] statistically significant difference between Quiz 1 and Quiz 2
[b] statistically significant difference between Quiz 2 and Quiz 3

Representations allowed them to understand and represent the word problems. From the five (5) MRs used in this study, the students reported the use of free-body diagram (FBD) and mathematical equation as most helpful in their conceptual understanding.

In a related study conducted among junior high school students [10], it was reported that the algebraic thinking ability of the students had been positively improved with the use of multiple representations consisting of orientation, exploration, internalization, and evaluation. Using a quasi-experimental methodology, it was found out that students who were exposed to multiple representations performed better in algebraic solving tasks and manifested learning completeness.

Similar results had also been shown in a study conducted among 115 college students taking Physics [11]. The inclusion of multiple representation in direct instruction had a positive effect on the student's mental modeling ability. It has increased the achievement of learning outcomes because students were found to be highly engaged during the problem-solving activities and they manifested increased conceptual understanding of the processes involved in the learning.

Table 2: Students' profile in the Metacognitive Awareness Inventory (MAI).

Subcategory	Pre-implementation	Post-implementation	
Declarative Knowledge	5.07	6.07	*
Procedural Knowledge	3.55	5.05	*
Conditional Knowledge	3.78	5.02	*
Planning	4.63	5.70	*
Information Management Strategies	6.13	7.00	*
Comprehension Monitoring	5.47	6.29	*
Debugging Strategies	4.28	5.65	*
Evaluation	4.09	5.64	*

Table 2 shows the specific knowledge and strategies of metacognition influenced by the Multiple Representations. It also shows that students' knowledge about cognition (declarative knowledge, procedural knowledge, and conditional knowledge) and students' regulation of cognition (planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation) have increased after the three-week implementation of the teaching – learning strategy. As observed in the current study, Dulger and Ogan-Bekiroglu reported that a medium level positive relationship existed between metacognitive awareness and problem solving strategies in secondary level Physics [12].

4. CONCLUSION

In this study, three Physics topics (Kinematics, Newton's Laws of Motion, and Universal Law of Gravitation) were taught using the integration of Multiple Representations (MRs) in the lessons. Using the five (5) MRs —- drawing/sketch, free-body diagram (FBD), description, mathematical equation, and conceptual map (Know – Want to know – Learned) —- integrated in the discussion showed improved conceptual understanding and metacognitive awareness in the students. We have seen a steady increase in the students' mean quiz scores. Paired sample t-test shows that this increase in the students' mean quiz score is significant at $p < 0.05$. The metacognitive awareness of the students, measured using the MAI, likewise revealed an increase when comparing the scores before and after the teaching – learning intervention. The qualitative responses on the questions further reveal that students became more aware of their strengths and weaknesses as a learner. They were able to identify the best MR they can use for specific lessons, they also figured out the main cause why they don't understand the topic, and they can correctly approach the word problem the next time they would encounter something similar.

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