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EXPLORING THE NEXUS AMONG MULTIPLE REPRESENTATIONS, PROBLEM-SOLVING AND MULTIPLE REPRESENTATIONAL ABILITIES OF PHYSICS STUDENTS

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ABSTRACT

This study examined the relationship among multiple representations, problem-solving and multiple representational abilities of senior secondary school physics students. Correlation and multiple regression analysis were adopted. Two hundred and ninety-four senior secondary school Physics students selected from six purposively sampled coeducational and urban schools in Education Districts V of Lagos State formed the sample. Test of Knowledge of Multiple Representations Abilities in Projectiles and Equilibrium of forces (TKMRA-PE), Multiple Representations Abilities Assessment Instrument (MRAI) and Problem-Solving Assessment Instrument (PSAI) were used to collect data. The reliability coefficients were determined to be 0.83, 0.75 and 0.70 using split-half reliability coefficient respectively. Three research questions raised for investigation alongside one corresponding null hypothesis were tested. Quantitative data gathered were analysed using the bar graph, Pearson Product Moment Correlation Coefficient and Regression analysis. Findings of this study revealed that there was no relationship between multiple representational and problem-solving abilities; $r = .260$; $p > 0.05$. Furthermore, the study revealed that there was a significant causal relationship among multiple representations, problem-solving and multiple representational abilities. Multiple representations and problem-solving accounted for 31.4% of the variance in the multiple representational abilities of physics students. The study concluded that multiple representations enhanced multiple representational abilities in Physics. The use of multiple representations should be explored by Physics teachers to develop in-depth conceptual understanding.

KEYWORDS

Multiple representations, problem-solving, multiple representational abilities.

Introduction

The knowledge of physics requires an understanding of physics concepts, principle and processes on one hand and the nature of physics on the other hand. Physics involves conceptual representations of a physical system, events and processes. A good understanding of physics concepts and principles is a pre-requisite for problem-solving (Redish & Steinberg, 1999).

In the process of solving physics problems, students are required to use various methods, techniques, and approaches to help solve problems correctly, such as the use of multiple representations (Dewati et al., 2019a). Multiple representations is a strategy that is being developed to foster understanding of concepts and solving physics problems (Dewati et al., 2019b; Prahani et al., 2016). Multiple representations are a tool in the learning process that can visualize various concepts and bridge them into various equations that are correct to solve problems (Dewati et al., 2019a, 2019b). Multiple representations help students to develop complex knowledge and scientific concepts, so students can develop their competencies (Dewati et al., 2019a).

In physics problems, multiple representations have several types including verbal or linguistic, diagrammatic, pictorial, graphic, symbolic, and mathematical forms. If students have the ability in many representations, it can be said that students have multiple representational abilities (Hung & Wu, 2018). Previous research proved that students who can translate verbal problems into diagrams have better problem-solving abilities than students who cannot translate the problem (Bollen, Kampen, Baily, Kelly, & Cock, 2017).

In a study conducted by Chiou and Anderson (2010) who examined the relationship between students' mental models and their explanations about heat conduction. The researcher conceptualized mental models as cognitive representations that become external through the use of analogies about heat transfer. Data, which included verbal, drawings, and written responses, were collected through in-depth clinical interviews with 30 senior undergraduate physics students. This finding showed the need to consider both the processes of analogy production and students' conceptual understanding.

Similarly, Fredlund et al. (2012) investigated the potential of different representations in supporting students' understandings of the properties of light in an interactive learning session. As the researchers argued, the use of representations in physics which includes spoken and written language as well as gestures plays a critical role in the effectiveness of student's understanding of the properties of light.

Kohl and Finkelstein (2005) examined students' competence to use different representational formats which refer to the many ways in which a particular concept or problem can be expressed. The study was conducted in two algebra-based introductory physics classes (n=546 and n=367) and included a combination of large-group lectures and small-group tutorials. The data included homework problems and quiz problems. The results showed that students' performance on physics problems varied with the representational format. Most of the students were successful with the use of the mathematical format. However, the researchers also noticed that the correlation between the representation format and the performance depended strongly on the topic of the problem.

To examine how and when students' performance in terms of problem-solving varies with problem representation (i.e., verbal, mathematical, graphical, or pictorial), Kohl and Finkelstein (2006) carried out a study with 16 students who were enrolled in an introductory physics course. The researchers interviewed the students to examine how they solved the problems, and specifically, the strategies that they employed. The findings showed that students' strategies ranged from very diverse to very consistent when confronted with different representations, and the students who use more variation in their strategies performed more poorly than the ones who were consistent...

A similar study was carried out by Meltzer (2005) who explored the impact of different kinds of representations on students' problem-solving performance. Five years of classroom data from 400 students were collected in an algebra-based general physics course. The instruction between the pre-test and post-test was based on an interactive engagement approach. The evaluation of the students' responses showed that the proportion of correct answers on the verbal question was consistently higher than on the diagrammatic question. Also, the pattern of incorrect responses to the questions differed consistently. Additional data were collected through four quizzes. Each quiz had four very similar questions posed in four representations: verbal, diagrammatic, mathematical/symbolic, and graphical. Based on the responses to both of the quizzes, the researcher compared the incorrect responses for each representation. It was found that there was a statistically significant difference in the Coulomb quiz (diagram versus graphical), but no significant differences were found between different representations in general.

Similar results were produced in a study carried out by De Cock (2012) who examined whether students performed differently when solving a physics problem formulated in different representational formats (i.e., verbal, pictorial, graphical), and what kinds of problem-solving strategies they use depending on the representational format in which the problem is stated. This study involved 200 first-year students enrolled in a mandatory physics course as part of the pharmaceutical science program in three consecutive years. Multiple-choice test items were used in different representational formats, and the students had to provide explanations of their answers. The results of this study showed that the representational format affected students' performance on the tasks.

Many studies also revealed that students 'construction of multiple representations of physics concepts can offer a new approach to teaching and learning in the physics classroom. (Carolan, Prain & Waldrip, 2008; Harrison & De Jong, 2005; Harrison & Treagust 1999; Haslam, Tytler,& Hubber, 2009; Howitt, 2009; Lemke, 2004; Prain & Waldrip, 2006).Despite this, students still attempt to solve problems by matching quantities listed in the problem statement to special equations that have been used to solve similar problems. They move between words and equations, with no attempt to connect other representations to a more qualitative representations approach that can improve understanding and intuition. In a typical procedure of solving problems, students often draw a sketch, develop qualitative physical representations, such as free-body force diagrams, and *then* apply mathematical equations. Constructing these physical representations can help understand the problem and set up correctly multiple representations. Therefore, to help students learn physics most especially the concepts of projectiles and equilibrium of forces better and develop expertise in problem-solving, it is necessary to assess the student's abilities in using multiple representations and devise a better way to encourage the integration of multiple representations in their learning. A study conducted by Gagatsis and Elia (2004) attested that every problem could be solved using various forms of multiple representations and this means that problem solving and use of multiple representations are connected as many studies of physics problem solving revealed that students who are consistent across different representations perform better on problem-solving tasks (Melzer, 2002; Nieminen, Savinamen&Vinci,2012). This showed that there was a link between problem–solving and multiple representations. So, students are expected to understand various forms of representation to make it easier to solve problems. This study sought to examine the connection among multiple representations, problem-solving and multiple representational abilities of secondary school physics students.

The purpose of this study is to investigate the contributions of problem-solving and multiple representations to senior secondary school physics students' multiple representational abilities. Specifically, the study investigated:

1. The effects of multiple representations learning strategies on multiple representational abilities of physics students.
2. the relationship between multiple representational abilities and problem-solving abilities of physics students
3. The causal relationship among problem-solving, multiple representations and multiple representational abilities of secondary school physics students.

The following Research questions and hypothesis were formulated

1. Are there effects of multiple representations learning strategy on students' multiple representational abilities?
2. Is there a relationship between students' multiple representational abilities and problem–solving abilities of physics students?
3. Is there any causal relationship among problem-solving, multiple representations and multiple representational abilities in physics?

Hypotheses

H_{O1}: There is no significant causal link among problem-solving, multiple representations and multiple representational abilities of senior secondary school physics students.

Method

This study employed a pretest-posttest; control group quasi-experimental design with a 3x2x3 factorial matrix was used. The sample consists of two hundred and ninety -four students who were made up of one hundred and sixty-three male and one hundred and thirty-one female students selected from six intact senior secondary school II classes. Four purposively sampled co-educational and urban schools from Lagos State Education Districts V were used. Purposive sampling was used so as to minimize experimental contamination (Fraenkel & Wallen, 2000) by using schools that are far from one another. Three instruments were used to collect data in this study. These instruments include:

Test of Knowledge of Multiple Representations Abilities in Projectiles and Equilibrium of forces (TKMRA-PE), Multiple Representations Abilities Assessment Instrument (MRAI) and Problem-Solving Assessment Instrument (PSAI). The Test of Knowledge of Multiple Representations Abilities in Projectiles and Equilibrium of forces (TKMRA-PE) instrument consisted Section A which inquires the demographic data of the students and section B which consisted of four essay items on the selected topics of physics which were meant to measure students' ability to solve problems in different representations. The instrument (MRAI) which is meant to measure the students' abilities in using multiple representations to solve physics problems consists of four essay type item in section B. All these questions covered the concepts of projectiles and equilibrium of forces as stipulated in SSS2 physics scheme of work. These topics were chosen because students experienced difficulty (Okpala, 1988; Owolabi, 2006) and exhibited misconceptions regarding them (Cataloglu, 1996; Eryilmaz, 2002; Yilmaz, 2001)

Data on the two research questions raised were answered using descriptive, bar graphs; Pearson Product Moment Correlation and Regression Analysis were used to test the hypotheses.

Result

Research Question 1: Are there effects of multiple representations learning strategy on students' multiple representational abilities?

To answer this question, bar graphs of the mean and standard deviation of students" multiple representations ability test scores in Physics were used. The result is presented in Figure 1

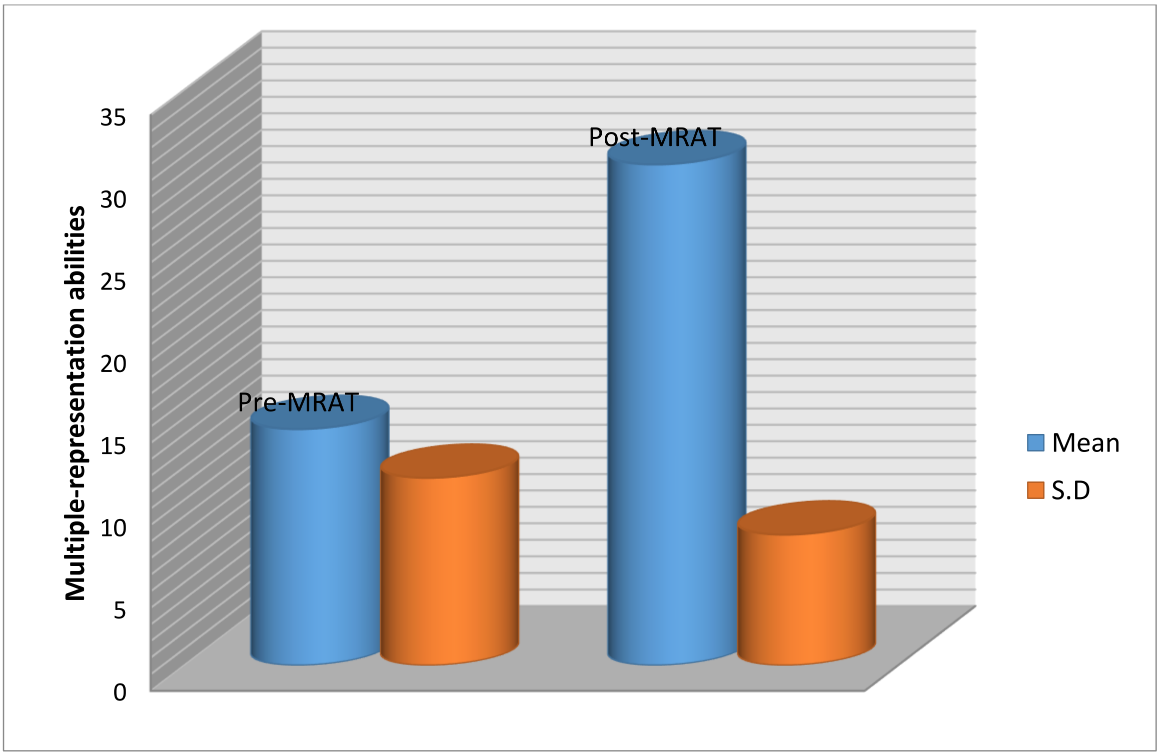

Figure 1: Graphical illustration of students' pre-test and post-test achievement in multiple representational abilities

Figure 1 shows the graphical illustration of the contributions of Pre –test and Post –test multiple representations to senior secondary school students" achievement in multiple representational abilities. The figure shows that the posttest scores of students' multiple representations abilities (M = 30.45, SD = 16.75) had higher contribution to their achievement in Physics than their pre-test achievement in multiple representational abilities (M = 14.31, SD = 11.33)

Research Question 2: Are there a relationship between students' multiple representational abilities and problem –solving abilities of physics students?

To answer this question, Pearson's Correlation between Students‟ multiple representational abilities and problem –solving abilities of physics students was used. The result is presented in Table 1.

Table 1: Significant test of Pearson's Correlation between Students' Concept Representation and their Achievement in Physics

Correlations

Multiple Representational	Problem-Solving	
Multiple Representational	1	.260
Sig	.300	
Problem-Solving	.260	1
Sig	.300	

Note = p > 0.05; =p > 0.01; N =294

The result in Table 1 shows that there is no correlation between Students' Multiple Representational and Problem-Solving Abilities in Physics and it was not significant: r = .260; p >.005. This means that there was a weak, but no positive relationship between students multiple representational and problem–solving abilities of senior secondary Physics students.

Hypothesis 1

H_{O1}: There is no significant causal link among problem- solving and multiple representations on multiple representational abilities of senior secondary school physics students.

To test this hypothesis, data obtained from the students‟ posttest achievement were organized and subjected to a Regression Analysis. The result is presented in Table 3

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.

(Constant)	31.454	4.492		7.003	.000
Gender	.318	1.743	.009	.182	.855
MRABL	7.508	1.524	-.270	4.925	.000
Group	-6.246	1.085	-.314	-5.757	.000

a. Dependent Variable: POST-KMRA – PE

Table 2 shows the relative effect (strength of prediction) of problem-solving and multiple representations (-0.314) on multiple representational abilities of senior secondary school physics students. This means that learning strategy (problem-solving and multiple representations) had the highest contributions which were significant to the dependent variable (Multiple representational abilities).This indicates that there was a significant causal relationship among problem-solving, multiple representations and the multiple representational abilities of physics students. The problem-solving and multiple representations accounted for 31.4% of the variance in the multiple representational abilities of students in this study.

Discussion

This study revealed that posttest scores of students' multiple representations abilities had higher contribution to their achievement in Physics than their pre-test achievement in multiple representational abilities. Maries (2014) affirmed that when students used different representations, they become better problem solvers. More specifically, when they learn to solve problems through the use of multiple representations, they can perform better compared to the students who traditionally learn problem-solving strategies, similarly, DeLeone and Gire (2005) explained that the use of multiple representations in physics becomes more important since it is connected to students' problem-solving ability. Moreover, in addition to students' prior knowledge as well as the subject taught, Kohl and Finkelstein(2006b)researched that the use of multiple representations in learning enhances students' understanding of science (physics).This implied that to become better problem solvers in physics, multiple representations learning strategy is the main processes that students need to develop an understanding of physics. This corroborates the finding of Van Heuvelen & Zou (2001) who found that multiple representations learning strategies were more effective than traditional instruction. Multiple representations learning strategy is very useful in physics education especially in developing the students' understanding of physics problem, building a bridge between the verbal representation and mathematics, and helping the students to develop an idea that gives meaning to the mathematical symbol.

Van Heuvelen and Zou (2001) reported that multiple representations are useful in physics education: they foster students" understanding of physics problems, build a bridge between verbal and mathematical representations and help students develop images that give mathematical symbols meaning.

This study further revealed that there was no relationship between students' multiple representations and problem- solving abilities (Table 1).This finding is not in agreement with that of Melzer (2002) and Nieminen, Savinamen& Vinci (2012) who reported that multiple representations abilities are connected with problem-solving abilities. Ozogul, and Reisslein (2011) showed a positive correlation between problem representation and problem-solving scores. However, the finding only focuses on the concreteness of the visual representation used. Hence, students need to understand the problems raised by using appropriate representations and planning problem solving to achieve the desired solution.

More so, Elia, Gagatsis, Panaoura, Zachariades and Zoulinaki (2009) reported that the ability of a person's multiple representations in solving problems is closely related to how a conceptual understanding of a particular concept

The difference in these findings could be due to the use of appropriate teaching methodology the students were exposed to. To improve multiple representations and problem abilities of physics students, there is need for learning strategies that would present the concept fully through multiple representations, because physics students need to acquire these abilities to reason analytically, critically and create productively. Cook (2006) and de Jong et al (2010) reported that to enhance and achieve problem-solving abilities, learners require a learning strategy that presents the concept through multiple representations. Similarly, Morris et al (2008) added that when students are taught problem-solving strategies that emphasize the use of different representations of knowledge, they construct higher quality and more complete representations and exhibit better performance than students who are taught traditional problem-solving approaches. This finding implies that if appropriate teaching methodologies are employed by a physics teacher, the students' abilities to represent physics concept successfully and their problem-solving abilities will be enhanced and students demonstrate a deeper level of understanding and visualize physics concepts which will result to a higher level of conceptual understanding and problem abilities.(Ainworth, 2008; Gibbert,2007& Mayer,2005).The simple regression analysis in Table 17 shows the relative strength of prediction and significant level of learning strategy on multiple representational abilities in physics. The strength of the learning probed the effect of utilizing multiple representations learning strategies while learning physics and solving a physics problem. This indicates that multiple representations can be effective to enhance students' physics Problem-Solving Abilities as well as Multiple Representational Abilities.

CONCLUSION

From the findings of the study, there was significant relationship among multiple representations and problem-solving on multiple representational abilities of senior secondary school physics students. This is an indication that students taught using multiple representations and problem-solving resulted in growth in student understanding of physics concepts, increased ability in physics problem solving, and correct use of multiple representations in physics problem-solving. This was attested by Waldrip & Prain (2004) that multiple representations learning strategy help students to master physics concept and use them for successful problem-solving.

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