Effects of Multiple representations and Problem- solving learning strategies on Physics students' problem-solving abilities

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Abstract

Student's learning in physics takes many forms. Equations, diagrams, graphs and words all can be used to describe physical phenomena. Constructing descriptions of physical situations with these representations and focusing on their correct usage led to this study which investigated physics students' knowledge of multiple representations and problem-solving abilities using multiple representations learning strategy and problem-solving learning strategy as an intervention. The pretest-posttest, control group quasi-experimental design with a 3x2x3 factorial matrix was used. A total of 294 Senior Secondary School-two (SSII) Physics students selected from six purposively sampled co-educational 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). The reliability coefficient of the TKMRA-PE, MRAI, and PSAI were 0.83, 0.75 and 0.70 respectively. Data gathered were subjected to statistical techniques of Analysis of Covariance (ANCOVA) at 0.05 level of significant. Findings from the results showed significant effect of multiple representations learning strategies on problem-solving abilities; $F_{(2, 291)} = 4.440$; $p< 0.05$, $\eta^2 =0.030$. *The descriptive statistics revealed the magnitude of problem-solving abilities across the groups. Students exposed to multiple representations learning strategy had the highest problem-solving abilities (x= 3.83),than their counterparts in problem-solving learning strategy(x = 29.4),and those conventional strategy group had the least problem-solving abilities(x =22.3).The finding showed that irrespective of gender and ability level, multiple representations and problem-solving strategies facilitate learning and should be recommended for teaching and learning of physics in senior secondary schools in Nigeria.*

Keywords: Multiple representations, problem-solving, representational abilities, problem-solving abilities

1. Introduction

Multiple representations provide an empowering learning tool that support students' understanding of physics concepts, and it is impossible to learn physics without representations. We always need text, formulas, symbols, graphs, and/or figures to learn physics. Multiple representations provide an effective learning strategy which can lead to significant improvement of students' conceptual understanding of physics concepts (Opfermann et al., 2017; Treagust et al., 2018). Multiple representations in learning physics can be used to minimize student difficulties in learning and develop the skills of representing problems such as constructing and using mathematical representations, words, graphs, diagrams, pictures, tables, equations, and symbol manipulation (Laras et al., 2015).

Multiple representations represent the role of helping students in developing a better understanding because a concept presented using multiple representations can increase deep understanding so that students can build a complete understanding of the related concepts. Multiple representations enable learners to see complex ideas in a way and then to apply these complex ideas to learn effectively (Masrifah et al, 2020).

Multiple representations are very supportive for use in conceptual learning, such as Physics, because multiple representations place greater emphasis on understanding concepts and qualitative reasoning in learning (Dufresne, Grace, & Leonard 1997). This is supported by Kohl, Rosegrant, & Finkelstein (2007) who states that multiple representations learning can be considered as the key to learning physics. A multiple representations approach to learning and teaching has the potential to produce an effective learning process. Through diverse representations will create an atmosphere of learning with the active role of all potentials of students, activating students' learning abilities, both minds-on and hands-on, so that learning is more meaningful than before. This is corroborated with the research results of Siswanto, Susantini, &Jatmiko (2016), which state that for the success of Physics learning, students need to understand the multiple representations of Physics concepts correctly and adequately. Furthermore, according to the research results of Widianingtiyas, Siswoyo, & Bakri (2015), physics learning using multiple representations has a positive influence on students' cognitive abilities because it can build students' understanding by providing complete information from various forms of representation presented. Other research results state that learning physics using multiple representations can improve student achievement and scientific consistency (Sari, Feranie, & Karim 2015).

Problem-solving develops students' ability in using the theoretical information in daily life and solving the problem they face, guiding them for studies and increasing their interest(Saribiyik, Huucekic& Yaman,2004) Ability in problem-solving is generally viewed as the ability to reason analytically, think critically and create productively which all involves quantitative, communication, manual and critical response skills. To enhance and achieve problem-solving ability, learners require a learning strategy that presents the concept fully through multiple representations (Cook 2006; de Jong et al, 2010).

Problem-solving abilities are the most important skills for a student to develop in their physics classroom. To be successful, the student must have mastered both the quantitative and qualitative skills that are a necessary part of the problem-solving process. One of the most important skills requires the student's ability to represent the problem in as many different ways as possible, which is one of the major ways that the student can show that he or she has obtained a firm conceptual understanding of the content.

The problem-solving is considered essential for understanding physics concepts and phenomena, and one of the main skills that senior secondary school physics subject is aimed to develop logical thinking structures (Jennifer, Docktor, Strand, Mestre, & Brian, 2015).Physics problem solving lends itself to the use of multiple representations to visualize problem scenarios, relationships between quantities, and express mathematical relationships. The core 21st-century skills set out by Kay (2010) consisted of problem-solving, critical thinking, creativity, innovation, collaboration and communication. These skills are interrelated in a variety of ways, and the development of problem-solving skills especially is often tackled through problem-solving strategy.

Multiple representations can be used to address specific learning difficulty among students and to address difficult concepts in physics such projectiles, equilibrium of forces, alternating currents. Therefore, this paper is set to ameliorate specific learning difficulty among physics students and to address students' problem-solving abilities in projectiles and equilibrium of forces so it can encourage physics teachers to utilize the appropriate learning strategies.

2. Literature review

This study was guided by the constructivist approach to teaching and learning. A constructivist approach is student-centred and focuses on students' background experiences and prior learning (Duit&Confrey, 1996; Kearney &Treagust, 2001; Solomon, 2000). Learning results from experience, thinking, memory and all the other cognitive processes that build connections between new information and prior knowledge. The works of notable constructivists like Vygotsky and Bruner have direct implication for collaborative learning. This study was based on social constructivist and socio-cultural theory as the research was based on assumptions about the importance of students constructing meaning through conversation with others and the need for students to understand the multiple representations of physics concepts if they are to solve problems in physics at macroscopic, sub-microscopic and symbolic levels.

Vygotsky's research revealed that children's higher mental functions are developed by interacting with others who are more capable than them cognitively. What this means is exemplified in the following example. When a child interacts with developmentally more advanced people, for example, the more capable peers/siblings, the teacher or his/her parents, the child hears how these people see some problems and how they solve the problems. It is through interactions that the thoughts of others are revealed to the child. Through such interaction, the child has opportunities to observe others thinking and internalize the pattern of thinking. In this way, he develops new ways of thinking.

Vygotsky described this process of mental development as one that happens first interpersonally (during interaction), then intra-mentally (during internalization). He believed that this is the main way human higher mental function develops. However, he explained that for such development to occur, one key condition is that the interaction needs to be within the Zone of Proximal Development (ZPD).

A ZPD is "the distance between the actual developmental levels as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978).

One problem that teachers have is they are cognitively far more advanced than the children they teach and at times they may operate beyond the ZPD of the children. Collaborative learning provides an antidote to this situation by creating multiple ZPD (Oshima, 1998). Given that every student has a different ZPD, when they are put in a group for collaborative learning, their ZPDs overlap one another's. While the teacher's teaching may be accessible to some more advanced students, the less advanced students can connect with the more advanced students. The overlapping ZPD of each student, when put in groups, form the multiple ZPDs which are theoretically more accessible to all the members.

2.1 Empirical Review

Many studies have been carried out on using multiple representations in problem-solving (Fredlund et al., 2012; Rosengrant, Van Heuvelen, &Etkina, 2006; Sia, Treagust, &Chandrasegaran, 2012; Tytler, Prain, Hubber, &Waldrip, 2013).Three issues developed from using multiple representations in problem-solving: how students use multiple representations when solving problems, how different representational formats affect student performance in problem-solving, and how the utilization of multiple representations learning strategies can lead to substantial improvements in problem-solving abilities. This is reinforced by the opinion Kohl and Finkelstein (2005) who examined student performance on homework problems given in four different representational formats (mathematical, pictorial, graphical, and verbal), with problem statements as close to isomorphic as possible. They found that there were statistically significant performance differences between different representations of nearly isomorphic statements of problems. They also found that allowing students to choose which representational format they use improved student performance under some circumstances and degrades it on others.

Kohl and Finkelstein (2006a) reported that students who learnt physics using lots of representations were less affected by the specific representational format of the problem. Finally, these authors investigated in more detail how student problem-solving performance varies with representation (Kohl & Finkelstein, 2006b). They discovered that student strategy often varies with representation and that students who show more strategy variation tend to perform more poorly. They also verified that student performance depends sensitively on the particular combination of representation, topic, and student prior knowledge. This is supported by the research result of Morris et al (2006) 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.

Furthermore, according to the research results of Waldrip, Prain and Carolan(2010) that students benefit from multiple opportunities to explore, engage, elaborate and re-represent ongoing understandings in the same and different representations.

Ainsworth, Prain and Tytler (2011) claimed that students' explanatory drawings of aspects of phenomena could support their reasoning as well as develop their understanding of the subject-specific literacy's of science.

Ibrahim and Rebello (2012) studied the strategies engineering students employed when solving problems from kinematics and work which were represented in graphical, textual and mathematical formats and found that the representational format, prior knowledge and familiarity with the given topic influenced the students' problem-solving abilities.

There are many reasons why using multiple representations in problem-solving is conducive to an improved knowledge structure of physics concepts. Problem-solving is the principal process through which students develop their understanding of physics concepts. It, therefore, stands to reason that using multiple representations in problem-solving will lead to physics concepts being understood better by students because, in the process of using multiple representations, students can learn meaningful and appropriate ways of representing these concepts. Furthermore, multiple representations can reduce students' cognitive load by providing an external rather than an internal representation of physical information, a process known as "distributed cognition".

More so, multiple representations provide an associated ''mental image'' of the physical processes in terms of principles and underlying concepts being considered, hence supporting comprehension. However, in many physics textbooks, multiple representations are often depicted in mathematical forms resulting in difficulty to perceive and grasp the underlying concepts or explanatory principles being highlighted by the theory under consideration and the design of multiple representations is crucial. Faulty depictions or excessive details may lead to failure in capturing the main message being communicated, hence impeding students' construction of representations and their understanding (Ibrahim& Rebello, 2013).

Also, the West African Examination Council Examiners' Reports(WAEC,2010) showed that students exhibited: poor manipulation of mathematical processes, skills in identifying, listing and labelling of some physics concepts; inadequate knowledge of basic concepts in physics (WAEC, 2010), poor skills on representing vector quantities, drawing correct labelled diagrams and poor computational skills (WAEC,2012); interpret the graphical representation of physical quantities and other diagrammatic problems (WAEC,2014,2017,2018),ineffectively handle scale drawing problems(WAEC,2015),careless in symbol identification and inability to interpret statements in workable diagrams(WAEC,2013,2018)and inability to plot graphs correctly(WAEC,2008,2017).

Many studies were also geared towards exploring the application of multiple representations for conceptual understanding (Van Heuvelen& Maloney, 1999) and enhancing problem-solving performance (Dufresne,Gerace& Leonard,1997). Also, studies have looked into the possible factors leading to the ineffectiveness of teaching and learning based on multiple representations.

Kohl, Rosengrant and Finkelstein (2007) reported that students' inability to relate and translate information within and across representations was found to be the main inhibitor to comprehension, in the learning process and improved problem-solving performance. It wasalso reported that although instructional strategies were designed to teach students to make connections within and across representations, they were not always successful (Rosengrant, Van Heuvelen&Etkina, 2006; Seufert, 2003)

Many elements come into play when dealing with multiple representations. These include the students' meta representational skills, representational competence, representational fluency, representation preference and representations format.

Nurrahmawati, Cholis Sa'dijah, Sudirman and MakbulMuksar (2019) explored the ability of multiple representations of college mathematics education students to solve word problems and what representation forms are used. It was found that multiple representations' ability of students in solving problems was influenced by individual characteristics and the learning experience that they get before.

Huda, Siswanto, Kurniawan and Nuroso (2016) used a learning tool based on multi-representations to improve problem-solving skills. They used the development approach and course of Fundamental Physics at Universitas PGRI Semarang for the 2014/2015 academic year. The result of the finding showed that multi-representation learning tools significantly improved students' problem-solving 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.

Kohl and Finkelstein (2017) presented a series of empirical studies on undergraduate students' use of representation in introductory physics to describe when and how students use representations and to understand the impacts of varied instructional strategies on student performance with representations. The results of the findings showed that student performance on isomorphic problems varies, depending on the representational format used.

3. Hypotheses

The following null hypotheses were tested at 0.05 level of significance

H_{O1} :There is no significant difference in the problem-solving abilities of students taught using multiple representations learning strategies and those taught using conventional strategy

H_{O2}: There is no significant interaction effect of treatment and gender on problem-solving abilities of senior secondary school physics students.

H_{O3}: There is no significant interaction effect of ability level and gender on problem-solving abilities of senior secondary school physics students.

4. Methodology

This sudy adopted a 3-group, pre-test, post-test and control group quasi-experimental design. To study the effect of each factor on the response variable, as well as the effects of interactions between factors-, a 3×2×3 factorial design was adopted in this study.

The experimental groups were diagrammatically illustrated below:

O_1 X_1 O_2 = Treatment Group 1(Multiple Representations Learning Strategy)

O_3 X_2 O_4 = Treatment Group 2 (Problem-Solving Learning Strategy)

O_5 O_6 = Control Group (Convectional)

Diagrammatic representation of the research design,
where:

$O_{1,3,5}$= Pre-test observation

$O_{2,4,6}$= Post-test observation

X_1 = Treatment one (Multiple Representations Learning Strategy)

X_2 = Treatment two (Problem –Solving Learning Strategy)

= Control Group (Conventional Strategy)

The ground method employed for the two learning strategies was collaborative learning. In other words, these strategies were combined with collaborative learning. Table.1shows the two experimental groups E1, E2 and one control group, C.

Table 1: Summary of the Research Design Employed in the Study

Groups	Pre test	Multiple representations learning strategy	Problem-solving learning strategy	Conventional method	Post test
Experimental group 1 (E_1)	*	*			*
Experimental group II (E_2)	*		*		*
Control group (C)	*			*	*

* = Treatment

4.1Treatment procedure

Pre-activity instruction

Treatment group I

- The teacher stated the learning objectives of the contents to be learnt by students
- The teacher informed students that they are going to learn the concepts using multiple representations learning strategies.
- The teacher informed students that they were expected to work in groups, solve problems and show their solution on cardboard

Activity tasks in class:

- Teacher guided students informing groups of eight students per group
- Teacher ensured that each group consists of mixed ability.
- Each group was instructed to choose a group leader
- Each group is directed to develop plans on how to involve all the members in the group in constructing representations.
- Learning materials and other relevant resources were distributed to students

- The teacher presents ideas visually on the chalkboard
- The teacher talks and writes notes on the board while students are writing notes
- Teacher and students interacting as a whole class during the lesson
- Students in small group discussion
- The teacher engages students in class activities constructing representations (i.e. verbal, diagram, symbol and mathematical)
- Each group interacts and proceeds to solve the problem on their own as follows
  - (a) Students construct representations to clarify the problem
  - (b) Students translate the words into the symbolic language of physics
  - (c) Students use specific physics representations to construct a mathematical equation Students use the equation to solve the problem.

Treatment Group 2

Activity tasks in class:

- Teacher guided students in forming groups of eight students per group
- The teacher ensures that each group consists of mixed ability.
- Each group was instructed to choose a group leader
- Each group is directed to develop plans on how to involve all the members in the group in constructing representations.
- Learning materials and other relevant resources were distributed to students
- The teacher presents ideas visually on the chalkboard
- The teacher talks and writes notes on the board while students are writing notes
- Teacher and students interacting as a whole class during the lesson
- Students in small group discussion
- Each group interacts and proceeds to solve the problem on their own as follows
  - a) Students construct an informative diagram of the physical situation
  - b) Students identify and list the given information in variable form
  - c) Students identify the unknown information in variable form.
  - d) Students identify and list the equation that will determine unknown from known information
  - e) Students substitute known values into the equation and use appropriate algebraic steps to solve for the unknown information
  - f) Students check answer if it was reasonable and mathematically correct.

4.2 Validity and Reliability of instruments

The instruments were given to two SSII physics teachers, who had over ten years teaching experience and two science education experts in physics and experts who were knowledgeable in test construction subjected these items to scrutiny and content validation. The items were moderated and the language used was modified to suit that of SSS II students. As a result of the corrections, some of the items were restructured while some were added. Thereafter, the instrument was administered to randomly selected SS2 students from schools that were not part of the sample to ensure that the questions raised are not beyond the understanding of the students. Multiple Representations Assessment Instrument (MRAI), Problem –Solving Assessment Instrument (PSAI), Knowledge of Multiple Representations in Projectile and Equilibrium of forces (TKMRA-PE test were determined using the SPSS version 23 on the responses of the sample and the split-half reliability coefficient computed value were found to be 0.75, 0.70 and 0.85 respectively and these values were considered adequate for using these instruments.

5. Results

H_{O1}: There is no significant difference in the problem-solving abilities of students taught using multiple representations learning strategies and those taught using conventional strategy

Table 1 revealed that there was a significant difference in the problem-solving abilities of students taught using multiple representations learning strategies and those taught using control; $F (2,291) = 4.440$; $p< 0.05$,$\eta^2 =0.030$.Therefore, hypothesis H_{O1} is rejected. Table 4 presented that those students exposed to multiple representations learning strategy had the highest problem-solving abilities mean score (38.32) followed by the students exposed to problem-solving learning strategy (29.48) while those exposed to control group had the least mean score (22.38).Table 5 presented Bonferroni analysis to determine the source of the observed significant difference. The table 4 showed that the multiple representations learning strategy performed significantly better than all the two other strategies. It was also revealed that there was a significant difference between the experimental group 1 and control groups. There was a difference in the mean score experimental group 1 and experimental group 2, but it was not significant.

Table 1 Summary of Analysis of Covariance on problem-solving abilities

Dependent Variable: Posttest TKMRA-PE

Source	SS	df	MS	F	p	η
Corrected Model	22495.425[a]	3	7498.475	36.398	.000	.274
Intercept	42472.830	1	42472.830	206.167	.000	.416
Pre-KMRA-PE	9162.908	1	9162.908	44.478	.000	.133
Treatment	1829.499	2	914.749	4.440	.013	.030
Error	59743.310	290	206.011			
Total	354818.000	294				
Corrected Total	82238.735	293				

a. R Squared = .274 (Adjusted R Squared = .266)

Table 2 Summary of 2-ways Analysis of Covariance on problem-solving abilities

Source	SS	Df	MS	F	p	η
Corrected Model	21822.099a	3	7274.033	34.915	.000	.265
Intercept	40571.291	1	40571.291	194.742	.000	.402
Gender * Treatment	21822.099	3	7274.033	34.915	.000	.265
Error	60416.636	290	208.333			
Total	354818.000	294				
Corrected Total	82238.735	293				

R Squared = .265 (Adjusted R Squared = .258)

Table 3 Summary of 2-ways Analysis of Covariance on problem-solving abilities
Dependent Variable: TKMRA-M

Source	SS	Df	MS	F	p	η
Corrected Model	22187.292a	6	3697.882	17.673	. 000	.270
Intercept	40892.007	1	40892.007	195.433	.000	.405
Ability level * Treatment	20173.812	3	6724.604	32.138	.000	.251
Error	60051.442	287	209.238			
Total	354818.000	294				
Corrected Total	82238.735	293				

a. R Squared = .270 (Adjusted R Squared = .255)

Table 4 Descriptive statistics on the treatment and problem-solving abilities scores

Learning strategy	N =294	
	Mean	SD
MRLS	38.3153	14.19154
PSLS	29.4824	22.15992
CS	22.3776	7.53208

Table 5: Summary of Bonferroni analysis of problem-solving abilities

Treatment	Control	Experimental I	Experimental II
Control		*	*
Experimental I	*		
Experimental II	*		

Table 2 revealed that there was significant interaction effect of treatment and gender on problem-solving abilities of senior secondary school physics students; $F(3,290) = 34.915$, $p < 0.05$,partial eta $\eta^2 = .265$. Therefore, H_{O2} is rejected.

Table 3 revealed that there was significant interaction effect of treatment and ability level on problem-solving abilities of senior secondary school physics students; $F(3,287) = 32.138$, $p < 0.05$, partial $\eta^2 = .251$.Therefore,H_{O3} is rejected.

6. Discussion of findings

The main focus of this study was to determine whether or not there would be any significant difference in knowledge of students exposed to the use of multiple representations learning strategy and problem-solving learning strategy and those in the conventional strategy. This study revealed that there was relative effectiveness in the effect of multiple representations learning strategies and problem-solving learning strategy and conventional method on problem-solving abilities of senior secondary school students in physics. Besides, students in experimental group 1 (multiple representations learning strategy group) had the highest mean score while the lowest mean was observed in the conventional method group in problem-solving abilities (Table 4). This shows that multiple representations learning strategy enhanced greater problem –solving abilities in students while the conventional method was the least. This finding was in line with other studies such as Adadan,Trundle&Irving, 2010; Aspinwall& Miller, 2001;Etkina, Rosengrant, & Van Heuvelen, 2008; Nyman, 2003; Berry&Hilton and Nichols, 2011, Wu& Puntambekar, 2012).These studies reported that students taught using multiple representations learning strategy 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 also corroborated in this study as it was found that students in the experimental group I (multiple representations learning strategy) performed better (mean = 38.32) than their counterparts in the (experimental group II) problem-solving learning strategy group with a mean score of 29.48 and the control group with the least mean of 22.38. Furthermore, it was also found that a significant difference exists among the problem-solving abilities mean scores of students exposed to multiple representations learning, problem-solving learning strategy and conventional method; multiple representations learning strategy and problem-solving learning strategy (Table 1). This is because the students were able to translate verbal problems to the appropriate visual, formulae and numerical solutions. This remarkable result could be as a result of the effectiveness of the intervention on the problem-solving abilities of physics students. Also, students learnt how to represent a physical situation in concert with physics concepts through diagrammatic representations and their agreement with other types of representations (verbal, symbolic and numerical) which enables them to develop mathematical solutions from problems that start in verbal and diagrammatic representation. This was in agreement with the findings of Finkelstein, Adam, Keller, Kohl, Perknis, Podolefsky&Reid(2005); diSersa&Sherin(2000);Finkelsteinetal(2005);VanHenvelen(1991a,1991b,2001) and Waldrip&Prain(2004) who found that multiple representations learning strategy help students to master physics concept and use them for successful problem-solving. In this study, a significant two-way interaction effect between teaching strategy and gender was found on problem-solving abilities in physics (Table 2). This means gender is dependent on the interaction effect of the teaching strategies to affect better problem-solving abilities.

This means gender is dependent on the interaction effect of the teaching strategies to affect better problem-solving abilities. The implication is that only the joint effect of strategy and gender could affect problem-solving abilities of senior secondary school physics students. This is so because the teaching strategies used in this study allowed students to interact with the tasks given irrespective of the sex and allow them to redefine their learning. The students were able to attain their personal goals by encouraging others within their group to do whatever will help the group to succeed. In other words, when students interact with each other's, they have to explain and discuss each other's perspectives which may lead to a greater understanding of problems solved. Therefore the students can be said to have constructed their learning by themselves instead of knowledge transmitted directly from the teacher to the learner. Teachers should therefore note that mixed gender group and teaching strategies with the appropriate learning activities will not only make students active learner, and make them restructure and construct their knowledge but improve their ability to build and transforming knowledge.

The study further found a significant two-way interaction effect of the strategy of learning and ability levels on problem-solving abilities when students are taught physics using multiple representations learning strategy and problem-solving learning strategy as presented in Tables 3.This shows that ability levels and strategy of learning jointly enhance problem-solving abilities of physics students. In other words, each of the variables depends on each other for effective and meaningful learning to take place. Therefore, problem-solving abilities could not be completely attributed to either the effect of a strategy of learning or ability level; rather it is a joint effect of both ability level and strategy of learning. This finding is in line with Adeyemo (2010) who carried out an investigation on students' ability level and their competence in a problem-solving task in physics and found out that students' ability has a significant influence on a problem-solving task. It can be concluded that problem-solving abilities among physics students are ascribed to both the effect of gender and ability level. Therefore, students' ability levels in this study could be considered in a mixed-gender physics classroom for better enhancement in problem-solving abilities. This finding is in disagreement with the work of Herrmann and Crowford (2008) when examining high school students complete various scientific tasks; found that males out performed females in interpreting results. However, the result agrees with Agomuoh, (2010) who mentioned that males and females are the same if they are treated under the same condition but, not in line with the study of Fatoba and Aladejana (2014) on gender. They found a slight difference in students' attitude in favour of females in Physics. This disagreement could be accounted for by the fact that the concepts investigated differ and the classroom settings are not the same. It may also be that the sample size and the sampling techniques differ.

7. Implication of findings

The findings of this study had shown that effective physics instruction needs more than talk and chalk approach. It requires the active involvement of the students in the physics learning process. Multiple representations learning strategy meet this need in a physics classroom. Also, in helping students develop representational ability, physics teachers must provide students with multiple opportunities to create representations on their own, similar to the writing-to-learn activities described in the work of McDermott and Hand (2012) and others (Hand et al., 2009; McDermott,2009).

The results have implications on the current trend of test development adopted by the public examining bodies in Nigeria and indeed in most countries in West Africa. This is because the West African Examinations Council conducts examinations (WAEC) for the Anglophone countries in West Africa. The current items generated for physics test items are lacking connections among representational modes of physics concepts. Almost all physics questions in WAEC and NECO exams only served to include the symbolic and diagrammatical modes of representations. More so, WAEC and NECO should endeavour to set test-items that determine the level of problem-solving abilities rather the level of knowledge the candidates can acquire

Conclusion

Multiple representations learning strategy is effective in helping learners to visualize physics concepts hence resulting in a higher level of conceptual understanding and problem-solving ability.

The problem-solving learning strategy has been found to develop students' ability in using theoretical information in daily life and solving the problems they face, guiding them to study and increasing learners' interest.

Therefore, teaching strategies that emphasis on activity-based learning which is an effective strategy of teaching and development of skills required of physics students towards learning for understanding should be adopted as modes of learning to replace the conventional method which dominates our secondary school classes. This, of course, may further solve the problem of large classes, inadequate instructional materials and make peers complement the teacher who cannot afford to attend to students one by one because of an over load of teaching and administrative duties.

Recommendations

Based on the findings of this study, the following recommendations were made:

1. Physics teachers should consider using multiple representations learning strategy to teach physics concepts especially difficult concepts. This strategy is student's centered and efficacious in raising achievement and problem-solving abilities which would avail the students the opportunity of constructing learning in their way thereby enhancing problem-solving abilities in physics.
2. Teachers should be mindful of the fact that different ability students are in their class and therefore vary teaching strategies to accommodate the differences in the ability of students is essential. In other words, incorporating activity-based approaches such multiple representations

teaching-learning situation could encourage and enhance problem-solving abilities since this would allow the students to learn from each other.

3. This study has shown that when students are taught with an interactive, innovative strategy such as multiple representations learning strategy the problem-solving abilities increases. It is also revealed that interaction between ability level and learning strategy improves the problem-solving abilities of physics students, therefore; learning strategy that takes into consideration the different ability levels should be employed in physics classes to enhance the problem-solving abilities of students.
4. Physics students should be taught how to represent concepts in multiple ways such as a verbal, diagram, symbolic and mathematically as a means of enhancing their problem-solving abilities in the subject.

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