



Changes in Students' Problem-Solving Skills: The Role of a Focused Teaching Intervention Based on Sequential Multiple Representations (SMR)

Suleiman Musa Bala, Saadatu Abubakar Muhammad, Musa Olanrewaju Dauda
Department of Science Education,
Faculty of Technology Education,
Abubakar Tafawa Balewa University Bauchi, Nigeria

ABSTRACT

This study was set to investigate the role of Sequential Multiple Representations in Enhancing Senior Secondary School Physics Students' Problem-Solving Skills in the context of a tightly focused teaching intervention. The intervention involved a sequence of four lessons conducted over a period of 6 weeks, with the first and last week used for pre and post-test. The intervention was set deliberately to push students to use multiple representations in a particular sequence (starting from word to symbols, diagram, and then generating equations) to solve electric circuit problems. The population of the study comprised of all students offering physics in the fifteen public senior secondary schools in Bauchi state, Nigeria. Cluster random sampling technique was used to select 40 students which constituted the sample size. The instrument used for data collection was a Physics Problem-Solving Task on Electric Circuit (PPSTEC) with a reliability coefficient of 0.76. An assessment rubric was developed by the researcher with four (4) levels of attainment of problem-solving skills (No attempt, Problematic, emergent and exemplary). The rubric was used as an analytical tool that characterised, assessed and ascertained the changes in students' problem-solving skills before and after the teaching intervention. The result shows that the intervention group made substantial improvement from about 89.75% at the level of no attempt and problematic response in the pre-test to 74.50% moved to the higher levels of emergent and exemplary. Based on the finding, it was concluded that the use of sequential multiple representations as a teaching strategy is an effective tool for enhancing students' problem-solving skills in the context of electric circuit problems. The research therefore recommends further research with different sets of students, and in different contexts across Nigeria to provide more empirical evidence on the role of sequential multiple representations as a means of developing students' problem-solving skills in electric circuit problems.

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INTRODUCTION

The importance of physics in terms of improving the quality of life by providing the basic understanding necessary for developing new instrumentation and techniques for several disciplines cannot be over emphasized. But

despite its contributions and importance, the teaching and learning of physics in Nigeria and Africa as a whole has not been given much attention. This is reflective considering the decline in the performance of students in physics examinations. Various studies have shown that



students have difficulties understanding physics concepts and students often lack problem-solving skills (Haratua and Judyanto, 2016). The lack of problem-solving skills has resulted in a situation whereby students develop negative attitudes towards physics (Mekonnen, 2014) and this has in turn limited their career choices in disciplines like medicine and engineering (Adeyemo, 2010).

Problem-solving constitutes a greater part of physics curriculum in secondary schools across different topics. It's an important skill that provides opportunities for application of scientific knowledge. Poyla offers 4 stages of problem-solving, they include understanding the problem, device a plan, carry out the plan and look back. But understanding the problem forms the bedrock of all the other stages because if a problem is poorly understood, the other stages will fall apart. The poor conceptualization of a problem within problem-solving has resulted in students not been successful in find correct answers to physics problems (Haratua & Judyanto, 2016). Research has shown that while students deal with an abstract concept, they need a tool such as a representation to be able to visualize the problem in order to understand it better (Kozman, 2013; McDermott, 2004) and a means to facilitate the solving of the problem (Van Heuvelen & Zou, 2001).

The content focus of the intervention is on Electric circuit. This choice was driven by a number of key factors: Firstly, Electric circuit is an important and fundamental aspect of secondary school Physics curricula in Nigeria. Secondly, there is extensive research in the field of physics Education related to Electric circuit with particular emphasis on the use of multiple representations (Metioui, 2012). Thirdly, a significant body of evidence in Nigeria points to difficulties across the teaching and learning of concepts related to this area (Erinosh, 2013). The Nigerian Educational Research and Development Council (NERDC, 2004) report confirms that many teachers who teach Electricity in secondary school believe that their students find this sub-discipline of Physics difficult to learn. The aim of this study therefore, is to offer a teaching intervention with particular focus on sequential multiple representations in the teaching of Electric circuit with the aim of

enhancing physics students' problem-solving skills.

LITERATURE REVIEW

A representation can be seen in different ways in connection with the teaching and learning of physics. A representation can be seen as any kind of mental state with a specific content, a mental reproduction of a former mental state, a picture, symbol or sign. Representation comes in two forms, the internal and the external representation (Norman, 1993). Internal representations are those that we construct in our mind, possibly for memory recall etc. while external representations are those that people construct on paper, on the board either by drawing or otherwise. The present study will only focus on external representations, such as verbal, sketch or pictorial, motion diagrams, force diagrams, graphs, bar charts, mathematical equations and many others such as ray diagrams, field diagrams and circuit diagrams may be employed when solving physics problems (Jonassen, 2011).

Various studies have been conducted on the positive effect of using multiple representations when solving physics problems. In a study by Haratua and Judyanto (2016), it was found that students who employed more than one representation while solving problems got higher score than students who did not indicating that multiple representation can be effective to enhance students understanding of physics concepts and problem-solving skills. Heckler (2010) investigated the effect of engaging students to draw. The work of Rosengrant (2005), Van Heuvelen and Zou (2001), Kohl and Finkelstein (2008) provides additional evidence regarding the positive effect of exposing students to the application of multiple representations for problem-solving skill.

While so much studies have been conducted on the positive effect of the use of multiple representations, these studies were conducted mostly for students in higher level. In developing countries like Nigeria for example where the teaching and learning of these concepts is been faced with numerous challenges such as the inadequate provision or non-availability of a functional laboratory that has



all the components involved in the teaching and learning in secondary schools. It is therefore important to find out whether the use of multiple external representations can play a significant in easing the difficulties students and teachers face in the teaching and learning of some difficult concepts in physics. The present study sought to find out how the teaching of the concept of electricity in particular Electric circuit be enhanced through the ability of learners to connect the components that makes the circuit through diagrams (circuit diagram). It intends to see if their ability to be able to draw good circuit diagram as part of the problem-solving heuristics will boost their understanding of physics principles and also improve their problem-solving process.

The present study will focus on how students move from word representation to symbolic representation and then to diagrammatic representation and finally mathematical equations sequentially in that order.

Research Question

The following research questions were answered

- i. What is the level of senior secondary school physics students' problem-solving skills prior to the teaching intervention?
- ii. What are the changes in senior secondary school physics students' problem-solving skills using sequential multiple representations after teaching intervention?

METHODOLOGY

The research employed a quasi-experimental one group pretest – posttest design. The population of the study comprised of all the 4500 SSI Physics students in all the 15 public senior secondary schools offering Physics in Bauchi Metropolis (Bauchi State Ministry of Education, 2017). The sample for this study was drawn from students in the selected schools in Bauchi, Bauchi state. Forty (40) respondents were selected as a total sample for the study in the experimental group and this was done using cluster random sampling technique.

Four (4) sequences of lessons on Electric Circuit were developed, and used in the

teaching intervention. Both the pretest, the teaching intervention and the posttest were carried out for 6 weeks. In each week, 2 periods (40) minutes each was used for the intervention.

The instrument that was used for data collection is a Physics Problem-solving Task on Electric Circuit (PPSTEC). The PPSTEC comprised of two sections, the first section sought to elicit students' demographic information while the second section has 4 Essay type questions and the questions were divided across the topic under consideration. The Essay type questions were used to measure students' problem-solving characteristics before and after teaching intervention. The questions for the PPSTEC were adapted from the past Senior Secondary School Certificate Examinations (SSCE). The questions are also aligned to Blooms taxonomy of classifying questions into lower and higher order cognitive objective.

The data collected from the study was quantitatively analyzed. A Rubric was developed based on sequential multiple representation and it was used for the analysis and also to answer research question one (1) and two (2) respectively.

RESULTS AND DISCUSSION

In order to ascertain the level of students' problem-solving skills prior to teaching intervention and to find the changes/shift in students' problem-solving skills acquisition as a consequence of their participation in the teaching intervention, the researcher designed a rubric that aided the analysis process. They are coded as: No attempt (level 0), Problematic (level 1), Emergent (level 2) and Exemplary (level 3). In other to categorize students' problem-solving skills, the researcher considered level 0 and 1 as possessing limited problem-solving skills and level 2 and 3 as possessing Satisfactory problem-solving skills.

Research Question 1: What is the level of senior secondary school physics students' problem-solving skill prior to the teaching intervention?

In order to comment on the level of senior secondary school physics students'



problem-solving skills, level 0 and 1 are combined together as limited problem-solving skill while level 2 and 3 are combined together as been satisfactory.

Table 1 shows the results of senior secondary school physics students' problem-solving skills prior to teaching intervention. The table shows that across each components of multiple representations; under skill to recognize symbols, 0% of students made no attempt, 100% (Problematic), 0% (Emergent) and 0% (Exemplary). Skill to model word problems into diagram; 3% of students made no attempt, 95% (Problematic), 2% (Emergent) and 0%

(Exemplary). Skill to generate equations; 5% of students made no attempt, 93% (Problematic), 2% (Emergent) and 0% (Exemplary). Skill to perform mathematical working; 1% of students made no attempt, 98% (Problematic), 1% (Emergent) and 0% (Exemplary). Collectively, it is observed that across all the 4 components of sequential multiple representations in physics problem-solving, majority of senior secondary school students demonstrated limited problem-solving skills with percentages ranging from 98% to 100% while few students (0% - 2%) possessed satisfactory problem-solving skills.

Table 1: Summary of Level of Senior Secondary School Physics Students Problem- Solving Skills Prior to Teaching Intervention

Component of students problem-solving using sequential multiple representations	No Attempt 0	Problematic 1	Emergent 2	Exemplary 3
Skill to recognize symbols	0 (0%)	120 (100%)	0 (0%)	0 (0%)
Skill to model word problems into diagram	4 (3%)	114 (95%)	2 (2%)	0 (0%)
Skill to use physics principles to generate equations	6 (5%)	112 (93%)	2 (2%)	0 (0%)
Skill to perform correct Mathematical working	1 (1%)	118 (98%)	1 (1%)	0 (0%)

Research Question 2: What are the changes in senior secondary school students' problem-solving skills using sequential multiple representations after the teaching intervention?

Table 2 shows the results of senior secondary school physics students' problem-solving skills after the teaching intervention. The table shows that across each components of multiple representations; under skill to recognize symbols; 11% of students made no attempt, 2% (Problematic), 2% (Emergent) and 85% (Exemplary). Skill to model word problems into diagram; 8% of students made no attempt, 16%

(Problematic), 18% (Emergent) and 58% (Exemplary). Skill to generate formular; 13% of students made no attempt, 15% (Problematic), 13% (Emergent) and 59% (Exemplary). Skill to perform mathematical working; 34% of students made no attempt, 9% (Problematic), 19% (Emergent) and 38% (Exemplary). Collectively, it is observed that across all the 4 components of sequential multiple representations in physics problem-solving, majority of senior secondary school physics students demonstrated satisfactory problem-solving skills with percentages ranging from 57% - 87%.



Table 2: Summary of Changes in Senior Secondary School Physics Students Problem- Solving Skills after Teaching Intervention

Component of students problem-solving using sequential multiple representations	No Attempt 0	Problematic 1	Emergent 2	Exemplary 3
Skill to recognize symbols	14 (11%)	3 (2%)	2 (2%)	102 (85%)
Skill to model word problems into diagram	10 (8%)	19 (16%)	21 (18%)	69 (58%)
Skill to use physics principles to generate equations	16 (13%)	18 (15%)	15 (13%)	70 (59%)
Skill to perform correct Mathematical working	41 (34%)	11 (9%)	23 (19%)	44 (38%)

DISCUSSION OF FINDINGS

Analysis of research question one suggest that majority of the senior secondary school's physics students had limited problem-solving skills prior to the teaching intervention. Most of the students were not able to shuffle between one forms of representation to the other. Students were not able to recognize symbols, model word problems into diagrams, generate equations/formula and perform mathematical calculations. Result of research question two shows that there was shift in students' problem-solving skills as a consequence of their participation in the teaching intervention. Collectively, it is observed that across all the 4 components of sequential multiple representations in physics problem-solving, majority of students demonstrated satisfactory problem-solving skills with percentages ranging from 57% - 87% as against 0% - 2% prior to the teaching intervention. This result is also in agreement with the work of Kohl and Finkelstein (2008), which provides additional evidence regarding the positive effect of exposing students to the application of multiple representations for problem solving. This finding indicates that sequential multiple representation is very important in enhancing senior secondary school students' problem-solving process. The findings also suggest that the intervention to help shift students from novice problem-solvers to that of experts who begin problem-solving with a

qualitative analysis of the problem (drawing one or several diagrams) to ensure that the problem is understood and try to relate the physics principles that is applicable to solve the problem was effective.

Finding of the study also indicates that students' performance in skill to perform mathematical working was not above average (44%). This may be due to the problem of mathematization. Students were able to transform from symbols to diagrams and then to equations (horizontal mathematization) but were not able to continue with the activities that follows that are related to the mathematical process, the solution of the problem, the generalization of the solution and the further formalization, which can be described as 'vertical' mathematization (Treffers, 1987).

CONCLUSIONS

Based on the findings and discussions, it can be concluded that Sequential multiple representation is very effective as a tool for enhancing students' understanding of physics concepts and problem-solving skills.

RECOMMENDATIONS

Based on the findings of this study, the researchers recommended that training and retraining should be organized for physics teachers on the role of Sequential multiple representations in Physics teaching/learning.



Physics teachers should be encouraged to use sequential multiple representations as a tool for enhancing students' conceptual understanding of physics concepts and problem-solving skills.

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