International Journal of Humanities and Social Sciences (IJHSS)
ISSN(P): 2319-393X; ISSN(E): 2319-3948
Vol. 3, Issue 3, May 2014, 33-46


International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations
IASET

# ANALOGIES, PROBLEM-SOLVING AND CONCEPT MAPPING INSTRUCTIONAL STRATEGIES AS DETERMINANTS OF SENIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN WAVE CONCEPTS IN ADAMAWA STATE, NIGERIA

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## ABSTRACT

The declining trends in high school science enrollment present science educators with the need to make informed policy decisions regarding the effectiveness and appropriateness of current instructional approaches. Therefore the effects of the three model-based instructional strategies (analogy, problem-solving and concept mapping) on achievement of High School Physics Students were investigated in this study. These strategies were crossed with two levels of cognitive style and three levels of quantitative ability which served as moderator variables employing a 4x2x3 posttest, control group, quasi-experimental design. Data were collected using three validated and reliable instruments namely: the Cognitive Style Test (CST), the Quantitative Ability Test (QAT) and the Achievement Test in Physics (ATP). Two hundred and forty-three (243) Senior Secondary School 2 students from eight Senior Secondary Schools in Adamawa State, Nigeria took part in the study. Data were analyzed using the Analysis of Variance, Multiple Classification and Scheffe-Post Hoc analysis. The results showed significant effects of the treatments and cognitive styles on achievement. In fact the most effective treatment was the problem solving strategy with the field independent students achieving significantly higher than their field dependent counterparts. These results have implications for improved instructional strategies on students learning of the 'tagged' abstract concept in physics.

**KEYWORDS:** Abstract Concepts in Physics, Academic Achievement, Cognitive Style, Model-Based Instruction, Quantitative Ability

## INTRODUCTION

Science education is considered to be in crisis not only in Nigeria and Ghana but globally. The cause of this is identified as the fall in number of students taking Physical sciences especially Physics and Chemistry, because while the numbers taking Physics and/or Chemistry are falling at higher levels of education, numbers taking Biology are much higher and fairly steady (Taale, 2010a). Physics is widely recognized to be the most fundamental of all the sciences and has also been recognized as the foundation of our society (Pravica, 2005), and indispensable in many professions and for economic development (Stokking, 2000). Also, of all the sciences, physics is at the heart of the technology driving the world economy and is present in almost every facet of modern life (Taale, 2011a). Physics as one of the core science subjects is peculiar having been identified by experts as abstract/difficult in nature and demanding high quantitative aptitude in aptitude in explicating most of its principles and concepts (Bassock, 1990; Franz, 1983; NERDC, 1994; Ogunsola-Bandele, 2001; Okoronka, 2004; Toews, 1988). In fact most high school and college students recoil from physics because they feel it contains too many facts/technical terms to learn, the textbooks are too difficult to read and has the reputation as an applied mathematics course (Ogunsola-Bandele, 2001; Toews, 1988). This has resulted in decreased enrollments in physics at a time when our society desperately needs scientifically literate citizens.

The selection of the wave concepts is based on the research findings that despite the importance of the concepts, there exist general weakness in student understanding of the fundamental ideas because it has more conceptual contents than it is usually accorded in teaching schemes (Dean, 1980; Okoronka, 2004). Therefore any instructional intervention meant to redress this trend should help the learner in making meaning and creating understanding of the various 'tagged' difficult concepts. Ausubel (1968) suggested the device called organizers which epitomize and inter-relate areas of knowledge and create better understanding. As such, a good organizer is a tool of model and analogies.

Model based instruction refers to a representational nature of knowledge (Greca & Moreira, 2000) which provides the theoretical elements that further explains the representations and processes underlying the experts' knowledge (Mayer, 1989). When these have been understood, then it can be "copied or modeled" as a standard to teaching the novices and help the students to learn better. Model-based Instruction (MBI) is strongly rooted in cognitive science with emphasis on the learner as the builder (constructor) of his own knowledge (Von Glasserfeld, 1989). What he or she constructs is seen as mental models or patterns, which become inferred structures as they cannot be directly observed (Johnson-Laird, 1983; Gentner & Stevens, 1983). Thus MBI ensures the implementation, resources and learning activities intended to facilitate mental model building in the learner (Gobert &Buckley, 2000).

Although several models have been identified by experts, this study however, concerned itself with the instructional effect of three of these expert models namely: analogies, problem solving and concept mapping. The researchers posit that if these models are used in the teaching of the abstract concept of waves in physics to Senior high school students of varied cognitive styles and quantitative abilities, their achievement will most probably improve. Cognitive style of students has been selected as a moderating variable since the way students perceive and process information is crucial to learning (Babalola, 1979; Ogunsola Bandele, 2004). Similarly, quantitative ability has been observed to be a necessary variable, which determines the level of achievement in physics (Egbugara, 1986; Bassock, 1990; Iroegbu, 1998).

**The Problem**

Waves are everywhere and whether we recognize it or not, we encounter them on a daily basis in the form of sound waves, visible light waves, radio waves, microwaves, water waves, waves on a string, earthquakes and so forth. For many students, the first thought concerning waves brings up pictures such as waves moving across the surface of rivers, oceans, lakes, ponds and other water bodies. Many students have difficulties in conceptualizing wave propagation in a medium and its characteristics. They do not recognize that wave superposition occurs by adding individual displacements point by point at any given time. This study therefore investigated the effect of three model-based instructional strategies (analogies, problem-solving and concept mapping) on High School (Grade 11) students' achievement in wave concepts. It equally examined the extent to which cognitive style and quantitative ability influenced students' achievement.

**Design/Procedure**

The study adopted a pretest, post-test, control group quasi-experimental design in which treatment (at four levels) was crossed with cognitive style (at two levels) and constitutive ability (at three levels) in a 4x2x3 factorial matrix design.

The subjects consisted of 243 Senior High School 2 physics students (102 males and 141 girls) with varied cognitive styles (127 field independent and 97 field dependent) and quantitative abilities (44 high, 102 medium and 97 low) in two educational zones namely, Mubi and Yola Local Government Areas (LGAs) in Adamawa State, Nigeria. Intact classes were selected using stratified random sampling from eight purposively selected high schools located distantly from each other within the selected local governments as a way of reducing external influence. Two schools were each randomly assigned by balloting to one of the four experimental conditions.

The average age of subjects was 16.1 years with a standard deviation of 3 years. Three valid and reliable instruments namely; the cognitive style Test, CST (Person Product Correlation Coefficient r =.27); the Achievement Test in Physics (ATP) (Guttman Split-half statistics α =.75 and α =.64 for the two halves of the test respectively) and the Quantitative Ability Test (QAT (Kuder Richardson Formula KR-21 =.64) with item difficulty index of.48 were used to collect data for the study.

**Quantitative Ability Test (OAT)**

This is a multiple choice test with 4 options provided on each item. The instrument was developed by adapting relevant items on the Otis-Lenon Standardized Mental Ability Test. A total of 29 items were initially adopted and adapted from the original test. The test was designed to last for 45 minutes.

**Validity and Reliability of OAT**

The instrument was subjected to two levels of internal consistency. First, they were administered on five Mathematics graduate teachers with upwards of six years teaching experience. Their responses, comments and criticism were noted. Second, the instrument was equally given to three lecturers in Mathematics Education and two in measurement and evaluation. Their observations and comments in addition to that of the Secondary School teachers were summed up and the items pruned to 26.

The instrument at this stage was then administered to some 60 Senior Secondary School Form 3 (SSS3) students in a Federal Government College in Lagos on a trial basis. The reliability coefficient was calculated using Kuder-Richardson formula 21 (Kr21). The result gave stability co-efficient of.69 for the total test with all the 26 items showing very high reliability co-efficient indices when subjected to item analysis. The average item difficulty index of .48 was also obtained.

**Achievement Test in Physics (ATP)**

This test has 3 sections A, B and C. Section A sought such background information about students as school, age, class and sex. Section B contained an initial 28 short answer questions while section C contained another 30 items of the multiple choice type. All the items were drawn from the wave concept selected for the study. The multiple choice items have four options which include one correct answer and three detractors. This was adopted as against 5 options construct based on arguments by Harper and Harper (1990). Furthermore, the items were drawn to evaluate mainly higher levels of cognitive domain, namely application and thinking. A few questions on information recall and comprehension were however added to reduce the level of difficulty of the test. The short answer question and the multiple choice item format adopted is consistent with practice in Senior Secondary Certificate Examination (SSCE) conducted by the West African Examinations Council (WAEC) and the National Examination Council (NECO) in physics theory paper.

**Table 1: Item Specification for ATP**

| Topic/Concept | | Cognitive Domain | | | |
|---|---|---|---|---|---|
| | | **Recall** | **Application** | **Reasoning/ Thinking** | **Total No of Items** |
| 1 | **Wave motion and** types of waves | 32 | **7, 8** | **6, 10, 11 12,** 33,34,35(7) | **10** |
| 2 | Wave profile/representation | 14, 15, 16, 17, 18,19 | 13 | 37, 38 | 9 |
| 3 | Wave equation/Nomenclature | 1, 3, 5, 23, 40 | 9, 24, 25, 26, 27,28,3O,3l | 2, 4, 29 | 16 |
| 4 | Properties of waves | 39, 41, 42, 43 | 21, 22, 36 ç) | 20 | 8 |
| | **Grand Total** | **16** | **14** | **13** | **43** |

**Validity and Reliability of ATP**

The original ATP constructed contained 58 items. The test items were given to three experts (Lecturers in Physics education) and three graduate physics teachers with upwards of five years teaching experience in the secondary school. This was done in order to determine the content and construct validity of the test items. On the basis of the recommendations and suggestions from these experts and teachers, the items were reduced to 52. This was then administered on a sample of 50 SSS3 Physics students in a Federal Government College in Lagos personally by the researcher.

This enabled the researcher take note of the reactions of the students in addition to using the analyzed result from the test to form the basis to further reduce the number of items. The test results were then subjected to item analysis for item reliability. An additional nine items were eliminated so that the final test was made up of 43 items. These items were considered to have good discriminating power, suitable difficulty characteristics, contain no ambiguities and able to elicit very brief responses (for the short answer questions). These were then analyzed using the Guttman split-half statistic which gave the result of alpha =.75 for one part and alpha.64 for the other half of the test.

**Rating Scale for Teachers (RST)**

This instrument was designed to measure the competence of the trainee teachers who implemented aspects of the study specified in the instructional guide for each of the experimental groups. Orji's (1998) Rating Instrument for Trainees (RIFT) was adopted here. It was considered adequate for this study since he had used it for rating teachers towards problem-solving and concept mapping strategies for instruction in physics. It was developed based on the activities for each of the instructional strategies. Each lesson activity was subdivided into four units. There were five main activities in all. Every unit was assessed on a scale from zero to maximum of five points. The RST had aspects asking for personal information about the teacher as well as directions on how the raters were expected to use the instrument.

**Validity and Reliability of RST**

The RST was revalidated by administering it on some eight physics teachers during the pilot phase of the study. The Spearman's Rank correlation coefficient of.92 was obtained which is comparable to Orji's calculated inter-rater reliability index value of.96.

**Scoring of the Instruments**

**Scoring of CST**

The scoring was made in such a way that ***one*** (***1***) mark each was allotted on analytic, inferential and relational responses. The score was based on the logic behind grouping two of the three pictures together. For each student, the responses were summed up separately for analytic/inferential and relational. It is possible for a student to score a maximum of 20. A student who scored above the median on analytic/inferential responses and below the median on relational responses was called field independent (FI). A student who scored above the median on relational responses and below the median on analytical/inferential responses was labeled field dependent (FD). Students who failed to meet these criteria were excluded from the sample.

**Scoring of QAT**

Each question on QAT carries a maximum of 1 mark. A wrong answer scores zero. This test was designed and used to categorize students into high, medium and low quantitative ability strata.

**Scoring of ATP**

Each correct answer attracts ***1 mark*** both in the short answer section B and multiple choice section C. A wrong answer scored zero. However, for the short answer questions, an incomplete but right attempt attracted ½ mark instead of the full 1 mark.

**Scoring of RST**

A total of 20 points was allotted to each main activity on the RST. Each unit of activity attracted a maximum of 5 points. Therefore a total maximum score of 100 points was obtainable by a trainee (teacher). For the purpose of this study, a mean score of 70 and above must be obtained before a teacher was considered adequate for teaching.

**General and Treatment Procedure**

The general procedure outlined below for the main study was equally adopted for the pilot testing. The research treatment procedure was carried out in four major stages namely:

- Preliminary and training stage
- Pre-treatment stage
- Treatment stage
- Post treatment stage

The entire study lasted for time duration often weeks. This study adopted two strategies which were designed to assure systematic difference in treatment conditions as well as boost the within group homogeneity among participating teachers so as to increase the sensitivity of the experiment. These include the:

- Employment of large sample size (n > 200). This was done in hope that such a sample size would increase the magnitude of the obtained F-ratio (Keppel & Sanfley, 1980) as well as bring about smaller critical F-ratio values (Cox, 1958).
- Training the teachers and providing them with instructional guides and conducting periodical checks on them during the treatment period to ensure that teachers adhered strictly to the modes of instruction stipulated. This way, a good measure of inter-teacher and intra-teacher reliability was maintained.

The training of teachers was done using the Researcher's Instructional Guide for Model Based Instruction

(RIGMI). RIGMI is made up of five major steps namely: Introduction, Presentation of theoretical/conceptual knowledge, implementation of experimental strategy for evaluation, feedback and review for breakdown of steps under each strategy).

**Table 2: Time Table for Treatment Procedure**

| Week | Activity Carried Out and Length of Time | |
|---|---|---|
| 1 | Training of teachers to handle the four experimental groups using the appropriate RIGMI This was conducted in the various schools. It lasted for one week | Preliminary and training stage |
| 2 | Administration of pre-tests. All the tests were administered on the subjects in the following order PAT, CST. QAT and ATP. This lasted for another one week. | Pre-treatment stage (pre-test) |
| 3 | 1. General briefing and training by the researchers. The researchers trained the teachers who in turn trained subjects to acquaint them with the objectives and major ideas of study. 2. Teacher was scored using RST to determine competence in handling the instructional guide. | Pres-treatment stage, general briefing and further training. |
| 4-8 | Five weeks of instruction/teaching using the respective instructional guides for each experimental group by a trained teacher. This lasted for five weeks. | Treatment stage |
| 9 | Revisions, corrections and completion of selected concepts. This lasted for one week. | Post-treatment (post- mortem) |
| | Administration of test items namely PAT and ATP | Post-test |

## TREATMENT PROCEDURE OF EXPERIMENTAL GROUPS

**Experimental Group 1 ($E_1$)**

**Analogy Instructional Model (AIM)**

Two of the selected schools randomly assigned to this group were exposed to four phases of treatment procedure, that is: preliminary and training; practice and review; treatment/exposition to selected concepts; and post-treatment/post-exposition. Analogy is the major treatment given to this group. Therefore the group was exposed to training and practice sessions on what analogical models are all about and how to use them to enhance learning and aid understanding in physics. This lasted for one week while the actual teaching lasted for five weeks using the AIM.

**Description of Phases**

**Preliminary and Training:** The researchers first administered the pre-test in the order stipulated on Table 2. Then, the trained teacher in conjunction with the researchers introduced students to the operational definitions of analogy, mental models, conceptual models, scientific metaphors and how these help to establish relationships or parallels between what is known and what is not known. Analogues and models are not to be mistaken for reality but should only be seen - in the light of the understanding and comprehension they help to foster particularly on difficult abstract concepts. To this end, students were encouraged to:

- Construct, suggest, represent, verbalize, draw or sketch their own mental/analogical models to express their understanding of an event, phenomenon or objects.
- Appreciate the fact that analogies/mental models are not always right the first time but continue to undergo change and revision. In this way, such mental models will approximate the conceptual/scientific models until no differences exist any longer between the two.

- Analogies are not relevant and do not apply to all situations or phenomena. Thus analogies have their limitations. They are only to be used for abstract difficult concepts if their use is to be maximized.
- The limitations of a given analogy/model must be clearly drawn or stated. This is possible by examining the similarities and differences between the true state of affairs and a given model or analogy.

**Practice and Review:** During this session, students were provided opportunity to express their mental models on some of the activities specified in the RIGMI based on the concepts under scrutiny. The session was also devoted to reviewing important definitions, analogies, discussing problematic areas, re-examining the mental representations; picking the best models for display on classroom walls for recognition and to serve as motivation to other students.

**Exposition to Selected Concepts:** Here students were taught the selected concepts on waves using RIGMI for analogy instruction provided by the researcher. The analogy used for each lesson was introduced early in the lesson. The lesson went on to pinpointing the similarities and differences between the given analogy and the real thing, object or phenomenon. Finally, the teacher ends the lesson by stating clearly the limitations of the analogy in question for a particular concept under consideration.

**Post-Treatment/Exposition:** Here the students were advised to revise or complete the selected topics and to make corrections with the teacher. The post-tests were then administered.

## EXPERIMENTAL GROUP 2 ($E_2$)

### Problem-Solving Instructional Model (PSIM)

These groups of subjects are those taught using the RIGMI for problem solving. They were therefore exposed to training, practice and review sections on what problem solving models are all about and how they could use them to enhance their learning in physics. This lasted for one week while the group was then taught for five weeks by the trained teacher using the PSIM.

### Description of Phases

**Preliminary and Training Phase:** The researchers first administered the pretests in the order stipulated. This was closely followed by trained teacher in conjunction with the researcher introducing the subjects to the key ideas governing this strategy namely:

- Problem identification, definition and representation: Here the students are made to learn:
  - How to focus a problem by identifying it clearly and defining or restating its key terms, concepts and ideas,
  - How to seek ways of representing a problem through diagrams, graphs, sketches, and short comments, which will help in the step by step analysis of the problem as well as provide a reliable basis for selecting appropriate strategies or approaches for solution.
- Choosing a solution strategy or model for problem solving. Here reasoning and thinking as well as ability to make decisions (meta-cognitive skills) which are higher order cognitive activities are involved.
- Taking action by applying the options or strategies selected to solve problem.

- Evaluation and Review - this involves checking back to ensure that all identified relevant information have been used following the identified/selected plan of action for problem solving. An example problem is used for illustration. The instructional guide specified the problem(s) to be used for each topic and how to follow the outlined problem solving steps.

**Practice and Review**

In this session, students are exposed to solve the problem specified in the instructional guide. They are given time to solve the problem following the steps highlighted during the training session. A debriefing discussion is held by the teacher with the students. Here emphasis is placed on mental models, representations, and to re-examine efforts made by students in following the steps in solving problems as well as the difficulties encountered while doing this. Best solutions are identified and read or displayed to the class as incentive to others.

**Exposition to the Selected Concepts**

Here the trained teacher used the PSIM to teach the subjects in line with the activities stipulated in the instructional guide. During lessons, students were made to take notes, paying attention to the things they considered as the main ideas in a given topic. In addition, the teacher emphasized the definition and explanation of key concepts or terms involved in a topic. A problem is posed to the subjects by the teacher as specified based on the topic being considered. The students are then allowed enough time to solve the problem in their work sheets. This was usually reviewed by the teacher whenever he returned the work sheets to the students.

**Post -Exposition**

Here time is allowed for the students to go over the concepts covered or to complete all the topics and make corrections where necessary with the teacher. The post-tests were then administered.

## EXPERIMENTAL GROUP 3 ($E_3$)

**Concept-Mapping Instructional Model (CMIM)**

Two of the randomly assigned schools from the selected ones formed this group. The students were exposed to training and practice session on concept mapping as contained in the instructional guide. In addition, they were taught the selected wave concepts for five weeks using this approach with pre and post-tests appropriately administered.

**Preliminary and Training**

The researchers first administered the pre-test on the subjects before this phase as commenced. The trained teacher started with the introduction of the operational definitions of terms applied to concept mapping such as concepts, propositions, relationships, hierarchies, cross links and general to specific, using the pre-requisite concepts to those selected for study. Samples of concept maps drawn by experts were used to illustrate the structural display of a concept map. The teacher then drew more concept maps with some selected words and concepts as examples as specified in the guide for instruction. Emphasis during training was placed on the following attributes of concept maps are that they:

- Are tools for organizing and representing knowledge in hierarchical form,
- Are technique for representing knowledge in graphical or diagrammatic forms with concepts enclosed in boxes or circles and linked with lines and phrases,

- Are drawn to branch out from more general concepts to less inclusive concepts and specific examples,
- Enable us to gain an over view of a domain knowledge based on their visual format and
- Undergo revision.

**Practice and Review:** In this session, students are given opportunity to draw concept maps based on the activities specified in the instructional guide. In addition, the teacher reviews important terms and definitions, examining students' maps, discussing problem areas, picking and displaying on classroom walls adjudged best map(s).

**Exposition to the Selected Concepts:** Here students were taught the selected concepts using the concepts mapping instructional guide by the trained teachers. During lessons, students were made to list and copy in their notebooks the key concepts, words, phrases or major ideas while the lesson was in progress. Before the end of a lesson, students were given time to draw concept maps using the concept/words listed. These maps were reviewed by the teacher and returned to the students before the next lesson when they were fully discussed. This was done with a view to helping students improve upon subsequent maps i.e. enable them to draw maps with richer linkages among concepts learnt.

**Post-Exposition:** A period of one week was allowed for the teacher to rehearse and complete all topics selected for the study. This was followed by the administration of post- tests.

## EXPERIMENTAL GROUP 4 (CONTROL C)

### The Conventional Instructional Teaching Method

This group was taught by trained teachers who used the traditional chalk, talk and board instructional approach. They were trained not in any of the activities of model based instructions but for purposes of ensuring uniformity in steps and procedures to take in teaching the selected concepts as stated in instructional guide for conventional method. The teachers gave exercises and assignments for students to practice and solve problems on the concepts treated. These were equally marked and reviewed in the class for all the students. The teachers were allowed one week to revise and complete the selected concepts for the study. The post tests were then finally administered on the subjects.

### Findings and Analysis of Data

Posttest Achievement Test (ATP) scores were subjected to analysis of covariance (ANCOVA) using the pre-test score as covariate. Multiple classification analysis (MCA) of achievement scores and the Scheffe Post-hoc comparison of treatment groups and achievement posttest scores were also carried out.

**Table 3: Mean and Mean Difference and ATP According to Treatment Groups**

| AIS N =52 | | | PSIS N =56 | | | CMIS N=54 | | | CIM N=54 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre-test | Post test | Mean diff. | Pre-test | Post test | Mean diff. | Pre-test | Post test | Mean diff. | Pre-test | Post test | Mean diff. |
| 6.00 | 16.63 | 10.65 | 6.20 | 18.95 | 12.75 | 4.93 | 16.90 | 11.97 | 5.97 | 14.28 | 8.69 |

The results in Table 3 reveals that the highest gain in mean score (12.75) was recorded by students in group II, followed by group III (11.97), followed by group I (10.63) and finally the control group IV with mean difference of (8.69). These mean differences obtained are substantial difference in performance of experimental and control groups. They were therefore subjected to the analysis of covariance to know whether these mean are statically significant. The results from Table 3 show the following at $p < .05$.

**Table 4: Summary of Analysis of Covariance (ANCOVA) of Achievement Test in Physics (ATP) by Treatment, Cognitive Style and Quantitative Ability**

| Sources of Variation | Sum of Square | Df | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| Covariates Pre-test | 684.948<br>684.948 | 1<br>1 | 684.948<br>684.948 | 33<br>33 | .000<br>.000 |
| Main Effects<br>Treatment<br>Cognitive style<br>Quantitative style | 889.466<br>484.449<br>221.236<br>116.677 | 6<br>3<br>1<br>2 | 148.240<br>161.480<br>221.240<br>58.338 | 7.1<br>7.8<br>11<br>28 | .000<br>.000*<br>.001*<br>.062 |
| 2-Way Interactions<br>Treatment x Cog. style | 151.512<br>20.308 | 11<br>3 | 13.774<br>6.769 | .669<br>.326 | .771<br>.566 |
| Treatment x qty. ability<br>Cog. style x Qty. Ability | 102.751<br>23.993 | 6<br>2 | 17.125<br>11.996 | .826<br>.576 | .551<br>.562 |
| 3-Way Interactions<br>Treatment x CST x QAT. | 100.2751<br>100.278 | 6<br>6 | 16.713<br>16.713 | .806<br>.806 | .566<br>.566 |
| Explain<br>Residential | 1826.204<br>4127.077 | 24<br>199 | 76.092<br>20.739 | 3.7 | .000 |
| **Total** | **5953.281** | **223** | **26.696** | | |

There is a significant main effect of treatment on achievement [$F_{(3,223)}$ = 7.8;P<.05 ]
There is a significant main effect of cognitive style on achievement [$F_{(1.223)}$ = 11 ]
There no significant main effect of quantitative ability on achievement [$F_{(3,223)}$ = 2.8 ]
There are two or three way interaction effects recorded on the dependent measure.

**Table 5: Multiple Classification Analysis (MCA) of Achievement Scores by Treatment Groups, Cognition Style and Quantitative Ability Grand Mean = 16.72**

| Variable + Category | N | Unadjusted Deviation | ETA | Adjusted for Independent Factor + Covariates | *BETA* |
|---|---|---|---|---|---|
| Treatment Groups | | | | | |
| 1. Analogy | 52 | -8.41 | | .31 | |
| 2. Problem solving | 56 | +2.23 | | 1.91 | |
| 3. Concept Mapping | 62 | .18 | | 1.34 | |
| 4. Conventional | 54 | -2.44 | .32 | -2.29 | .29 |
| Cognitive style | | | | | |
| 1. Analytical | 127 | .97 | | .93 | |
| 2. Non-Analytical | 97 | -1.27 | .21 | -1.22 | .21 |
| Quantity Ability | | | | | |
| 1. High | 43 | 1.72 | | 1.46 | |
| 2. Medium | 93 | -8.5 | | -.53 | |
| 3. Low | 88 | 5.40 | .18 | -.15 | .14 |
| Multiple R Squared =.264, Multiple R =.514 | | | | | |

Results in Table 5 show that group II (problem solving) had the highest adjusted posttest mean score of 18.63, followed by group III (concept mapping) with posttest means score of 18.06, followed by group I (analogy) with 17.03 adjusted posttest score. The lowest adjusted posttest means score of 14.43 was recorded by the control group. Thus, the MCA table shows that the treatment main effect accounted for less than one percent $(0.7)^2$ of the observed variance in data.

**Table 6: Summary of Scheffe Post-Hoc Comparison of Treatment Groups and Achievement Post Test Mean Scores**

| Treatment | Groups | | | | |
|---|---|---|---|---|---|
| | Mean | 1 | 2 | 3 | 4 |
| 1 | 17.03 | | | | * |
| 2 | 18.63 | | | | * |
| 3 | 18.07 | | | | * |
| 4 | 14.43 | * | * | * | |

**Key:** * denotes pairs of groups significantly different at.5 level.

The results (Table 6) of the post-hoc analysis (Scheffe multiple range comparison) showed that none of the means of treatment condition had significantly higher mean score than the other except the control group. The overall results of this study showed that the model-based instructional strategies were superior to lecture method in enhancing achievement in physics in the order: problem solving-concept mapping-analogy-lecture method.

Another finding is on the significant main effect of cognitive style on achievement which agrees with Mc Robbie (1994); Okebukola (1992); Ogunsola-Bandele (2002); Tamir and Kemp (1976); but disagrees with Orji's (1998) finding of no significant main effect of cognitive style on achievement in physics. The study did not record any significant main effect of quantitative ability alone or its interaction effects with the other measures on achievement in physics as recorded by Orji (1998) and Iroegbu (1998). This is a pointer to the effect of considering cognitive style on teaching difficult concepts over quantitative ability.

**Contribution to the Teaching and Learning of Physics**

Declining trends in both high school and college-level science enrollment present science educators with the need to make informed policy decisions regarding the effectiveness and appropriateness of current instructional approaches and curricular resources. In physics, these decisions often involve a choice between a more traditional mathematics – based approach and an alternative conceptual approach (Sousa, 1996). Because of the long established philosophy of teaching physics with mathematics-based approach, physics instructors who support conceptual approach are faced with the difficult task of changing the manner in which curriculum is presented to students. The model-based instructional strategies (analogy, problem solving and concept mapping) should be adopted as viable alternative strategies for teaching difficult concepts in physics as they not only actively engage the students and make them builders of their own knowledge, but also enable them to make meaning and create understanding. They are equally viable strategies for raising achievement levels of the students.

## CONCLUSIONS

Physics has been reported worldwide to be the least popular and perceived as the most abstract, irrelevant, and confusing science course in the high school curriculum (Fanz, 1983; Jones and Zander, 1998); Ogunsola-Bandele, 2001; Okoronka, 2004; Toews, 1988). The selection of the wave concept is also based on research finding that despite the importance of the concept, there exist general weakness in students' understanding of fundamental ideas (Dean, 1980; NERDC, 1994; Okoronka, 2004). In fact numerous questionnaires and surveys have been administered to determine the reason for the low enrollment among high school students and the results are consistently similar: most high school students feel physics contains too many facts /technical terms to learn, requires too much of math background, and the textbooks are too difficult read (Ogunsola-Bandele, 2001). This continuous decrease in enrollment is an unfortunate development at this science and technology era. It then should be of particular interest to educators to find a way round this problem in their classrooms. The effective use of the three model based instructional strategies used in teaching this difficult concept in physics offers itself to science educators as one of the solutions.

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