EFFECT OF MODEL-BASED INSTRUCTIONAL STRATEGIES ON STUDENTS' ATTITUDE TOWARDS PHYSICS IN SECONDARY SCHOOL EDUCATION

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Abstract
This study investigated the relative effects of model-based instructional (MBI) strategies of analogy, problem solving and concept mapping on the attitude of students to physics. It equally examined the moderating effects of cognitive style and mathematical ability on attitude. A pretest, posttest, control group, quasi-experimental design was employed for matching the variables. 243 SSII physics students drawn from eight senior secondary schools in Lagos metropolis were sampled out. From this subjects were categorized into field independent (FI): 127, and field dependent (FD): 97, cognitive style using the Cognitive Style Test (CST). Two other research instruments used were the Mathematical Ability Test (MAT) and the Physics Attitude Test (PAT). Data were analyzed using the analysis of covariance (ANCOVA), multiple classification analysis (MCA) and graphs. The results did not show any significant main effect of MBI, cognitive style or mathematical ability on the dependent variable. However, there was an interaction effect of MBI and cognitive style on attitude to physics ($F_{(3, 223)} = 3.927$, $p = .05$). FD learners exhibited more positive attitude towards physics than their FI counterparts. In addition, concept mapping strategy was most preferred by FD learners while problem solving strategy was most preferred by FI students. The main implication of these findings is that classroom teachers, curriculum planners and all others involved in science educational processes should incorporate model-based instructional strategies and align them with students' cognitive styles in science instruction.

Key Words: attitude to physics, cognitive style, mathematical ability, model-based instruction, analogy, concept mapping and problem solving.

Introduction

There seems to be a consensus of opinion among science education researchers concerning the pivotal role played by the quality of teaching method or strategy of instruction adopted as classroom variable in affecting students' attitude towards science (Simpson and Oliver, 1990; Ebenezer and Zoller, 1993; Simon, 2000; Okoronka, 2004). This is because instructional process brings together students, teachers (or the surrogate teacher) and the curriculum content into interaction. It is at this juncture that the learner's interest and attitude are best and most aroused, sustained or marred. Available literatures on the theme of attitude to science identify three most important factors influencing attitude towards science as effective teaching, perceived difficulty and gender. Ebenezer and Zoller (1993) report that the most important variable affecting students' attitude towards school science was the kind of instruction they experienced. This is supported by the findings of Sundberg and Dini (1994).

On the perceived difficulty of science, Harvard (1996) has identified students' perception as being a determinant of subject choice. Also, Simpson and Oliver (1990) in their longitudinal study showed a strong relationship between attitude towards science, motivation to achieve and the self concept of an individual, of his own ability and their achievement. The inherent characteristic as well as the nature of concepts in physics (as a science) makes it seemingly difficult and abstract to learners (Okoronka and Ogunsola–Bandele, 2008). These factors have combined to bring about low enrolment and poor achievement in physics exacerbated by poor attitude to the subject.

The promotion of enthusiasm and enhancement of interest which will ultimately lead to positive attitude formation towards science is one of the key aims of secondary school science education. It is only when appropriate intervention (including the instructional strategies used in the classroom) have been employed, that any significant result or change in attitude could be achieved. Human affective characteristics and the method of instruction are factors that not only shape learners' disposition to learning but also determine attitude and interest within the educational setting. The advantage of this is that they can be altered through appropriate interventions.

Three learner characteristics that this research considers significant to attitude formation include cues, reinforcement and participation. Cues deal with clarity, variety, meaningfulness and strength of the teacher's explanations. Reinforcement refers to the amount of acknowledgement or social support the learner receives for learning. On the other hand, participation pertains to the extent to which students are allowed to engage actively in the learning process. It could be submitted that all these factors individually and collectively contribute to attitude formation towards a subject and are basically linked to the teacher's instructional method. It is against this background that this researcher posits that the model based instructional strategy will be capable of eliciting positive attitude from physics learners. Model based instruction has its theoretical underpinning in cognitive science and principles of knowledge construction, and emphasizes the incorporation of what the learner already knows (mental models) and how the learner reasons (VonGlasserfeld, 1995; Lebow, 1995). This translates to utilizing the mental models of the learner and emphasizing his active engagement while copying "expert models" as a standard to learn better.

This study therefore seeks to relate students' attitude forming towards studying physics to effects of their cognitive style and potential in mathematics that will be reflected in aptitude scores. Model Based Instruction (MBI) strategies: analogy, concept mapping and problem solving, are employed in teaching physics topics to evaluate both performance in and attitude formed towards the subject. Results are analyzed using both descriptive and inferential statistical tools for estimating formation of students' attitude.

Literature Review

The present study adopts three "expert models" for instructional purposes: analogy, problem solving and concept mapping. An analogy is a parallel or system used to support the process of reasoning and restructuring mental frameworks of learners. It is used by practicing scientists and teachers to facilitate transfer of relationships from familiar analogous domain to an unfamiliar target domain (Orgill, Badner 2006; Bulgreen, Deshler, Schumaker and Lenz, 2000; Harrison and Treagust, 2000). Problem solving is a byproduct of conceptual and procedural knowledge. As an instructional tool, a problem (ill structured) is purposefully created to cause cognitive dissonance to the learner who is then set on the path of cognitive processing to solve the problem. Experts solve problems first by developing a framework or mental model which consists of structural knowledge, procedural knowledge, reflective knowledge and mental images. Metaphors of the system along with executive or strategic knowledge are used to support this process (Jonassen and Henning, 1999). Learners use concept maps to achieve an expert framework for representing knowledge and interrelations between the concepts in order to facilitate their learning. The concepts are enclosed in boxes/circles which are linked with lines and phrases (Novak, 1991). The ability of a learner to draw concept maps will depend on the learner's existing conceptual framework or mental models and the connections or propositions inherent in the new knowledge.

Two other variables which have identified to influence attitude of learners towards physics are cognitive style and mathematical ability of the learners. Cognitive style describes the individual's characteristic way of processing information or a learning task and characterizes the person. Two cognitive style dimensions of interest in this study are field independent (FI): (analytical) and field dependent (FD): (non-analytical) orientations. FI students tend to be more analytical, logical and better able to restructure and abstract subtle aspects of a problem. By contrast the FD students have their social skills, attitudes, perceptions, qualities and feelings strongly influenced by their physical and social background. Physics is generally regarded as difficult by students due to its high mathematical demands in explicating some of its concepts (NERDC, 1994; Iroegbu, 1998; Ogunsola-Bandele, 2001). Bassock (1990) observes that students who have no mastery of mathematical skill usually have significant difficulty in physics problems.

The problem

This study addressed the issue of low interest of students towards physics and the resultant low performance in the subject. It sought to investigate the relative effects of model based instructional strategies of analogy, concept mapping and problem solving on students' attitude formation towards physics. It also examined the extent to which cognitive style and mathematical ability influence attitude. Based on the problem, answers were sought to the following research questions:

i. Which of the four instructional strategies namely analogy, concept mapping, problem solving, and lecture method would best enhance senior secondary school students' attitude to physics?
ii. Would students' cognitive style influence their attitude towards physics?
iii. Would students' mathematical ability influence their attitude towards physics?
iv. Would there be any interaction of treatment, cognitive style and mathematical ability on attitude towards physics?

In order to address these questions, three main effect and four interaction effect hypotheses were tested at 0.05 alpha level.

Research Design

The study is a non-randomized, pretest, post test, control group quasi-experimental design which adopted a 4x2x3 factorial matrix for the purpose of analyzing the data.

Population and Sampling

The study is on school children who offer and study physics at the Senior School Certificate Examination (SSCE) level. Samples for the research came from all government secondary schools that have presented candidates for the SSCE examinations for a consecutive period of five years in Lagos State. In addition, such schools should have a graduate physics teacher and a WAEC approved physics laboratory. Eight out of the sixteen schools which met these criteria were purposively selected from the Etiosa Local Government Area of the State. Schools involved were distantly located from each other so as to reduce contamination from interaction among subjects. A total sample size of 243 subjects made up of 102 males and 141 females with varied mathematical ability grouping (high, medium, and low) were involved. Intact classes of SS II physics students, and only those identified as FI (127) and FD (97) using the cognitive style test (CST) qualified for analysis in the experiment.

Instrumentation

Three (3) instruments were used for data collection namely: the Cognitive Style Test (CST), the Mathematical Ability Test (MAT) and Physics Attitude Test (PAT). The CST adopted is a modified model of the Siegel Cognitive Style Test which has been systematically adapted and modified in Nigeria over the years. For instance, the model by Ughmadu (1990); Ekwere (1998) and Ige (1998). Ekwere and Ige each revalidated the test and calculated Pearson Product Moment Correlation Coefficient, r = .71 and r = .72, respectively. These were considered satisfactory for the purpose of the present study.

The PAT was developed by the researcher based on a review of earlier studies on students' attitude to science, e.g. Orji (1998). The test consisted of attitudinal inventory made up of 35 items of 4–point Likert Scale scored as follows: Strongly Agree (SA): 4; Agree (A): 3; Disagree (D): 2; and Strongly Disagree (SD):1, respectively. Cronbach Coefficient of .69 was obtained from the validation carried out on the instrument.

The MAT was developed as a 4-option multiple choice test adapted from the Otis-Lenon Standardized Mental Ability Test. It was made up of 26 items. Each correct answer scored 1 point but zero (0) for the wrong selection. The reliability coefficient calculated using Kuder Richardson Formula 21 (KR_{21}) was .69 and the mean item difficulty index obtained was 48.

Treatment Procedure

The eight purposively selected Senior Secondary Schools were randomly assigned by balloting to four treatment conditions (two schools for each experimental condition) as follows: Group 1 - Analogy mediated; Group 2 – Problem Solving mediated; Group 3 – Concept Mapping mediated and Group 4 – Control. Both the teachers and students who participated in the study were trained on the purpose, principles and procedures governing model based instruction. An instructional guide appropriate to each group was developed by the researcher along five steps: introduction, presentation, implementation, evaluation and feedback/review.

Results

Results of the study are presented in two summary tables: Table 1 being an analysis of Covariance of Attitude Scores by Treatment, Cognitive Style and Mathematical Ability, while Table 2 gives a Multiple Classification Analysis (MCA) of Post Attitude Scores by Treatment Groups, Cognitive Style and Mathematical Ability. Both tables result from administration of instruments MAT, CST and PAT during the study. Results from Table 1 show as follows:

i. there is no significant main effects of treatment, cognitive style and mathematical ability on attitude to physics;
ii. there is a 2-way interaction effect of treatment and cognitive style on attitude to physics [$F_{(3,223)} = 3.927$; $P < .05$]; and
iii. there is no significant 3-way interaction effects of treatment, cognitive style and mathematical ability on attitude to physics.

Table 2 shows the multiple classification analysis (MCA) of post PAT scores by treatment groups, cognitive style and mathematical ability. The table shows that the mean scores of post PAT are not significantly different from each other.

Table 1:
Summary of ANCOVA of Attitude Scores by Treatment, Cognitive Style and Mathematical Ability

Source of Variation Significance	Sum of Squares	Df	Mean Squares	F	
Covariates	6000.550	1	6000.550	76.25	.000
Pre-attitude Test	6000.550	1	6000.550	76.25	.000
Main Effects	388.987	6	64.831	.824	.553
Treatment	121.559	3	40.520	.515	.672
Cognitive Style	11.707	1	11.707	.149	.700
Treatment x Mth. Ability	201.819	2	100.910	1.283	.280
2 – ways interactions	1437.471	11	130.679	1.661	.085
Treatment x Cog. Style	927.061	3	309.020	3.927	.009*
Treatment x Mth Ability	604.812	6	100.802	1.281	.268
Cog. Style x Mth. Ability	17.356	2	8.678	.110	.896
3 – way interactions (i.e. Treatment x Cog. Style x Mth. Ability)	578.961	6	96.493	1.226	.294
Explained	8405.969	24	350.249	4.451	.000
Residual	15661.01	99	78.699		
Total	24066.98	23	107.924		

Table 2:
Multiple Classification Analysis (MCA) of Post Attitude Scores by Treatment Groups, Cognitive Style and Mathematical Ability

Variable + Category *Factor + Covariate*	*N*	*Unadjusted Deviation*	*Eta*	*Adjusted for Independent*	*Beta*
Treatment Group					
1. Analogy	52	.39	8.83		
2. Problem Solving	56	2.71	1.14		
3. Concept Mapping	62	.77	- .28		
4. Conventional	54	-2.3	.18	.95	.07
Cognitive Style					
1. Analytical	127	-.73	-22		
2. Non-Analytical	97	.95	.08	.28	.02
Mathematic Ability					
1. High	43	-1.74	-1.01		
2. Medium	93	-.62		-.68	
3. Low	88	1.51	.12	1.19	.09

Grand Mean = 98.74
Multiple R Squared = .265
Multiple R = .515

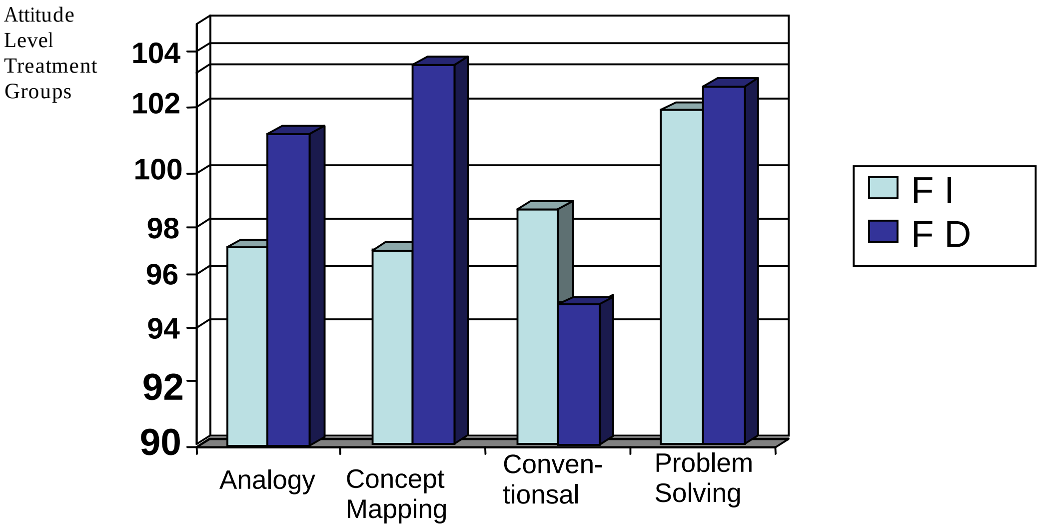

Fig.1: *Bar chart of interaction effect of instruction and cognitive style on students' Post attitude mean scores in physics.*

An interaction is recorded between instructional strategies and cognitive style of learners affecting attitude to physics. To further explain this interaction effect of instructional strategy and cognitive style on attitude, an analysis of gain in post-test mean scores was done. The bar chart in Fig. 1, based on the two-cognitive style categorization (FD and FI) for each treatment condition, was obtained. The chart reveals how students exhibited change in attitude towards physics in descending order from the highest effect: 1. FD subjects under concept mapping treatment condition; 2. FD subjects under problem solving treatment condition, 3. FI subjects under problem solving treatment condition, 4. FD subjects under analogy condition and 5. FI under control treatment condition, among the most significant.

Discussion

The study did not record any significant main effect of treatment alone on attitude to physics as recorded by Onwuegbu (1998) and Iroegbu (1998). This implies that none of the MBI strategies alone would produce a positive attitude towards physics. However, the study recorded a significant interaction effect of treatment and cognitive style on attitude towards physics in agreement with Orji (1998). This shows that when treatment and cognitive styles were combined, they produced a statistically significant effect on attitude as opposed to when these variables were taken singly. This could be explained by taking a look at the concept of cognitive style, which describes an individual's characteristic way of processing information, mode preference and information representation to form knowledge. The cognitive skills of interpreting, adapting, prioritizing, generating ideas and reflecting on ideas by learners which prevail are complex processes that demand more than a single variable. The requirements may therefore be difficult for subjects who were already used to the traditional lecture method.

However, when model-based instructional strategies were considered in conjunction with the cognitive style categorization of the subjects, a significant effect on attitude was produced. This occurred in favour of field dependent learners who by their nature are not usually very good science and mathematics students like their field independent counterparts (McRobbie, 1991; Okwo and Otubah, 2007). This implies that model based instructional strategies have the potency of improving attitude to physics when considered along with the cognitive style of learners. This is because the strategies tend to appeal to such subjects who under normal circumstances would not choose to offer physics because they are believed to lack what it takes to do it (Okwoh and Otubah, 2007). The opportunity of active participation offered in MBI strategies seems to arouse interest and consequently results into a positive attitude towards physics particularly among the FD learners. This is consistent with some studies that a positive attitude in a subject correlates positively with students' choice, enrolment and achievement in that subject, for example, that of Ebenezer and Zoller (1993).

Instructional strategy (the type and quality) has been observed as the most important variable affecting students' attitude towards subjects (Ebenezer and Zoller, Ibid; Sundberg and Dini, 1994). In the present study concept mapping instructional strategy was found to be the most appealing intervention among FD subjects. This may not be unconnected with the power of the strategy to combine both visual and verbal information to create understanding when concept mapping strategy is used to make learning meaningful (Novak, 1993).

Conclusion

The results of this study show that:

i. Model based instructional strategies, cognitive style or mathematical ability of learners cannot singly and separately have a significant effect on the attitude of students for physics.
ii. Model based instructional strategies when considered jointly with cognitive style of learners produce statistically significant effect on students' attitude to physics.
iii. Field dependent learners under the three experimental conditions generally exhibit more positive attitude towards physics than their field independent counterparts, although the FI students taught using problem solving instructional strategies show better attitudes than students taught through analogy methods (Fig. 2).
iv. Concept mapping instructional strategy is the most preferred method by the field dependent (Non-analytical) learners as opposed to problem solving strategy preferred most by the field independent Analytical) learners.

Implications of Findings

The findings of this study have some significant implications which bother on such areas as classroom practice, teacher education curriculum and educational planning as well as for educational publishing.

First, is the attitude of field dependent students found to be positive towards physics due to the application of the model-based instructional strategies. This tends to suggest that model based instructional strategies when used in consideration of the cognitive style of learners have the potential to increase enrolment/choice in physics which has been a major issue in physics. The implication is that educational practitioners, teachers, parents and guidance counselors should device a means of ascertaining the cognitive style of students in secondary schools and then use this as a basis for helping them to choose subjects rather than a blind selection.

Moreover, the more positive attitude exhibited by the field dependent students as compared to their field independent counterparts is suggestive that didactic, teacher-centered, conventional method need to be discouraged in favour of the model based strategies which are learner-centred. This further implies that the training of the would-be physics teacher must provide adequate exposure to such principles of instruction that emphasize building mostly on the students' mental models in the development of the meta-cognitive skills for learning.

Equally of importance is the gain of a positive attitude towards physics exhibited by those students (field dependent) who naturally may be regarded as weak and not having what it takes to study physics. The dividends of a positive attitude to science learning are important for causing increased enrolments in the subject and improved performance.

Recommendations

On the basis of the findings of this study, the following recommendations are made:

1. Teachers should be trained in the use of learner centered instructional strategies such as model-based instructional strategies of concept mapping, problem-solving and use of analogies. The use of such strategies will promote better attitudes for the learning of physics as it will create interest in learners.

2. Cognitive style tests should be administered by the guidance and counseling units in secondary schools so as to identify students who are field dependent and those fields independent. This will enable counseling and guiding students properly in choosing science subjects.

3. The writers and publishers of physics text books in Nigeria should be made to seriously consider the incorporation in books of models, pictures, graphs, simulations and other forms of representations as tools for creating meaning, understanding and promoting interest in potential physics students.

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