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Generative Instructional Strategy Enhances Senior Secondary School Students' Achievement in Physics

By

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Abstract

The period 1999 to 2009 in Nigeria witnessed persistent poor students' performance in Physics at the Senior School Certificate level. This has been linked to the adoption of instructional strategies which did not give enough consideration to learners' previous knowledge and how they reasoned in order for learners to construct their knowledge based on these. This study therefore implemented generative instructional strategy for teaching selected Physics concept using the pre-test, post-test control group quasi-experimental design. Findings showed that students exposed to the generative instructional strategy performed better (adjusted mean =29.14) than their peers in the conventional teaching group (adjusted mean =25.16) to a significant extent ($F_{(1.205)} = 18.08$; $p < .05$)*. Based on these, recommendations were made for Physics teachers to adopt generative instruction which encourages student construction of their learning and active involvement in classroom activities while capacity building programmes for science teachers should be organized to popularize the strategy.*

Background to the Study

Science and Technology has become an indispensable culture in the world. This is due to the fact that the economic and political strength of any nation depend on her scientific and technological achievement (Adepitan, 2003; Olagunju, Adesoji, Iroegbu and Ige, 2003). Also, the development of any nation is indicated by the overall social, economic and political progress and dependent upon man's activities in his natural environment. These activities revolve around science and its technological applications. It, therefore, implies that for any meaningful national growth and development to be achieved, Science and Technology must be an essential part of the nation's culture (Nwagbo, 2002; Opara, 2004; Adeniyi, 2005). Indeed, Science and Technology is a critical instrument for the upliftment of the nation's economy. Hence, it should form the basis for development as well as an influencing factor of peoples' thinking and working processes.

Physics as a science subject at the secondary school level is an important subject that is required for the scientific and technological development of any nation. Okoronka (2004) asserts that Physics is a vehicle for achieving the long-term goals of science because it is instrumental to technological and socio-economic growth across the globe. The role of Physics in the education of scientists, engineers, chemists and practitioners of other physical and biological sciences are enormous (Oludipe, 2003). It is a *sine qua non* to the technological development of any nation and its application is found in all spheres of human life and it is the foundation upon which the scientific and technological advancement of any nation rests. The subject is the foundation of scientific knowledge as it has contributed immensely to the existence and activities of man towards improved standard of living and growth in wealth.

Despite the importance of Physics, there are a number of observable problems plaguing the teaching and learning of the subject, especially at the secondary school level. These problems include poor method of instruction (Kalijah, 2002). This is supported by the assertion of Agommuoh and Nzewi (2003) that attributed the deterioration in students' achievement in Physics to ineffective method of teaching Physics.

These perhaps may be the reasons for students' poor academic performance in the subject both at the secondary and tertiary school levels. Based on this deplorable trend of poor performance, Physics educators have designed some instructional strategies over the years to curb the problem of underachievement in the subject. For instance, Iroegbu (1998) designed Problem-Based learning for better achievement, problem solving and line graphing skills in Physics. Orji (1998) recommended the use of problem solving and concept mapping strategies and cognitive style to improve achievement in Physics.

In spite of the scope, depth and supposed efficacy of these varieties of strategies, Physics students at the secondary school level continue to exhibit poor performance in the subject. Statistics obtained from the Research Library of the West African Examinations Council Headquarters Office, Lagos shows that between 1999 and 2009 in Nigeria, students' performance in Physics at the Senior School Certificate level is poor as the percentage pass at credit level and above consistently falls below 50% except in the years 2004 and 2006 when it was 51.02% and 58.05% respectively. In one of the years with these fairly high percentage passes i.e. 2006, the highest proportion of candidates who sat for the examination had their results either cancelled or withheld. This incidence might be due to students' involvement in one form of examination malpractice or the other out of desperation to pass. This puts to question the reality and reliability of the high level of performance and by extension the quality and effectiveness of the teaching-learning process in schools. This trend of poor performance is not good enough for a technologically aspiring country as Nigeria where there is the incidence of poor enrolment of students and consequently few numbers of persons aspiring to study in the fields of science, technology and related disciplines. A pass in Physics at the distinction or credit level is a pre-requisite for university admission into these fields of study.

Poor student performance in Physics perhaps may be linked to the use of instructional strategies which have not totally incorporated learners' previous knowledge and how they reasoned (Ezeliora, 2004; Okoronka, 2004; Okoli, 2006; Longjohn (2009). This is more so as instructional strategies adopted by teachers have not solved the problem probably because those strategies have not actually focused on learners as constructors of their own theories and knowledge. Learners need to be made to construct their own knowledge and ideas in learning because they are the architects of their own learning and constructors of their own ideas and knowledge (Ausubel, 1969; Glasserfield, 1995; Okoronka, 2004). Otherwise, continued use of teacher-centered or teacher-dominated strategies would yield nothing but learning by rote thereby making it difficult for students to recall pieces of information from memories.

It is against this background that the present study is designed to adopt the Generative Instructional Strategy (Wittrock, 1991) which involves active participation of learners and has the potential of engendering improved Physics achievement. This strategy is credited with the possession of potentials for allowing the self-efforts and abilities of learners through active process leading to good performance in Physics.

Generative Instructional Strategy is a step-by-step instructional strategy, which is based on learners' views and experiences in active classroom activities (Wittrock, 1999). It is a learner-centered approach whereby pieces of information retrieved from learners' memories on a particular concept, are explained and modified by learners themselves Ormrod, 2003). Generative Instructional Strategy allows for individualized form of learning and empowers learners with the ability to express their personal views. Learners are at the center of the learning process while teachers are facilitators (Ige, 2003). The major idea of Generative Instructional Strategy is that learners must not only make connection between the content being taught and his prior knowledge but also re-organize them for meaningful explanation. Generative Instructional Strategy is therefore, a model of teaching for comprehension.

The model of Generative Instructional Strategy is a functional model of instruction and not a structural model. As a functional model of instruction, it focuses on the cognitive processes that learners use to comprehend concepts as well as the teaching and instructional procedures useful for increasing comprehension (Wittrock, 1992). This model states that the process of understanding new concepts involves active learners' generation of two types of meaningful relations. The first type is generating meaningful relation between information to be learned and learners' prior knowledge and experiences. The second type is generating meaningful relation among the parts of the information to be learned. For instance, during instruction the teacher provides ample opportunities for learners to generate their own summaries, explanations, analogies and so on from the materials presented in class. The model of Generative Instructional Strategy involves a process of conceptual change, motivation, attention and meta-cognition.

The teachers' role in Generative Instructional Strategy is to facilitate the learning process and this will be effective if the teacher accepts some responsibilities while instructing learners:

- ♦ that learning with understanding is a generative process;
- ♦ that success in school begins with a belief in themselves, their abilities and values of efforts;
- ♦ the process of constructing meanings for instruction and for subject matter;

- ♦ to generate meanings for what they are studying;

This model of Generative Instructional Strategy is a specific approach to active Instructional Strategies. Its focus is to enable learners to be actively engaged and to use the engaged time productively. This will be achieved only if learners can actively generate their own ideas and relate them together. It is a form of inductive reasoning, which is reasoning from observation to generalization.

The constructivist's theory of learning states that learning is a process in which the learner actively constructs new ideas based upon current and past ideas. That is, "learning involves constructing one's own knowledge from one's own experiences" (Ormrod, 2003). This is applicable to Generative Instructional Strategy .Constructivists view learning as a personal endeavour, whereby internalized concepts, rules and general principles may consequently be applied. This school of thought views knowledge construction and occurrence of learning in three ways viz: subjective, shared and adaptation from one's own experiences as obtainable in the Generative Instructional Strategy. The constructivists believe that the teacher acts as a facilitator who motivates learners to discover facts and principles for themselves and to construct knowledge by working together to solve realistic problems usually in collaboration with others. This is known as knowledge construction in social process and it involves working individually through exploration within a given classroom structure. This process of knowledge construction leads to conceptual change with learners and teacher responsible for modifying learner's knowledge and working to solve realistic problems in collaboration with others.

Statement of the Problem

The role of the teacher in students' learning has been changing over time. Presently, the teacher-dominated teaching-learning strategies are no more fashionable as students' performance in Physics continues to be poor. Hence, the need for the teacher of the subject to adopt learner-centered strategies in active classroom activities based on learners' experience. One of such strategies is generative teaching whereby pieces of information retrieved from learners' memories on a particular concept, are explained and modified by learners themselves. This study therefore found out the effect of generative teaching on students' achievement in Physics.

Research Question

What are the pre- and post-test achievement scores in Physics of students in the

(a) experimental group?
(b) control group?

Null Hypothesis

There is no significant difference in the post-test achievement scores of students exposed to generative teaching and those taught using the conventional strategy.

Research Design

The study adopted the pre-test, post-test control group quasi-experimental design. This is applied in the study as:

O_1 X_1 O_3 ------- experimental group
O_2 X_2 O_4 ------- control group

Where O_1 and O_2 represent pre-test measures for experimental and control groups respectively

O_3 and O_4 represent post-test measures for experimental and control groups respectively

X_1 represents the generative teaching

X_2 represents the conventional instruction (control)

Participants

Two hundred and eight SSII Physics students from intact science classes purposively selected from six public Senior Secondary Schools participated in the study. The schools were selected based on availability of standard Physics laboratory as well as one graduate Physics teacher who would be trained to teach the concepts selected for the study using the instructional guides. In all, two hundred and eight students participated in the study.

Content Selection

The contents selected include Temperature and Heat as well as their measurements. The following specific sub-topics were treated in the study: Concept and measurement of Temperature, Different types of instruments for measuring temperature, Concept of Heat and Specific Heat Capacities, Latent Heat and its measurement, melting and the boiling points determination, Evaporation, Principles and operations of refrigerators and pressure cookers, concepts of clouds, dews and Relative Humidity. The contents were selected based on the WAEC Chief Examiners' Reports of 2002, 2003 and 2004 that students were not performing well in these topics.

Instruments

Three self-developed instruments were used for the study. These are:

1. Instructional Guide on Generative Instructional Strategy
2. Instructional Guide on Conventional Teaching Strategy
3. Students' Physics Achievement Test.

1. Instructional Guide on Generative Instructional Strategy (IGOG)

This instructional guide was adapted from Osborn and Wittrock (1983) and was used for the teaching of treatment group one. In this group, learners work in-groups of five. The instructional guide contains information to the teacher who is a facilitator in the teaching-learning environment. The instructional guide provides opportunity for learners to play active roles and be at the center of the learning process. It is made up of five procedural steps, which include: the introductory, the focusing, the activity, the discussion and the application Phases.

Introductory Phase: The facilitator introduces learners to the task ahead of them. He/she then distributes them into different activity groups. He/she supplies all necessary materials to each group and assigns learners in each group to specific tasks to be performed. He/she also exposes them to the concepts to be learnt. He/she familiarises learners with the processes and methods of Generative Instructional Strategy.

Focusing Phase: The facilitator presents the problem area to learners. Learners are then expected to recall information and ideas from their memories as well as experiences on the problem presented. After this, every member of the group brainstorms and discusses the problem presented by the facilitator. All these pieces of information were expected to be written down and mentioned verbally. The facilitator then goes round to supervise but never correct learners' misconceptions.

Activity Phase: Every learner in a group is involved in performing diverse activities. This includes carrying out some demonstration as well as performing some practical activities through following some procedural steps provided by the facilitator.

Discussion Phase: Learners discuss the results of the activities performed in their respective groups. The facilitator guides learners to provide correct answers to their misconceptions where applicable. Summaries of results are made in each group.

Application Phase: Learners present their summarised results to the whole class. Also, they are expected to apply the new knowledge acquired to other similar or related situation with the assistance of the facilitator.

Validation of IGOG

For validation, this instructional guide was presented to experts in Physics education including two Physics lecturers from colleges of education and two secondary school Physics teachers. Copies were also given to two English teachers and finally to the researcher's supervisors for corrections on the suitability of content, language of presentation and the workability of the Instructional Strategy. Corrections were then effected based on the recommendations received.

2. **Instructional Guide on Conventional Teaching Strategy (IGOC)**

This instrument was used in the control group and it is known as Conventional Teaching Strategy. This teaching approach is commonly used in classroom teaching. It is a teacher-centred approach because it focuses more on the teacher and his activities in the classroom. The following are the steps involved in Conventional Teaching Strategy:

- The teacher introduces the concept to be learned and asks questions on Learners' prior knowledge. Learners sit down facing the chalkboard while the teacher writes on the chalkboard.
- The teacher explains the new concept, while learners listen to the teacher.
- The teacher demonstrates, solves numerical and non-numerical problems and performs experiment using the Conventional Method which includes the following steps:

(a) The teacher sets up the apparatus for the experiment.
(b) The teacher manipulates the apparatus.
(c) The teacher takes readings of measurement.
(d) The teacher constructs table of values.
(e) The teacher plots graphs from the table of values.
(f) The teacher allows learners to copy notes.
(g) The teacher concludes the lesson by marking learners' notes.

Validation of IGOC

The instructional guide was presented to experts in Physics Education for corrections on the suitability of the content, language of presentation and the workability of the steps proposed. Their reactions were used to improve on the draft instrument.

3. **Students' Physics Achievement Test (SPAT)**

This was designed to measure students' level of performance at the knowledge, comprehension and thinking levels of cognition of the selected Physics concepts in line with the work of Okpala, Onocha and Oyedeji (1993). The instrument consists of 60 multiple-choice objective test items. The questions contain one correct answer and four distractors. Questions were drawn from the concept of temperature and its measurement, heat energy and its measurement, evaporation, boiling and freezing points, humidity and its measurement. This was based on the Table of Specification presented in Table 1.

Table 1: Table of Specification on SPAT

S/N	Topic/concept	Knowledge	Comprehension	Thinking	Total (%)
1	Measurement of temperature	11 (52.3%)	7 (33.3%)	3 (14.3%)	21(35%)
2	Measurement of heat energy 1	3 (42.8%)	2 (28.6%)	2 (28.6%)	7 (11.6%)
3	Measurement of heat energy II	3 (42.8%)	2 (28.6%)	2 (28.6%)	7 (13.3%)
4	Saturated vapor pressure	10 (40%)	6 (24%)	9 (36%)	25 (40%)
	Total	**27**	**17**	**16**	**60**
	Total percentage	**45%**	**28.3%**	**26.7%**	**100%**

Validation of SPAT

100 items of the achievement test were initially drawn and presented to two experienced graduate Physics Teachers of Secondary School, two experienced Physics Teachers and lecturers at the tertiary level of education for content and face validity. Necessary modifications and corrections were effected based on the assessors' comments. 20 items were removed and 80 items survived. These 80 items were then administered to a group of 30 SS II Physics Students in a School that was not part of the sample in Oyo Township of Oyo State, Nigeria. This was to provide for item analysis of the multiple choice tests, and further empirical validation of the items using KR-21 formula. 60 items were retained and 20 items with negative and low positive correlation values respectively were removed. This yielded a reliability value of 0.88 and an average item difficulty value of 0.42. These imply that the test is reliable and is neither too simple nor too difficult.

Procedure for the Study

Training of Participating Teachers: Six Physics teachers, one from each of the six selected schools, were trained in the use of relevant instructional guide. This took two weeks.

Pre-Test: The pre-test was conducted across the six schools using the Achievement test.

Treatment Implementation: Treatment was administered for a period of six weeks simultaneously both for the experimental and control groups.

Steps involved in Generative Instructional Strategy

Phase 1:Introductory Phase

Grouping of learners into small heterogeneous groups of 5 or 6; Examination of the materials/concepts to be learned under a given topic; Listing of what learners know on the topic or concept; Listing of what learners do not know and what they hoped to do.

Phase 2: Focusing Phase

Verification of what learners think they know; Learners were exposed to some fallacies to confirm what they professed to know; Learners were led to discover what they did not know; they consulted some learning materials such as textbooks to get more facts and knowledge in the activity phase.

Phase 3: The Activity Phase

Collection of materials; Learners consulted and studied the materials presented together; Learners wrote out the important points and interpreted what they have written individually and listed their findings.

Learners listed the materials needed for demonstration/experiment, collected the materials, set up the experiment, took their readings, displayed and interpreted the data collected.

Phase 4: The Discussion Phase

Learners discussed their results among themselves, summarised their findings and discoveries and each group compiled their results.

Phase 5: Whole Class Presentation

The groups presented their results to the class, made summary of findings and application of findings.

Steps Involved in the Conventional Teaching Strategy (Control Group)

In this group, the following steps were followed.

- The teacher introduced the concept.
- The teacher explained the new concept.
- The teacher solved problems.
- The teacher performed some experiments/demonstrations and:
  - (a) set up the apparatus for the experiment.
  - (b) manipulated the apparatus.
  - (c) took readings of measurements made.
  - (d) constructed table of values.
  - (e) plotted graphs from the table of values.
  - (f) allowed learners to copy notes.
  - (g) concluded the lesson and marked learners' notes.

Post-Test: At this stage**,** the achievement test was administered.
The entire study lasted eight weeks.

Methods of Data Analysis

Data collected were analyzed using descriptive statistics of mean and standard deviation as well as inferential statistics of Analysis of Covariance (ANCOVA). Line graph was also used to represent results on the research question.

Results

Table 2: Descriptive Statistics for Students' Pre- and Post-Test Achievement in Physics

Treatment Group	N	Mean Score		Deviation		Mean Gain
		Pre-test	Post-test	Pre-test	Post-test	
1.Generative Teaching	117	14.48	29.59	4.29	7.78	15.11
2.Control	91	12.02	24.58	3.65	4.68	12.56

Table 2 shows that at the pre-test level, students' achievement in Physics was higher for the generative instructional group ($\overline{x}$ = 14.48; Dev. = 4.29) than for the conventional instructional group ($\overline{x}$ = 12.02; Dev. = 3.65). At post-test, the same trend was obtained as the generative instructional group obtained higher achievement score ($\overline{x}$ = 29.59; Dev. = 7.78) than the control group ($\overline{x}$ = 24.58; Dev. = 4.68). Further, the mean gain in the experimental group (generative teaching) was 15.11 as against the 12.56 gained by the conventional instruction group.

Table 3: Summary of ANCOVA of Post-test Achievement Scores by Treatment

Source of Variance	Hierarchical Method				
	Sum of squares	df	Mean square	F	Sig.
Covariates (Pre-Test)	1143.98	1	1143.98	27.94	.00
Main effects (Treatment)	740.45	1	740.45	18.08	.00*
Model	1884.83	2	942.21	23.01	.00
Residual	8393.63	205	40.94		
Total	10278.07	207	49.65		

**significant at p < .05*

From Table 3, the pre-test achievement scores of students in the two groups were different significantly ($F_{(1,205)}$ = 27.94; p< .05). This means that the two groups were not comparable initially and justifies the use of ANCOVA which adjusted the post-test scores based on the initial differences obtained.

Table 3 further reveals that there is significant effect on the variance in students' post-test achievement in Physics ($F_{(1.205)}$ = 18.08; p < .05). This means that the difference in students' achievement scores at the post-test level is significant. Hence, the null hypothesis is rejected.

Table 4 presents the descriptive Multiple Classification Analysis.

Table 4: Multiple Classification Analysis of Post-test Achievement by Treatment Groups

Grand mean=27.40

Treatment Groups	N	Predicted Mean		Deviation			
		unadjusted	Adjusted for Factors and Covariates	unadjusted	Adjusted for Factors and Covariates	Eta	Beta
Generative Teaching	117	29.59	29.14	2.19	1.73	.35	.28
Control Group	91	24.58	25.16	-2.82	-2.23		
R = .428							
R = .183							

From Table 4, students in the experimental group i.e. generative teaching obtained adjusted mean score of 29.14 which is higher than that of students in the control group ($\overline{x}$ = 25.16; Dev. = -2.23). This shows that the generative teaching strategy was more effective at improving students' achievement in Physics than the conventional teaching strategy.

Implications of the Finding

The main finding of this investigation is that the generative instructional strategy was more effective than conventional teaching strategy at improving students' achievement in Physics. This could be attributed to the basic feature of the strategy as a learner-centered approach where learners perform activities by themselves, identifying their conceptions, tasking them to identify their own misconceptions and correcting such misconceptions identified. These learners' activities helped to make learners become autonomous in their learning.

Learners in generative instructional strategy were also able to perform better in achievement than their counterparts in the control group sequel to the kind of self-initiated and self-directed activities which they participated in during classroom instruction. This is expected as learning becomes more concrete, real, meaningful and permanent when learners are engaged in the learning activities, the kind that was afforded students in the experimental treatment of generative teaching implemented in this study.

The generative instructional strategy was more effective than the conventional teaching strategy also probably because learners in the generative instructional strategy were in full control in the setting up of the experiment, in the manipulation of the apparatus, in taking readings and in plotting of graphs. Learners in these groups, therefore, acquired skills such as manipulative, measurement, graphing and observation skills. They also would be able to retain these skills because they actually performed the practical activities. This might have accounted for their higher scores in achievement and hence, the better effectiveness of the generative instructional strategy over the conventional teaching strategy.

The result of this study is in agreement with the result obtained by Emily and Zee (2000) who found that generative instructional strategy was effective in the teaching of Physics concepts and other science related topics. The situation in the experimental treatment group as described was quite different from that of the conventional teaching strategy where learners were passive recipients of information and the teachers were actively providing information and thereby dominating the lesson. This strategy encouraged learners to learn by rote and they would not be able to master whatever they were taught. Learners could easily forget the content of the lesson easily within a short interval of time.

Conclusion and Recommendations

The study has shown the relative effectiveness of the generative instructional strategy in improving students' achievement in Physics. Based on this, the following recommendations are hereby made:

- Teachers of Physics and science subjects alike should adopt the generative instructional strategy in their teaching towards improved students' achievement.
- Students should be encouraged by Physics teachers to construct their own ideas, identify their conceptions and misconceptions and they should be allowed to correct their own misconceptions with little assistance from the teachers in any science classroom instruction.
- Students should be given the opportunity to perform all tasks whether simple, complex, specific or general in any science instruction so as to construct their own knowledge, test and evaluate their initial knowledge for conceptual change.
- Government should organise capacity building programmes for secondary school science teachers in the effective use of generative instructional strategy through organisation of workshop, seminars and conferences.

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