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Towards Exploring Strategies for Teaching Integrated Science to Low Achievers: A Test of Efficacy of Conceptual Change Pedagogy

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Abstract: The search for more effective and alternative instructional strategies has led to focusing attention on conceptual change pedagogy which places much premium on the use of students' prior ideas during instruction. The results of some studies on the efficacy of this pedagogy seem to demonstrate its superiority over the traditional expository strategy. But while the search for enhancement of achievement in science through the use of conceptual change pedagogy goes on, there is the need to relate it to some student characteristics that could affect their learning of science. This study, therefore, sought to find out if low achievers in integrated science taught using conceptual change pedagogy will achieve significantly better than their counterparts taught through the expository strategy. A total of 100 (57 boys, 43 girls) junior secondary school (grade 8) low achievers in integrated science participated in this study. Using a non-equivalent control-group design the experimental subjects were taught some energy concepts using conceptual change pedagogy while their counterparts were taught using expository method. Analysis of data collected showed that conceptual change pedagogy is superior to expository strategy for developing affective components of learning. Implications of the study are discussed and suggestions for further studies presented.

Keywords: Conceptual change pedagogy; constructivist epistemology; low achievers; integrated science

1 INTRODUCTION

Several strands of research evidence converge to attest to lack of efficacy of the traditional as well as other strategies of instruction in improving the learning of science (Shuell, 1986; Martin and Ramsden, 1986; Eniaiyeju 1986; Biggs, 1988; Okebukola, 1986; Jegede and Okebukola, 1989; Baker and Taylor, 1995; Jedege, 1996). This has led to focusing considerable attention to the search for alternative strategies for teaching science to enhance meaningful learning.

One of such strategies that is gaining acceptance in recent times, as having the potentials to bring about effective learning by science students, is the emphasis on learners' prior knowledge or alternative conceptions. The strategy sponsored by this emphasis is referred to as conceptual change pedagogy. This mode of teaching is premised on constructivist epistemology. The major highlight of this epistemology, as can be distilled from different works by Driver and Bell (1986), Driver and Oldham (1986), Taber (2006), are:

i. Individuals are purposive: Learning does not take place by the learner responding in a passive way to the environment, but by actively interacting with it.
ii. Prior knowledge matters a lot: Learning depends not only on the learning environment, but on what knowledge the learner brings to the learning situation.
iii. Knowledge is constructed by individuals through social interactions and experience with the physical environment. Personal knowledge is constructed so as to "fit" with experiences in a coherent way.
iv. Meaningful learning involves the construction of links with prior knowledge. The construction of meaning by making links with prior knowledge occurs in situations provided by reading texts, listening to someone talking or observing or manipulating physical phenomena.

v. The construction of meaning is an active process: Making links with prior knowledge is an active process in which the learner generates possible hypothetical links and checks these for "fit" in the situation.
vi. Learning science involves conceptual change. It involves not only adding and extending one's conceptual structure but may involve radically reorganizing it.

The proponents of conceptual change pedagogy argue that meaningful learning of science results when the learner's alternative conceptions are identified before instruction. These conceptions are used for providing learning experiences that can assist the learner to examine the intelligibility, plausibility and fruitfulness of their conceptions (Strike and Posner, 1985) vis à-vis the scientific conception of study. In this type of learning experience, learners are actively involved in construction of meaning by making links with their alternative conceptions. A stark contrast exists between this strategy and the traditional approach in which learners are viewed as acolytes who should passively imbibe the corpus of scientific knowledge presented by the teacher.

The contrast is strong enough to encourage conjecture that the strategy will result to meaningful learning. Indeed, evidence seems to be accumulating to support this conjecture (Rowell and Dawson, 1985; Zietsman and Hewson, 1986; Mitchell and Baird, 1986; Trumper, 1990, 1991; Driver, 1990; Asim, 1998; and Bajah and Asim, 2000). But a study by Igwebuike (2000) indicated no significant difference in the achievement by students taught using the strategy and their counterparts taught using the traditional mode of instruction. There is therefore a penumbra of uncertainty about the efficacy of the strategy.

While the search for the promotion of meaningful learning through conceptual change pedagogy continues to receive attention, there is need to relate it to some learner characteristics which could affect the learning of science. Walberg (1970) puts up a proposition which shows that curriculum, learning environment and students' characteristics are predictor variables of learning outcomes. One of the students' characteristics is ability level. Since conceptual change pedagogy involves active participation in the learning situation by the learner, it can be hypothesized that low ability students of integrated science taught through conceptual change pedagogy will achieve more than their counterparts taught through the traditional mode. Experimental evidence was sought in this study to test this proposition.

1.1 *Previous Research*

Studies carried out by Zietsman and Hewson (1986), Trumper (1990, 1991), Asim (1989), Bajah and Asim (2000), Ndioho (2007), Nwagbo (2008), Igwebuike and Oriaifo (2012) provide strands of evidence which support the conclusion that conceptual change pedagogy enhances learning of science. For instance, Ndioho (2007) carried out a study on the effectiveness of this model for teaching genetics to mixed ability senior secondary biology students (Grade II). He found that the model was significantly more effective than the conventional expository method.

But studies by Chang (2000) and Chang and Bell (2002) provide lines of evidence which indicate a stark contrast to the findings of the studies mentioned earlier. By implication, the issue is not resolved, especially with reference to a model for teaching integrated science to low achievers.

1.2 *Significance of the Study*

This study is significant because underachievement in science at the primary and secondary school levels has been a major source of discomfort to different stakeholders considering the pivotal nature of these levels to development of science and technology. Positive relationship between science education and the development of science and technology has been highlighted by Oriaifo (2000), Godek (2004), Igwebuike (2013a), and Ogunkola (2012). For instance, Godek (2004) says that in the developed world, science education has been developed to bring about scientific and technological development. This application of science education has facilitated the bifurcation of countries into industrialized and non-industrialized.

A number of reasons have been advanced for underachievement in science in developing countries. Oriaifo(2000), Iheonumekwu (2006), Igwebuike and Oriaifo (2012), Ogunkola (2012), Igwebuike (2013a,b) implicate stereotyped and ineffective methodology of teaching science, among others, in the underachievement saga. By implication, any investigation conceptualized within a rationale that investigates the efficacy of a contemporary method of teaching science, especially among the low achievers, will help to throw more light on the saga. Conceptual change pedagogy is one of the contemporary methods of teaching science. Results obtained from this study can suggest to Integrated Science teachers a better method of teaching the subject. Science teacher educators can also obtain some insights on how to revamp their teacher education programmes.

2 METHODS

2.1 *Sample*

A total of 100 (57 boys, 43 girls) junior secondary school (grade 8) students of Delta Career Secondary School, Warri, Nigeria and Step Forward Secondary School, Warri, Nigeria formed the sample. These students were low-achievers. They were distinguished from their counterparts by making a median split on a list in which all the students were arranged according to their achievement level in integrated science examination. Those that fell within the second half of the split were identified as low achievers. The two schools were randomly selected from 24 secondary schools in Warri Township. Two classes were randomly selected from each of the schools and each of the classes was intact to avoid disruption of other classroom activities. Treatments were localized to annul the effect of contamination which could confound the study. Each of the two schools was randomly assigned to a treatment; either conceptual change strategy or traditional (expository) strategy. All the subjects of the study took integrated science as one of their courses preparatory to the junior secondary school certificate examination.

2.2 *Instrumentation*

Cognitive achievement was measured using cognitive achievement test on energy concepts referenced to the objectives of the instruction. The test had 30 multiple choice items. Four sub-concepts of energy were used for developing the lesson. They were: Energy as an invention, forms of energy, systems undergoing change and conservation of energy which had 6, 8, 8 and 8 items respectively. The test initially had 35 items but based on the recommendations of a panel of 3 experts in integrated science teaching and 2 in measurement and evaluation, the items were reduced to 30. Psychometric integrity of the test was guaranteed in two ways. The first is that the discriminatory power and the difficulty indexes of the items were determined using suggestions by Mehrens and Lehmann (1975). These measures were found to be within acceptable ranges. The second is that the reliability coefficient was determined using Cronbach alpha. This exercise yielded a value of 0.75 which was considered high enough and the test was used.

Questionnaire to measure affective achievement designed and factorially validated by Afemikhe (1985) was adapted to measure affective components resulting from the use of conceptual change strategy. This instrument had 4 sub-scales of self-concept, confidence, attitude and motivation with 12, 3, 8 and 3 items respectively. The reliability coefficients of the items using Cronbach alpha were 0.65, 0.59, 0.46 and 0.45 respectively. Using test-retest method and another sample of grade 8 students ($N = 51$), a composite reliability coefficient of 0.55 was established for the instrument. This value is low when compared with 0.60 which is threshold value recommended by Nunnally (as cited in Ampiah, 2006). This constitutes a limitation of the study.

Interview-about-instances designed and popularized by Osborne and Gilbert (1980a, 1980b) was used for probing the students' alternative conceptions. Instances of the sub-concepts were presented on different cards by means of line-drawings. Guides for the interview protocol suggested by the Learning in Science Project of the University of Waikato, New Zealand were followed carefully. From the interviews, a catalogue of the students' alternative conceptions in the various sub-concepts was developed and was used during the instructional phase.

2.3 *Design and Procedure*

A non-equivalent control group design with random assignment of classes to experimental and control groups was employed to examine any possible treatment effect due to exposure to conceptual change pedagogy. Experimental group was made up of subjects taught using this strategy while the control group had subjects who were taught using expository method. The two treatments shared a common curriculum content-energy. The concept was sub-divided into; energy as an invention, forms of energy, systems undergoing changes, and conservation of energy.

Cognitive achievement test and questionnaire on affective achievement (described earlier) were administered to all subjects as pre-tests. Interview- about-instances was organized for 15 randomly selected subjects in the experimental group using cards with line drawings of the sub-concepts. From this exercise, a catalogue of 17 alternative conceptions was obtained. These were compared with scientific conceptions and used as basis for organizing instruction based on CCP.

This was followed immediately by eight weeks of instructional treatment. The researcher administered the treatments to control for the effects of some plausible teacher variables like skills-gap, commitment to the use of conceptual change strategy for teaching the experimental group, perceptions of classroom practices and knowledge of subject matter. Each group was taught for eight weeks with a total of twelve lessons of about 40 minutes per lesson.

Specifically, the conceptual change strategy involved presenting the alternative conceptions, which have been catalogued, to the subjects in the experimental group. After this, the scientific conceptions were presented and the subjects were assisted by the researcher to assess the usefulness and plausibility of their conceptions. Following contention by Lawson and Thompson (1988) that students at the concrete operational level find it difficult to evaluate competing theories, guides were given to the subjects in the experimental group for analyzing implications of both their conceptions and scientific conceptions.

Interview-about-instances was not carried out on subjects in the control group. They were taught using the traditional lecture/expository approach. After eight weeks of teaching the two groups were given both the post-tests on cognitive and affective achievements. These tests were administered in the same manner as the pre-tests.

3 RESULTS

A t - test analysis revealed a significant difference between the mean pre-test scores on cognitive achievement of the experimental and control group [$t(98) = 4.60$, $p < 0.05$]. Similarly, there was significant difference between the mean pre-test scores on affective achievement of the two groups [$t(98) = 3.93$, $p < 0.05$]. These results informed the use of analysis of covariance (ANCOVA) which adjusts for initial differences between groups.

The aim of this study was to investigate whether instruction using conceptual change strategy had any significant effect on cognitive and affective achievements of low achievers in integrated science.

Table 1: Descriptive statistics of Pretest Cognitive and Affective Scores according to group

Measure of Comparison	**Group**	**N**	**Mean**	**SD**
Cognitive	Experimental	50	3.34	1.23
	Control	50	4.72	1.71
Affective	Experimental	50	56.10	7.80
	Control	50	49.82	8.20

Table 2: Descriptive statistics of Posttest Cognitive and Affective Scores according to group

Measure of Comparison	**Group**	**N**	**Mean**	**SD**
Cognitive	Experimental	50	10.55	1.87
	Control	50	9.51	2.01
Affective	Experimental	50	52.15	8.37
	Control	50	46.43	8.76

Table 3: Summary of ANCOVA on Cognitive Achievement Test Post-test Scores

Source	**SS**	**DF**	**MS**	**F**	**p>**
Method	25.675	1	25.675	2.481	0.118
Explained	53.398	2	26.699	2.48	0.081
Residual	1003.762	97	10.348		
Total	**1057.160**	**99**	**10.678**		

$p > 0.05$

The results obtained suggest that conceptual change pedagogy did not improve cognitive achievement among low achievers significantly [F (1,97) = 2.481, P > 0.05] (see Table 3). Multiple classification analysis indicated that low achievers who were exposed to conceptual change strategy had an adjusted post-test cognitive achievement mean score of 10.74 while their counterparts exposed to the traditional method recorded an adjusted post- test cognitive achievement mean score of 9.70.

Table 4: Summary of ANCOVA of Affective Achievement Test Post-test Scores

Source	**SS**	**DF**	**MS**	**F**	**p>**
Covariates	3142.951	1	3142.951	222.880	.000
Method	567.787	1	567.787	40.264	.000
Explained	3710.738	2	1855.369	131.572	.000
Residual	1367.852	97	14.102		
Total	**5078.590**	**99**	**51.299**		

Significant at $p < 0.05$

Table 4 indicates that conceptual change strategy significantly improved low achievers' affective achievement [$F(1,97) = 40.264$, $p<0.05$]. Multiple classification analysis indicated that low achievers exposed to conceptual change strategy had an adjusted post-test affective achievement mean score of 54.19 while their counterparts exposed to the traditional strategy recorded an adjusted mean score of 44.39.

4 DISCUSSION

With respect to cognitive achievement, the results of this study agree with earlier findings of Igwebuike (2000) in a study not specifically conceptualized and executed using low achievers as subjects. The results indicated that there was no significant difference in cognitive achievement between students taught using conceptual change pedagogy and their counterparts taught using expository/lecture method. But the results of the present study disagree with the findings of Zietsman and Hawson (1986); Trumper (1990, 1991), Asim (1998), Bajah and Asim (2000), Ndioho (2007), Benjamin and Egho (2008). In particular, Bajah and Asim (2000) indicated that low ability pupils exposed to conceptual change strategy achieved significantly better their counterparts exposed to the expository strategy. This and other lines of evidence of the efficacy of this pedagogy may have converged to inform the recommendation by Cey (2010), Karagiorgi and Symeou (2005), Jaber (2006), Fittell (2010) that it should be used for teaching science in schools. In particular, Karagiorgi and Symeou (2005) have strongly suggested that the use of constructivist perspective upon which the pedagogy is based by instructional designers can facilitate their responding to the learning requirements of the 21st century.

Speculatively, two factors have influenced the results obtained from this study. The first and perhaps the more important factor is the novelty of this teaching strategy. The students were used to teacher-dominated mode of instruction in which their alternative conceptions were not explored. The type of classroom climate provided by the conceptual change strategy in which the teacher respects the students' views, and is part of the problem-solving group, definitely, from the students' point of view, would not be for the purpose of examination or test. The hunch therefore, is that they were not adequately teased for the post-test. It is likely that the teacher-dominated traditional strategy conditions students more for test and examinations.
The second factor emanates from the nature of the test used in this study. If, perhaps, interview-about-instances which was used for probing their alternative conceptions prior to instruction was incorporated in the post-test, the results would be different.

With respect to affective achievement, the result indicated that low achievers taught using conceptual change strategy achieved better than their counterparts taught using the expository method. The results were expected and can be explained by the nature of conceptual change pedagogy. It probes students' alternative conceptions and provides a learning environment for the students to assess the plausibility of their conceptions vis-à-vis the scientific conceptions offered by the learning situation (Strike and Posner, 1985). Students participate actively and collaboratively during such lessons. Above all, the strategy provides for negotiations (Jegede & Taylor, 1998) and argumentation (Matthews, 1990; Zhou, 2010) instead of impositions of corpus of scientific knowledge which characterize teacher-dominated lessons. Definitely, these qualities of the strategy will boost students' self-concept, science confidence, attitudes and motivation.

These results are heart-warming and should be received with trepidation. According to West and Pines (1983), while it is important to create situations which will challenge students' alternative conceptions to bring about conceptual changes, their feelings and dispositions are an important aspect of the process. They say that the learner should feel good, or proud, or satisfied after a conceptual change lesson. He should not feel bad, demeaned or dissatisfied.

It is also gratifying to obtain positive results with the affective components because of the time-honoured evidence that they correlate positively with cognitive achievements (Khan, 1969; Soyibo, 1982; Byrne 1984; Odubunmi and Balogun, 1985; Okpala, 1985; Emma, 1986; Iran-Najed, 1987; Aghadiuno, 1992; Ukwungwu and Nworgu, 1999). This relationship suggests the possibility of improving cognitive achievement through the use of conceptual change pedagogy, which boosts affective achievement, though the first set of results of this study does not confirm the suggestion.

5 CONCLUSION AND IMPLICATION

The results of this study support the conclusion that conceptual change pedagogy did not significantly improve cognitive achievement by junior secondary school students (grade 8) in integrated science. But the results provide strong evidence that the pedagogy improved the students' affective achievement.

A major implication of this study for science teaching is that science teachers, as well as teacher educators, should recognize the likely effect of conceptual change pedagogy on affective achievement. One of the goals of teaching science in schools, as also reflected in the nature of science, is development of affective components. This study suggests that conceptual change pedagogy is efficacious in attempts to realize these goals for low achievers.

A replication of this study is advocated for two major reasons. The first is that the design used in the study does not provide strict control that can guarantee external validity. The second is that the study is a single-variable study. But Walberg (1970) suggests that each of the predictor variables of learning outcomes may be necessary but insufficient by itself for classroom learning to occur. A study that will increase the number of independent variables and determine their interaction effects is advocated. By implication, cautious interpretation and application of the conclusions of this study to integrated science teaching are encouraged.

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