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Effects of Process-oriented Instructional Strategies on Spatial Abilities and Basic Science Achievement of 9th Grade Students in Kogi State, Nigeria

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Worried by the massive and persistent failure in secondary school science in Nigeria, the need to research into the effect of process-oriented instructional strategies on spatial abilities and basic science achievement of 9th grade students in Kogi state became very compelling. The study is a quasi-experimental design of pretest, posttest and non-randomized control group type. A total of 702 students (n=316 boys and 386 girls) participated in the study. Three null hypotheses formulated were tested at 0.05 alpha level. While the experimental group received instructions through process-oriented instructional strategies, the control group was through lecture method. Spatial Ability Test (SAT), and Basic Science Achievement Test I and II (BSAT I & II) with reliability coefficients of 0.81, 0.87 and 0.85 were used for data collection. Frequency, percentage, correlation and t-test (for independent respondents) statistics were used for data analysis. It was found that students exposed to process-oriented instructional strategies achieved significantly higher in spatial ability and basic science achievement, among others. Process-oriented instructional strategy was therefore recommended for use by basic science teachers especially when the emphasis is on the development of spatial abilities in learners.

Keywords: Process-oriented instructional strategies; spatial abilities; basic science achievement; 9th grade.

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1. INTRODUCTION

On a global scale, experience has shown that education, especially in science and technology, is the most effective weapon that drives the wheel of socio-economic development. Communities are classified as developed and developing (or underdeveloped) using the education parameters as indicators. In a nutshell, developed nations do not toy with the educational development of their citizens, sadly enough, the developing nations display high levels of unseriousness in their commitment to educational programmes. This is evident in their failure to fund education adequately and translate educational policies and programmes into conerete developmetal realities that can bail the citizenry out of poverty, hunger, malnutrition, disease, poor shelter, epidemics and dependence on advanced economies and technologies for survival and progress. In Nigeria, for example, Martins [1] bemoaned the sorry state of basic science, he reported a study conducted in Kaduna state where only 34% of the sample of 1807 were successful. In the same vein, Bomide [2], decried the sorry state of Integrated Science (now Basic Science) in Nigerian schools. He noted that evidence abounds to show that pupils' achievement of the objectives of the Nigerian Integrated Science Project (NISP) were below expectation. Rossier [3] reported that the result of an international study from different countries showed that Nigerian pupils came last in primary science and last but one in secondary science.

Any discourse on the overriding influence of education on socio-economic or socio-cultural development must of necessity emphasises the dynamic role of sound pedagogy and learning that is child-centred, hands-on-minds-on and anchored on the understanding to begin early. The Teach Thought Staff [4] also strongly recommend learning by doing science which involves active engagement of students. Students' engagement is enhanced through activities that interest children like science quizzes, science games, resolving jigsaw puzzles, visits to museums, wild life parks and zoological gardens, and so on. This concern underscores the choice of this topic of research which is aimed at investigating the effects of process-oriented intructional strategies on the spatial abilities of basic science students in Kogi state.

The importance of science, technology, mathematics and engineering in national development compelled Chapman [5] to assert that for self–preservation, health and life, maintenance, preservation of national life, enjoyment of art in all its forms, moral and religious discipline, the most inportant study is science. This being the case, it is imperative for nations yearning for development to enforce the teaching and learning of science at all levels of her education.

Process-oriented instructional strategies, otherwise process approach, is a teaching strategy that emanated from the post-sputnik era (that is, a period after 1957), codenamed alphabet curricula in the United States (US) and the Nuffield project in Britain. These curricular reforms had one common thread, that is, a teaching strategy that emphasised hands-on-activities or students' active engagement with the materials and resources of science teaching and learning. For example, "Science, A Process Approach (SAPA)", according to Stohr–Hunt [6], developed by the American Association for the Advancement of Sciences (AAAS) commission on education emphasised process criteria or the development of process skills through the laboratory method or hands-on-experiences. The teaching method that promotes process skills include those that promote or encourage skills like observing, measuring, classifying, experimenting, predicting, inferring, etc. In a nutshell, these processes call for students' active engagement with the materials of science. In the same vein, Researchgate [7] added that teaching using game like environments and simulations help a lot. Activities which engage all the senses-not just visual and auditory hold better prospects for science learning. Open-ended projects, in-class discussions and brainstorming sessions with teacher as a facilitator are very promising. All these innovative strategies are subsumed under process-oriented instructional strategies because they basically emphasise hands-on and minds-on engagements in the service of science education.

Spatial abilities, according to WiseGEEK [8], King [9], Gage and Berliner [10], and Kali and Orion [11] are categories of reasoning skills which refer to the capacity to think about objects in three dimensions and draw conclusions about those objects from limited information. Brosnan [12], from meta-analysis research defined spatial ability as skill in representing, transforming, generating, and recalling symbolic non-linguistic information. In a nutshell, it involves mental rotation, spatial perception, and spatial visualisation, or seeing or reasoning beyond the given. Dewar [13] says that spatial skills predict young people's achievement in science, technology, engineering and mathematics (STEM). Yet, he continued, traditional schooling does little to develop these abilities. He reported that people develop these skills with training, so, it should be developed early in life through an active physical exploration of the real world. Khine [14] emphasised the predictive power of spatial ability for students' success in science, technology, engineering and mathematics (STEM) subjects.

Lecture method or expository method is a content-based, teacher centred delivery approach that tends to undermine the learners who are supposed to be at the centre of their own learning. It is oflen regarded as chalk–and–talk method and pupils are in most of the cases passive listeners. Chiappetta and Koballa [15] argued that lecture is a traditional teacher-centred method that involves the didactic presentation of facts and information. Lecture does not promote meaningful science learning because science is not a"telling" but a "doing" subject. Innovative learning and teaching strategies abound in modern times. The Edsys [16] discussed 50 innovative teaching methods in science namely hands-on-learning, story telling, role play, sports-based learning, visual clues, instructional conversation, word games, projects, ICT enabled learning, science games, science kits, and so on. The Teach Thought Staff [4] presented 10 innovative learning strategies for modern pedagogy. They include crossover learning, argumentation, incidental learning, context-based learning, computational learning, learning by doing, embodied learning, adaptive learning, analytics of emotions and stealth assessment. The foregoing methods create rich varietiesand encourage active participation of the students in their own learning.

The advent of the fourth Industrial Revolution is sweeping the global scene with its clarion call on its citizens to exhibit innovation, creativity, automation, and Information and Communication Technology (ICT) competencies with high powered analytical and problem solving skills required in Science, Technology, Engineering and Mathematics (STEM). This research responds proactively to this international, regional, and national debate in Nigeria to produce future employable and technologically astute citizens.

This study investigated the effects of process–oriented instructional strategies on the spatial ability and basic science achievement levels of 9th gradestudents; effects of lecture method on spatial abilities and basic science achievement were also investigated. Three null hypotheses were tested, results were presented, discussed and recommendations were also made.

1.1 Hypotheses

The following null hypotheses were stated to guide the study:

1. There is no significant mean difference in the spatial ability scores between students taught with lecture method and those taught with process-oriented instructional strategies.
2. There is no singificant mean difference in basic science achievement scores between students taught with lecture method and those taught with process-oriented instructional strategies.
3. There is no significant relationship between spatial ability and basic science achievement scores of 9th gradestudents.

2. THEORETICAL FRAMEWORK

The study made use of Genetic epistemology, a theory propounded by Jean Piaget, to undergird the study. Piaget's main pre-occupation was to discover the origin (genesis) of intelligence or knowledge (epistemology) among children. McArthur and Wellner [17] reported that Piaget's interest was to study the embryology of the child's concept of space namely topologic, projective and Euclidean spaces. Piaget believes that spatial ability has a genetic linkage and is influenced by the child's active involvement with the environment. Piaget found that children pass from sensorimotor intelligence (0-2 years), to pre-operational (2-7 years), to concrete operational (7-11 years) and formal operational stages in the same order but not at the same time. Children make sense of their environment by the use of cognitive structures like assimilation, accommodation and equilibration. These progressive adjustments enable the child make sense of his environment, which is learning. The child as a result, grows from egocentric frame, that is, child's immediate environment, to allocentric frame, which is the environment outside his immediate influence. This is the same way that topologic, projective and Euclidean spaces operate, topologic is more primitive, projective is less primitive, while Euclidean is the most advanced form of spatial ability. It presupposes a movement from mere sense appreciation of things to abstract construction even when actual materials may not be present. Teaching emphasis in science must reflect these virtues that encourage active engagement of the children in their own learning. This active engagement is the concern expressed by Dewar [13], Edsys [16] and Researchgate [7]. This promotes the development of spatial abilities among children. The pattern of this development can be explicated by the picture of this skill among basic science students and thus provide a useful index for an intervention.

2.1 Statement of Problem

Teachers are teaching, students are failing; this statement reflects the worrisome status of science teaching in Nigeria. A good number of science teachers employ lecture method in the science classroom and are unmindful of the effect of their action on learning out comes. The nature of the effects of process-oriented instructional strategies on spatial abilities among basic science students is not quite understood. The influence of spatial abilities on students' achievement in basic science and the relationship between spatial abilities and basic science achievement are also not clear. Dewar [13] amplified this concern when he lamented the failure of traditional schooling to develop spatial abilities inspite of its importance in predicting achievement in science, technology, engineering and mathematics (STEM).The foregoing problems compelled this reseach and it is hoped that the use of sound teaching strategies can reverse the sorry state of students' performance in science and improve their spatial abilities which has been shown to influence science achievement in schools.

3. METHODOLOGY

The study employed non-randomised pretest–posttest control group design being a quasi-experimental research; however, subjects were randomly assigned to the experimental and control conditions. The population is all 9th gradestudents in kogi state of Nigeria . The sample of 702, made up of 316 boys and 386 girls was used for the study. The research instruments are "Spatial Ability Test" (SAT) with a reliability of 0.81, Basic Science Achievement Test I (BSAT I), with a reliability of 0.87 and Basic Science Achievement Test II(BSAT II) with a reliability of 0.85. SAT. A 29-item test was developed, adapted and used to measure the spatial ability levels of the students. BSAT I was used to classify the students into ability levels while BSAT II was employed to measure the achievement level of the students. All three instruments were validated by experts and reliabilities were computed accordingly. Data collection procedure was preceded with preliminary survey visit to the schools to obtain consent of school administrators and relevent information about the schools and respondents. Schools that were sampled met the criteria of having enough human and material resources for the teaching and learning of basic science and must have presented students for basic science certificate examination(9th grade) previously, popularly called junior WAEC. The basic science teachers were trained for two weeks as research assistants, the training was to get them acquainted with the demands of the research. They were told from the outset to expect being monitored from time to time in the course of the study. Groups of intact classes in the selected schools were randomly assigned to the exprimental and control conditions. SAT, BSAT I and BSAT II were administered to all the groups as pretest for 10 weeks. The experimental groups were taught basic science using process approach while the control groups were taught the same topics using lecture method. SAT and BSAT II were administrered to both groups as posttest, the posttest scores formed the raw data for the subsequent analysis.

3.1 Data Analysis

Data was analysed using t-test for indepedent samples; simple descriptive statistics like means, frequencies and percentages were also used. An alpha value of 0.05 was used to test for siginficance. However, for the fact that the design of the study is quasi-experimental, the students in control and experimental groups could not be assumed to be equivalent. They were therefore administered pretest before treatment. The pretest scores were subjected to t-test and found not to be statistically significant. Arising from this development, post test scores only were used for the analysis.

4. RESULTS

The pretest and posttest means for spatial ability and basic science achievement for the group taught by process approach, that is, the experimental group and the group taught using the lecture approach, that is, the control groups were not significant:

Data for answering hypotheses 1 to 3 are contained in Tables 1, 2 and 3.

Result in Table 1 show that the spatial ability mean scores for process-oriented and lecture method groups was significant.

From Table 2, the basic science achievement scores of the group taught by process-oriented instructional strategies and those taught by lecture method was significant.

Result on Table 3 shows that the relationship between spatial ability and basic science achievement was significant.

Hypothesis 1 was tested using data in Table 1. Result showed that mean differenc in spatial ability is significance at .05 alpha level. The experimental group had a higher mean gain of 3.74% in spatial ability than the control group which scored 1.82%. This difference is significant, so, the hypothesis was rejected. So process-oriented instructional strategies are better in promoting spatial abilities than lecture method.

Hypothesis 2 was tested with data in Table 2. Result showed that a significant difference existed in the basic science achievement of students taught with process-oriented instructional strategies and those taught with lecture. So, the hypothesis was rejected. While the process group had a mean score of 1.90%, the lecture group had -1.03%.

Hypothesis 3 was tested with data in Table 3. Result showed that the relationship between spatial ability and basic science achievement was significant. In light of this finding, the hypothesis was rejected.

5. FINDINGS

The findings of the study are as follows:

1. There was a significant mean difference in spatial ability between students taught basic science with lecture method (1.818) and those taught with process-oriented instructional strategies (3.742) as in Table 1 in favour of the latter. In other words, the experimental group had a higher mean gain than the control group.
2. A significat mean difference in basic science achievement was found between students taught basic science with the lecture method (-1.025) and those taught with process–oriented instructional strategies (1.899) as shown in Table 2, in favour of the latter.
3. A significant relationship was found between spatial ability and basic science achievement of the group studied.

Table 1. Spatial ability mean scores for process-oriented and lecture method groups

Methods	N	Mean	S.D	df	t-test	Sig.(2-tailed)
Process	345	3.7420	4.89721	700	4.924	.000
Lecture	357	1.8179	5.43066			

Key: N = Sample size, S.D = Standard deviation, df = Degree of freedom

Table 2. Basic science achievement scores of process-oriented and lecture method groups

Methods	N	Mean	S.D	df	t-test	Sig.(2-tailed)
Process	345	1.899	9.49655	700	4.692	.000
Lecture	357	-1.025	6.84269			

Key: N = Sample size, S.D = Standard deviation, df = Degree of freedom

Table 3. Relationship between Spatial Ability Test and Basic Science Achievement Test II

Test	N	Mean	S.D	Pearson Correlation (r)	Sig.(2-tailed)
SAT	702	15.911	6.46708	.501**	.000
BSAT II	702	32.267	15.3192		

*Key: N = Sample size, S.D = Standard deviation, df = Degree of freedom, ** = Correlation is significant at .05 alpha level*

6. DISCUSSION OF FINDINGS

Results showed that the spatial ability of the experimental group, that is, the group taught by process-oriented instructional strategies, is higher than that of the control group that was taught by the lecture method. This finding is supported by the views of Lord [18] and Kali and Orion [11] who affirmed that remedial instruction in spatial understanding and relevant experience improved performance in biology. The Science Teachers Association of Nigeria [19,20] Winn [21] and Dewar [13] also supported this view in their report that practice, relevant experience and training in spatial skills promote the development of spatial abilities in children.

A significant difference in basic science achievement was found between the experimental and control groups in favour of the experimental group. This finding is supported by those of Stohr –Hunt [6], Germann et al. [22] Swatton [23] and Shaw [24] who reported that problem solving ability and teaching methods that engage students actively in practical activities improve performance in science tasks. This finding implies that teaching strategies that emphasise hands–on-experiences hold greater promise for science teaching than those that do not.

A significant relationship between spatial ability and basic science achievement was found. This implies that students who score high in spatial ability are likely to score high in basic science achievement and vice versa. This finding agrees with those of Smith et al. [25] who reported that spatial ability influences achievement in science and mathematics. Again, Cohen [26], Piburn [27], Carter et al. [28] Pribyl and Bodner [29], Piburn [27], Keig and Rubba [30], and McArthur and Wellner [17] attested to the powerful influence of spatial ability on science achievement.

7. CONCLUSION

This study showed that process-oriented instructional strategies was a better teaching method than lecture having resulted in a more robust gain in spatial ability and basic science achievement among the group studied. A relationship was also found between spatial ability and basic science achievement among the group studied, implying that students who score high in spatial abilities are likely to score high in basic science and vice versa.

8. RECOMMENDATIONS

The following recommendations are made based on the findings of this study:

1. Since a significant difference in spatial ability was found between the experimental and control groups in favour of the former, it is recommended that basic science teachers should emphasise process-oriented instructional strategies in the classroom so as to improve students' achievement. By implication, all sound time tested teaching strategies in the class of innovative learning and teaching strategies like hands-on-science, exploratory approach and role plays should be employed in all basic science classrooms.
2. Basic science teachers should emphasise process-oriented instructional strategies in class and de-emphasise lecture method because a significant difference between basic science achievement of the control and experimental groups was found in favour of the latter. This is pertinent as science cannot be effectively taught to students without their active involvement and questioning.
3. For the fact that a significant relationship was found between basic science achievement and spatial ability, it is strongly recommended that process-oriented instructional strategies should be emphasised in basic science teaching so as to develop spatial abilities which will in turn promote basic science achievement among learners.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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