

Effectiveness of Modeling Instruction and Secondary Students' Performance in Physics in Rivers State

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Abstract

This study investigated the effectiveness of modeling instruction and secondary students' performance in physics in Rivers State. Three research questions and three hypotheses were formulated to guide the study. The design used for the study was the quasi-experimental design, specifically the pretest-posttest non-equivalent control group design. The sample consisted of 205 SS2 physics students from C.S.S., Nkpolu-Oroworkwo in Port Harcourt L.G.A., which was purposively selected. Secondary School Physics Achievement Test (SSPAT), developed by the researcher himself, was used as instrument for data collection. For the analysis of research questions, means and standard deviations were used. Z-test analysis was employed in testing the hypotheses. A major finding of the study was that the mean achievement score of students taught physics with modeling instruction was significantly higher than the mean achievement score of those taught with conventional lecture method, notwithstanding students' ability level and gender. It was therefore concluded that modeling instruction, in comparison with conventional instructional method, is an effective instructional method capable of enhancing secondary school students' academic achievement in physics. Hence, some recommendations were offered in this regard.

Key Words: *Effectiveness; Modeling Instruction; Student Performance.*

Introduction

The incorporation of science education into the school curriculum was for the purpose of providing trained manpower in the applied sciences, with adequate scientific knowledge necessary for addressing problems related to the environment and the convenience of mankind (FRN, 2013). Accordingly, one would expect this increasing significance of science to be accomplished by a corresponding growth in interest and performance in science subjects by secondary school students. However, this does not seem to be so, especially in physics, which is a branch of science concerned with matter and energy and how they interact with each other. Physics is regrettably understood as the most problematic science subject and which, because of its perceived difficulty, traditionally attracts fewer students than chemistry and biology from secondary school level to tertiary level. Student's negative attitude to physics has also been blamed on instructional practice, lack of qualified and experienced teachers, non-conducive learning environment, students' gender, government policies, arrangement pattern of classrooms and laboratories, inadequacy of teaching aids and materials (Ibeh, Onah, Umahi, Ugwuonah, Nnachi & Ekpe, 2013). Other factors that can affect student learning are student background,

home life, and socio economic factors.

Sanders, Wright and Horn (1997) as cited in Arseneault (2014) noted that the impact a teacher can have on student learning can be two to three times the impact due to any other variable. Effective teaching, according to them, can counteract some of the negative factors that affect students' learning. So, teacher performance in the classroom and the progress their students make can be used as effective indices for identifying effective teachers.

Progress made by students is measured by academic performance which indicates the level of accomplishment of specific goals which form the focus of activities in instructional environment such as the secondary schools and universities (Steinmayr, Meißner, Weiding & Wirthwein, 2014). Academic performance can therefore be taken as a term used to determine whether a student has mastered the content and competencies required to receive a certificate. It is commonly measured by examinations or continuous assessments. Differential academic performance is usually associated with differences in individual intelligence.

School evaluations based on continuous assessment/end of term or session and end of course/programme test have shown abysmal performance in physics by secondary school students. Akanbi (2009) investigated students' performance in secondary school physics and found out that performance in physics examination was deteriorating. In support of this finding, Adurokia and Popoola (2011) had in their report indicated that physics students topped the chart in terms of the numbers of those who failed in WAEC/NECO examinations. While this abysmal performance in physics may be attributed to many and varied factors by different researchers, Onah and Ugwu (2010) noted that performance in physics at the secondary school level depended on gender, teacher qualification, teaching methods, and laboratory facilities. In the same vein Jegede and Adebayo (2013) carried out a study on "Enriching physics education in Nigeria towards enhancing a Sustainable Technological Development" and found out that the problems facing physics education are curriculum content, teaching methods, teachers quality, negative attitudes of students towards physics, students ignorance of the relationship between physics and the environment, and teaching materials. Brown & Cooney (1982) as cited in Omoosewo (2014) identified factors contributing to effective teaching, and hence high academic performance, to include the characteristics of the teacher and all teaching-related activities some of which are proper understanding of students, effective selection and utilization of instructional materials, choosing and implementing appropriate teaching strategies, and evaluating students' progress.

Regarding the works of the researchers cited above, the key and central factor that affects student's academic performance is teaching methods. Supporting this assertion, Mills (1991) as cited in Wambugu and Changeiywo (2008) viewed teaching methods as a crucial factor that affects academic performance. To achieve an improvement in the performance of physics students, the teaching methods component needs to be vigorously addressed. In his study of the effect of teaching methods on students' achievement, Haas & Twifford (2002) recommended that for the attainment of higher effectiveness, teachers should emphasize more interactive engagement instructions such as direct instruction, technology aided instruction, and problem-based learning. They identified specific teaching methods to include co-operative learning, problem-based learning manipulatives and models. Wikipedia (2014) acknowledged that physics

concepts are better understood (and performance enhanced) when lectures (of lecture method) are used in conjunction with demonstration and hand-on experiments. All these can be broadly categorized as interactive engagement approaches.

Confronted with the problems of how to select a more effective teaching approach from amongst the many interactive approaches, modeling instruction has interestingly been identified as an interactive engagement strategy that is effective in improving students learning outcomes. With modeling approach students learn or refine their thinking by developing mental models that they can use to describe a type of force or a particular kind of motion, for instance.

Modeling instruction involves a teacher's demonstration of a new concept or approach to learning which the students learn by observation (Coffey, 2000). Coffey asserted that learning by observation could offer itself an effective instruction strategy since it makes room for the teachers' thought process to be observed by students'. A document on modeling instruction by Physics Education Research Group at Florida International University (2010) defined modeling as

“a student-centric, constructivist approach whereby students build their physics knowledge by developing models through guided activities in a studio format”.

Under this arrangement, topics are organized into models developed through a cyclic approach. These models are usually in the form of diagrams, tables, sketches, graphs, motion maps, algebraic formulas or a combination of these.

Hake (1998) discovered that students taught physics with interactive engagement strategies significantly performed better than their counterparts taught physics with conventional methods. In their efforts towards improving students' achievement in secondary school physics, Hestenes & Halloun (1987) cited in Arseneault (2014) noted that if students are expressly trained in developing mental models of physical phenomena, students' understanding and problem-solving skills will increase. The results of their study showed that students taught physics with modeling instruction performed better than those taught with traditional lecture method. The researchers also discovered that the low-performing or low-ability students had more impressive conceptual gains. In her examination of the claim made by Hestenes, (1987) cited in Schober (2014), that “... problem-solving in physics is a modeling process”, Malone (2008) found out that students who are taught with modeling approach had better knowledge structures and problem solving skills than students taught with a traditional method. Modeling instruction helps students to develop the tools used by scientists, which among others, include critical thinking, development and validation of models and using these models to solve problems and make predictions. In a similar study on the effects of modeling instruction on high school physics students, Arseneault (2014) noted that physics students taught with modeling instruction had significantly higher conceptual learning gains when compared with those taught with traditional method. In another comparison of the effectiveness of modeling instruction and traditional lecture method, Wright (2012) found out that there was no significant difference between FCI gain scores for gender, that is, gender was found to have no effect on the academic achievement of students in high schools. However, female students' gain scores were higher than male students' gains scores under modeling instruction.

All these success stories about the effectiveness of modeling instruction in foreign classrooms, to

the best of this researcher's knowledge, are yet to be empirically replicated in our local secondary classrooms. It has therefore become imperative to explore the efficacy of modeling instruction in redressing the negative consequences of the lingering abysmal student performance in secondary school physics.

Statement of the Problem

The problem of this study is: Can modeling instruction enhance secondary school students' academic performance in physics?

Aim and Objectives of the Study

The aim of this study was to investigate the effectiveness of modeling instruction and secondary school students' performance in physics. The objectives are to:

1. Find out the effect of modeling instruction on students' achievement in physics.
2. Determine the effect of modeling instruction on the performance of physics students of different ability levels.
3. Find out the effect of modeling instruction on students' performance in physics based on gender.

Research Questions

The following research questions were used for the study:

1. What is the effect of modeling instruction on students' performance in physics?
2. What is the effect of modeling instruction on the performance of physics students of different ability levels?
3. What is the effect of modeling instruction on students' performance in physics based on gender?

Hypotheses

The following null hypotheses were formulated for the study.

1. There is no significant difference in the achievement scores of physics students taught with modeling instruction and those taught with conventional instruction.
2. There is no significant difference in the mean achievement scores of low and high ability physics students taught with modeling instruction.
3. There is no significant in the mean achievement scores of male and female physics students taught with modeling instruction.

Method

Quasi-experimental design was used for the study. Intact classes were used since complete randomization of the subjects was not feasible. The independent variable of the study was instruction type (modeling instruction) while the dependent variable was students performance (as indicated by the pretest and posttest scores). The sample consisted of 205 SS 2 physics students from Community Secondary School, Nkpolu-Oroworukwo in Port Harcourt Local Government Area. This school was purposively selected due to its high student population and the experimental nature of the study. The population of physics students in this zone (comprising Ikwerre, Emohua, Obio/Akpor and Port Harcourt Local Government Areas) stood at 5,251. The instrument used for data collection was Secondary School Physics Achievement Test (SSPAT) which the researcher developed himself based on the physics topics taught: Newtonian forces and projectile motion, which were drawn from SS2 physics curriculum.

The instrument SSPAT consists of fifteen multiple choice questions covering concepts in

Newtonian forces and projectile motion. Two experts in the field of science education established the validity of the instrument. Thereafter, the reliability estimate was found using the test-retest method after a period of two weeks. The Pearson Product Moment Correlation Coefficient formula was applied and a reliability coefficient of $r = 0.78$ was obtained. Intact classes of SS2 physics students were randomly assigned, two each to experimental and control groups of the study, with 105 and 100 students respectively. The two groups were taught Newton's laws of motion and projectile motion using the conventional lecture method. The treatment group was taught the same topics but using modeling instruction. The researcher used the usual lesson notes for the control group and modeling instruction lesson plans for the experimental group all developed by the researcher. Using the SSPAT, all students were pretested and later posttested after the treatment. Means and standard deviations were used in answering the research questions, the z-test analysis at $\alpha = 0.05$ was applied in the test of hypotheses.

Results and Discussion

The data collected and analysed in line with the research questions and hypotheses are presented below.

Research Question 1

What is the effect of modeling instruction on students' performance in physics?

Table 1: Mean Scores and Standard Deviations of the Experimental and Control Groups in Physics Achievement Tests

Group	No. of students	Pretest Mean achievement score	Std Dev.	Posttest Mean achievement score	Std Dev.	Gain in mean achievement scores
Experimental	105	26.39	8.75	51.17	8.07	24.78
Control	100	24.17	7.84	30.20	9.91	6.03

From the table above, it is evident that students taught physics with modeling instruction outperformed those taught with conventional methods as evidenced by their posttest mean scores of 51.17 and 30.20 respectively and mean achievement gains of 24.78 and 6.03 respectively.

H₀₁: There is no significant difference in the mean achievement scores of physics students taught with modeling instruction and those taught with conventional instruction.

Using the data from the posttest for both experimental and control groups, the summary of z-test analysis is as in the table below.

Table 2: Summary of z-test Comparison of Mean Achievement Scores of Physics Students Taught with Modeling Instruction and Conventional Instruction

Group	No of students	Mean achievement scores (%)	Std Dev.	Calculated z-value	Acceptance Region	Remarks
Experimental	105	51.17	8.07	16.51	±1.96	Rejected
Control	100	30.20	9.91			

Since the calculated z-value of 16.51 falls outside the acceptance region of ± 1.96 at $\alpha = 0.05$, the null hypothesis is therefore rejected. Hence, the difference between posttest mean achievement scores of students taught physics with modeling instruction those taught with conventional method is statistically significant.

Analysis of research question and the test of its corresponding hypothesis show that the mean pretest achievement scores (26.39) of students in the experimental group were not significantly different from the achievement scores (24.71) of the students in the control group, both groups' scores falling into failure grades. The mean achievement gain for the experimental group students (24.78) was quite higher than the gain (24.17) recorded by the control group students.

These findings have revealed that the mean score of experimental group students was above-average because of being taught with modeling instruction, and that the control group students had a very poor mean score in tune with the prevalent WAEC/NECO results (Akanbi, 2009, Adurokia & Popoola, 2011). The superiority of experimental group's scores to those of the control group is in consonance with the findings of earlier researchers who employed modeling instruction in their studies (Hestenes, 1987; Malone, 2008; Arseneault, 2014).

Research Question 2

What is the effect of modeling instruction on the performance of physics students of different ability levels?

Table 3: Comparison of Mean Achievement Scores for Students in Experimental and Control Groups Based on Ability Levels

Group	Student ability level	No. of students	Pretest Mean achievement score	Std Dev.	Posttest Mean achievement score	Std Dev.	Gain in mean achievement scores
Experimental	High	42	32.19	5.76	63.57	7.21	31.38
	Low	62	20.29	7.13	50.30	8.38	30.01
Control	High	38	29.45	6.69	32.68	5.59	3.23
	Low	63	20.21	6.58	24.57	6.07	4.36

From the above table, it is observed that the achievement gains between the pretest and posttest scores for high and low ability level students in the experimental group are 31.38 and 30.01 respectively. Similarly, the achievement gains between the pretest and posttest scores for high and low level students in the control group are 3.23 and 4.36 respectively. This shows that both high and low ability physics students taught with modeling instruction improved significantly in

their posttest scores.

H₀₂: There is no significant difference in the mean achievement scores of low and high ability level students taught physics with modeling instruction.

Using the data from posttest for experimental groups, the summary of z-test analysis is as in the table below.

Table 4: Summary of z-test analysis comparing the mean posttest achievement scores of high and low ability physics students taught with modeling instruction

Group	Ability level	No. of students	Mean achievement scores	Std Dev.	Calculate d z-value	Acceptance Region	Remarks
Experimental	High	42	63.57	7.21	8.51	±1.96	Rejected
	Low	62	50.30	8.38			

Since the calculated z-value of 8.51 falls outside the acceptance region of ±1.96, the null hypothesis is therefore rejected. This implies that the difference between the mean achievement scores of low and high ability physics students taught with modeling instruction is statistically significant.

Analysis of the research question and the test of its corresponding hypothesis show that the mean achievement gain score (31.38) of high ability students taught with modeling instruction was not significantly higher than that (30.01) of low ability students taught with the same method. However, both high and low ability students taught with modeling instruction improved significantly.

This finding has shown that in the case of different ability students, high ability student's taught with modeling instruction marginally outperformed their low ability counter parts. However, this finding is not in conformity with the finding of Hestenes and Halloun (1987) cited in Arseneault (2014) which revealed that low-ability students had more impressive conceptual gains.

Research Question 3

What is the effect of modeling instruction on students achievement in physics based on gender?

Table 5: Mean Achievement Scores and Standard Deviations of Male and Female Students in Physics Achievement Tests

Group	Sex	No. of students	Pretest Mean achievement score	Std Dev.	Posttest Mean achievement score	Std Dev.	Gain in mean achievement scores
Experimental	Male	81	26.56	5.61	54.88	7.52	28.32

	Female	24	20.04	7.41	35.34	7.17	15.30
Control	Male	72	27.39	6.04	33.92	5.98	6.53
	Female	28	21.25	6.89	23.11	7.11	1.86

From the above table, the mean achievement gains of male and female students taught with conventional method are 6.53 and 1.86 respectively. Also, the mean achievement gain of male and female students taught with modeling instruction are 28.32 and 15.30 respectively. This indicates that both male and female physics students improved upon their mean pretest scores as evidenced in their post SPPAT scores.

H₀₃: There is no significant difference in the mean achievement scores of male and female physics students taught with modeling instruction.

Using the data from posttest for experimental group, the summary of z-test analysis is as in the table below.

Table 6: Summary of z-test analysis on the Mean Achievement Scores of Male and Female Physics Students Taught with Modeling Instruction

Group	Sex	No. of Students	Mean achievement scores	Std Dev.	Calculated z-value	Acceptance region	Remarks
Experimental	Male	81	54.88	7.52	12.77	±1.96	Rejected
	Female	24	35.34	7.17			

Since the Z-calculated value (12.77) falls outside the acceptance region of ± 1.96 , the null hypothesis is therefore rejected. This implies that the difference in mean achievement test scores of male and female physics students taught with modeling instruction is statistically significant.

Analysis of the research question and the test of its corresponding hypothesis show that the mean achievement gain score of male students taught with modeling instruction was significantly higher than that of female students taught with the same method, with 28.32 and 15.30 respectively. However, both sexes improved significantly upon their pretest scores.

In the case of gender, the findings of this study showed that although both male and female physics students taught with modeling instruction improved significantly upon their pretest scores, male physics students performed better than their female counterparts. The finding does not agree with the finding of Wright (2012) to the effect that there is no significant difference in achievement gain scores for gender.

Conclusion

On the basis of the findings, it is concluded that modeling instruction is practically more efficacious than conventional instructional strategy and is capable of enhancing secondary school physics students' academic performance, but without any significant influence on the basis of students' ability level or gender.

Implications of the Study

From the stand point of this study, the conclusion reached could be said to have some implications for all stakeholders in the education industry including the students, teachers,

curriculum planners, and government.

1. The implication of the study findings for students is that lessons in class are made more meaningful if students are allowed to participate actively. This is the case with modeling instruction approach; students participate actively and learn and correct the many fears and misconceptions about physics by constructing mental models for use in describing its concepts. This is not the case when they remain less active in class and learn in abstraction.
2. The implication of the findings for teachers is that teachers should adopt modeling instruction in physics classroom since learning by observation, which modeling instruction entails, could offer itself an effective instructive strategy whereby students build models through guided activities. This offers even the low-ability students and the female students the opportunity to have more impressive conceptual gains.
3. The study findings also have some implications for curriculum planners. Since the use of modeling instruction has been shown to be practically more efficacious than the conventional instruction strategy, curriculum planners can promote the use of modeling instruction in secondary schools by including it in physics curriculum. This, when done, will make the teaching and learning of physics at the secondary level more interesting and result-oriented.
4. The implication of the study findings for the government is that if government does not act fast in the matter of encouraging the adoption of an effective interactive engagement approach, like modeling instruction, in senior secondary physics teaching, the realization of the goals of physics education in Nigeria will ever remain a mirage.

Recommendations

Against the backdrop of the study findings, the following recommendations are made:

1. Government should encourage physics teachers to use modeling instruction in physics classroom for improved performance of students in physics.
2. There is an urgent need for the NUC (National Universities Commission) to include modeling instruction in the curriculum of teacher training institutions to fully expose the trainees to the intricacies of modeling instruction programmes.

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