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Scientific Reasoning Ability and Acquisition of Science Process Skills Using Improvised and Standard Instructional Materials in Secondary School Physics in Uyo

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Abstract **Original Research Article**

The influence of students' Scientific Reasoning Ability on their Science Process Skill acquisition using improvised and standard instructional materials in current electricity was investigated. The quasi experimental research design was adopted. 163 senior secondary two students in four intact classes drawn from four schools in Uyo local government area of Akwa Ibom State formed the sample of the study. Lawson's Classroom Test of Scientific Reasoning was used to determine the Reasoning Ability of the students before treatment. Pre-test on level of Science Process Skills of the students in current electricity was determined using a Physics Practical Test (adapted from SSCE past questions) and a researcher-developed Science Process Skills On-the-Spot Assessment Rubric (SPSOTSAR). After the respondents were exposed to three weeks of teaching using standard and improvised instructional materials, post-test was done using the same instrument to determine the level of Science Process Skill acquisition. Data obtained were analyzed using mean, standard deviation and analysis of covariance. Findings of the study showed that there is no significant difference among the mean achievement scores of high, average and low reasoning ability students on acquisition of Science Process Skills when taught Current Electricity using improvised potentiometer and Metre Bridge; and when taught with standard potentiometer and Metre Bridge, respectively. Also, it was observed that there is no interaction effect of type of instructional material and Reasoning Ability on SPS acquisition in current electricity. Improvisation and utilization of improvised instructional materials in practical experiments in the laboratory to help the students acquire requisite skills for the future is recommended.

Keywords: Scientific Reasoning Ability, Science Process Skills, Improvisation, On-The-Spot Assessment.

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INTRODUCTION

Scientific Reasoning Ability (SRA) is a foundational construct that underpins science learning. It refers to students' capacity to apply logical thinking, evidence-based reasoning, and systematic analysis to solve scientific problems. These skills span the cognitive domain—such as identifying variables, formulating hypotheses, and interpreting data—and the psychomotor domain, where learners manipulate apparatus, execute experiments, and handle data methodically (Luo et al., 2025).

According to Lawson (in Ahmad, Shah, & Raheem, 2020), scientific reasoning involves intellectual strategies that extend beyond direct experience. It is essential for developing students' analytical, creative, and problem-solving skills in science (Novia & Riandi, 2017). Through SRA, students internalize classroom experiences and transform them into meaningful scientific understanding.

Physics, as a science subject, emphasizes systematic inquiry—hypothesizing, observing, manipulating variables, and reasoning from data to conclusions. This naturally leads to the development of Science Process Skills (SPS), which are transferable skills crucial for scientific inquiry and lifelong learning (Chinda & Achigbe, 2024; Yumusak, 2016). SPS include observation, measurement, inference, prediction, classification, communication, experimentation, and more (Kurniawati, 2021). These skills enhance student participation and develop their capacity to conduct scientific investigations and pursue science-related careers.

The Nigerian senior secondary Physics curriculum seeks to promote scientific literacy, conceptual understanding, skills acquisition and technological application (Usman & Abubakar, 2019). However, poor laboratory engagement and teacher-centered methods hinder the acquisition of SPS

(Adejimi, Nzabalirwa & Shivoga, 2021). Active participation in laboratory activities is essential for building both theoretical and practical competencies (Wilcox & Lewandoski, 2017). Despite this, studies show that many students still graduate with underdeveloped SPS. Widyaningsih et al. (2019) found that over 45% of students' SPS scores were below average. In Nigeria, poor performance in STEM education persists due to limited laboratory access, lack of instructional materials, and minimal student-centered practical activities (FME, 2018; Ojih, Esiekpe & Okafor, 2016).

To address this, improvisation of instructional materials has become a vital strategy. Improvised materials are locally sourced or fabricated tools used when standard apparatus is unavailable. Improvisation supports conceptual understanding, particularly in resource-limited schools (Udo, 2019; Oyediran, 2010). However, most existing studies have focused on cognitive outcomes, neglecting the impact of improvisation on students' psychomotor and process skills—especially in self-performed practical work.

Scientific reasoning is closely linked to SPS acquisition. Kambeyo (2017) observed that reasoning ability predicts students' success in science content and process skill mastery. Ismail and Jusoh (2015) found a strong correlation ($r = 0.599$) between logical thinking and SPS achievement, emphasizing their interdependence. Tanti et al. (2020) further showed that students' SPS influence their critical thinking in science, with disparities based on school location.

STATEMENT OF THE PROBLEM

Despite the recognized importance of practical activities in science education, many Nigerian schools lack the standard materials needed for effective laboratory work. Improvisation offers a solution, but little is known about how students' scientific reasoning ability interacts with instructional material type to influence science process skill acquisition. This study, therefore, investigates the effect of students' scientific reasoning ability on their acquisition of science process skills in Physics when taught using improvised versus standard instructional materials.

RESEARCH QUESTIONS

What is the difference between the mean achievement scores of high, average, and low reasoning ability students in the acquisition of science process skills (manipulative, observational, computational, and communicative) when taught using improvised and standard materials?

What is the interaction effect of treatment and reasoning ability on students' acquisition of science process skills in current electricity?

RESEARCH HYPOTHESES

H_{01}: There is no significant difference among the mean achievement scores of high, average and low reasoning ability students on acquisition of Science Process Skills (Manipulative, Observational, Computational and Communicative skills) when taught Current Electricity using improvised potentiometer and Metre Bridge; and when taught with standard potentiometer and Metre Bridge, respectively.

H_{o2}: There is no significant interaction effect between treatment and reasoning ability on students' acquisition of science process skills.

METHODOLOGY

The study adopted a non-randomized pre-test, post-test control group design. The sample comprised 163 Senior Secondary Two Physics students from four public co-educational schools in Uyo Local Government Area, selected using multistage sampling. Students were divided into two groups. The experimental group used improvised potentiometers and metre bridges developed by the researcher, while the control group used standard equipment.

Three instruments were used: Lawson's Classroom Test of Scientific Reasoning (multiple choice), A Physics Practical Test (adapted from SSCE past questions), and a researcher-developed Science Process Skills On-the-Spot Assessment Rubric (SPSOTSAR) containing 24 items assessing manipulative, observational, computational, and communicative skills on a 4-point Likert scale. The instruments were validated by experts, and the SPSOTSAR reliability was established using Cronbach Alpha ($\alpha = 0.92$) and Intra-Class Correlation.

Teachers were trained as research assistants and guided on the use of instructional packages and assessment procedures. The scientific reasoning test was administered before the instructional intervention. The treatment lasted three weeks, after which students engaged in practical tasks while assessors scored them using the SPSOTSAR.

DATA ANALYSIS

Mean and standard deviation were used to answer the research questions. Analysis of Covariance (ANCOVA) was employed to test the hypotheses at a 0.05 level of significance.

RESULTS

Research Question One: What is the difference between the mean achievement scores of high, average, and low reasoning ability students in the acquisition of science process skills (manipulative, observational, computational, and communicative) when taught using improvised and standard materials?

Table 1: Mean and standard deviation of students' pre-test and post-test scores on acquisition of Science Process Skills using Science Process Skills On -The -Spot Assessment Rubrics (SPSOTSAR) classified by treatment groups and Reasoning Ability

Treatment Groups	Reasoning Ability	N	Pre-test		Post-test		Mean Gain Score
			$\bar{x}$	sd	$\bar{x}$	sd	
Improved materials	High	35	25.94	6.54	63.83	5.64	37.89
	Average	19	28.11	6.98	63.05	4.87	34.94
	Low	21	25.43	2.77	64.57	4.25	39.14
Standard materials	High	31	26.13	6.20	64.71	5.72	38.58
	Average	29	26.34	5.24	64.48	4.95	38.14
	Low	28	27.29	3.86	64.14	6.08	36.85

Table 1 shows that the low ability students taught using Improved Materials had the highest mean gain scores (39.14) followed by their high ability counterparts in the standard materials group (38.58). . The scattering of the raw scores about the post-test mean was closest for the students' in the Improvised materials group.

Hypothesis One: There is no significant difference among the mean achievement scores of high, average and low reasoning ability students on acquisition of Science Process Skills (Manipulative, Observational, Computational and Communicative skills) when taught Current Electricity using improvised potentiometer and Metre Bridge; and when taught with standard potentiometer and Metre Bridge, respectively.

Table 4.8: Summary of 3 x 2 Analysis of Covariance (ANCOVA) of students' post-test scores on acquisition of Science Process Skills using Science Process Skills On-The-Spot Assessment Rubrics (SPSOTSAR) classified by treatment groups and Reasoning Ability with pre-test scores as covariate

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Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Decision at p<.05 alpha**
Pre-test	6.314	1	6.31	.22	.64	ns
Treatment	15.486	1	15.49	53	.47	ns
Reasoning Ability	8.46	2	4.23	.15	.87	ns
Treatment * Reasoning Ability	18.93	2	9.47	.33	.72	ns
Error	**4529.81**	**156**	**29.04**			
Total	**675816.00**	**163**				
Corrected Total	**4579.19**	**162**				

Squared = .011 (Adjusted R Squared = -.027)

From Table 2, the calculated F-ratio for the main effect of instructional materials on students' acquisition of Science Process Skills at F(2,156) = 0.53; and the alpha level is 0.47. This level of significance is greater than .05 on which the decision was based; indicating that there was no significant difference between the students' acquisition of Science Process Skills in Current Electricity taught given the instructional materials used. The F-cal value for the main effect of Reasoning Ability F(2, 156) = 0.15; and alpha level is 0.87. This significant level is greater than 0.05 alpha in which the decision was based, indicating that the influence of Reasoning Ability on the students' acquisition of Science Process Skills was not significant. With this observation, null hypothesis one was upheld.

Hypothesis Two: There is no significant interaction effect between treatment and reasoning ability on students' acquisition of science process skills.

Table 3: Summary of 3 x 2 Analysis of Covariance (ANCOVA) of students' post-test scores on acquisition of Science Process Skills using Science Process Skills On-The-Spot Assessment Rubrics (SPSOTSAR) classified by treatment groups and Reasoning Ability with pre-test scores as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	580.16	24	24.17	.83	.69	ns
Intercept	23859.56	1	23859.56	823.35	.00	ns
Pretest	11.12	1	11.12	.38	.54	ns
Instructional Material	5.01	1	5.01	.17	.68	ns
Reasoning Ability	.41	2	.21	.01	.99	ns
Instructional Material * Reasoning Ability	16.58	2	8.29	.29	.75	ns
Error	3999.00	138	28.98			
Total	675816.00	163				
Corrected Total	4579.19	162				
a. R Squared = .127 (Adjusted R Squared = -.025)						

Table 3 answers the research question two and shows the testing of hypothesis two as well. From Table 3, the calculated F-ratio for the interaction effects of treatment and Reasoning Ability on the students' acquisition of Science Process Skills at df 2, 138 is 0.29; and alpha level is 0.75. This level of significance is greater than 0.05 in which the decision is based; indicating that there was no significant interaction effects of treatment and Reasoning Ability on the acquisition of Science Process Skills of the students on Current Electricity taught. With this observation, null hypothesis 2 was upheld. With respect to research question two the observation indicates that the two instructional resources had the same effects with the three levels of reasoning ability on acquisition of SPS, and vice versa.

DISCUSSION

The finding of this study has shown that there is no significant difference among the mean achievement scores of high, average and low reasoning ability students on acquisition of Science Process Skills when taught Current Electricity using improvised potentiometer and Metre Bridge; and when taught with standard potentiometer and Metre Bridge, respectively. The findings showed that the influence of reasoning ability was not statistically significant. This is attributed to the active involvement of all the learners, irrespective of their reasoning ability level in the teaching – learning process. The observed no significant influence of reasoning ability suggests that this variable is not a strong determinant of students' acquisition of science process skills.

The finding is contrary to that of Kambeyo (2017) who found that Reasoning Ability predicts SPS acquisition and that of Ismail and Jusoh (2015) who observed a positive correlation between reasoning ability and acquisition of SPS. This study has proven also that there is no interaction effect of type of instructional material and Reasoning Ability on SPS acquisition in current electricity. This shows that despite the level of Scientific Reasoning Ability, students develop almost equal level of Science Process Skills with both standard and improvised material. This explains why students, who may not be able to further beyond the Senior Secondary level of education in Physics related courses, can fit favourably into trade where they are exposed to skills training despite their reasoning ability.

CONCLUSION

Physics students' Scientific Reasoning Ability does not influence the level of acquisition of Science Process Skill in Current Electricity despite the nature of the instructional material used while teaching them. This explains why students who cannot reason the cognitive aspects of Physics very well can fit into trades that relate to electrical and technical work when they cannot further their education to tertiary institutions. Physics teachers are therefore expected to improvised and utilize instructional materials in practical experiments in the laboratory so as to help the students acquire requisite skills for the future.

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