ABSTRACT

DEVELOPMENT, VALIDATION AND RELIABILITY OF A TEST INSTRUMENT ON SCIENCE PROCESS SKILLS IN INTEGRATED SCIENCE.

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Science Process Skills are claimed to enable an individual to improve their own life vision and give a scientific view, or literally as a standard of their understanding of the nature of science. The aim of science education is to help students understand scientific knowledge and to develop students' ability to use the scientific approach to inquiry. The science process skills, along with the knowledge those skills produce, are the instructional objectives of science education. The main purpose of this study was to develop and validate a reliable, convenient, and cost-effective complementary paper and pencil test instrument for assessing integrated science process skills in Junior Secondary School Class III. The test is used to measure acquisition in the process of science. The test assesses performance on a set of integrated science processes associated with planning investigations. They include operational definition of variables, identifying and controlling variables, experimental design, stating hypotheses, as well as graphing and interpreting data. The test of integrated science process skills (TISPS) consisted of 30 multiple-choice items. Science process skills are not subject-specific. These skills operate in conjunction with specific knowledge. The design of the study was causal comparative/ex-post facto. A sample of three hundred (300) JSS III students was drawn from six secondary schools within the Nsukka education zone of Enugu state. Five research questions and three hypotheses guided the study. The mean, standard deviation, percentages, and analysis of covariance (ANCOVA) were used to analyze data collected on integrated science process skill instrument tests. The findings from the data analysis show that the test has sound psychometric properties. The findings also reflect the students' acquisition of the integrated science process skills in the content area of science. These tests (paper and pencil format) with sound psychometric properties will be useful in assessing the progress in the learning of integrated science process skills in junior secondary schools, especially by those educators teaching poorly resourced large classes.

Key words: Science Process Skills, Test development, Test validation and reliability, paper and pencil test format, integrated science, junior secondary school 3.

INTRODUCTION

Science teaching and learning has changed from a text-based to an activity-based (hands-on) approach. This has generated an increase in the research and development of different types of assessment. Science curriculum innovations and reforms attempt to incorporate more inquiry and investigative activities into science classes. (Okey 2015). Since the methodology used to teach sciences has changed, the ways to assess what the students are learning also need to be modified. The different approaches to methodology and evaluation have generated an increase in research and the development of different types of assessment in science teaching and learning. Assessment of science learning requires instruments and techniques that are aligned with the methodology used and the depth and complexity of what students understand and can do in their discipline. Therefore, assessments need to include a large range of types of tests, formats, and instruments. Some of these assessments include multiple choice tests, open-ended questions, performance assessments, paper and pencil tests, etc.

One of the aims of science education is to help students develop the ability to use a scientific approach to enquiry and to understand scientific knowledge. The purpose of science is to improve students' understanding of the nature of science. When a scientist faces a problem around him, all he has to do is to design and conduct an investigation so as to find a solution to the problem. The nature of scientific investigation involves the identification of scientific data, scientific behavior, and the gathering of information (Budak, 2014).

The most vital dimension of the nature of scientific investigation is the ways to gather information and the phases of scientific methods. The ways of gathering scientific data are technical processes. Any scientist who wants to conduct an investigation must possess some skills called science process skills (SPS) in order to gain the knowledge.

Therefore, it is very important to teach students how to get knowledge by themselves instead of teaching all knowledge in science education developed by others. Science process skills (SPS) are very important in teaching ways of reaching knowledge and have become the major aim in science education. A Science process skill (SPS) is the application of methods and principles to problem solving (Ugwu, 2014).He also postulated that the activities, which consist of basic and integrated process skills, are the key factors of science literacy. Padilla (2016) also put these skills in the category of basic and integrated scientific skills because students use them at different stages of their learning.

Integrated science process skills have become a vital component of the integrated science curriculum in junior secondary schools in our country, Nigeria, and have also become one of the recent approaches to giving students science education more efficiently and effectively. According to Otegburu (2010), the mastering of science process skills together with scientific attitudes and knowledge will enable students to think, formulate questions, and find out answers systematically by means of critical and analytical thinking. Students begin with assignments such as real-world experiments or activities, and then progress to independent learning.

It is no longer adequate for students to leave schools with just content knowledge. In other words, the emphasis in human capital development is no longer just on the development of knowledge but rather on the development of higher-order-thinking skills (science process skills). The Nigeria science curriculum department of education (2012) aims to produce active learners by engaging process skills in which science students are given ample opportunities to observe, ask questions, formulate and test hypotheses, analyze, interpret data, report and evaluate findings. Science students are expected to be familiar with these languages of science process skills right from the start as they experience science learning. These skills enable an individual to improve their own life vision and give a scientific view or literacy as a standard of their understanding of the nature of science (Ngozi, 2012). Because of the vital need for science process skills, there is an urgent need for the corresponding instrument (authentic assessment) to evaluate the learning. Hence, the development of a test instrument to assess the science process skills becomes a task to be executed. In order to determine the change of students' inintegrated science process skills (ISPS), students should be assessed to what extent they (students) understood the topic and their usage of integrated science process skills (ISPS) in novel learning situations (Ojobo, 2010). Assessment using hand-on procedures (practical work) to determine integrated science process skills acquisition by a group of students is most appropriate and effective. Practical work assesses actual samples of the kind of behaviour seen in integrated science process skills. Unfortunately, the traditional method of assessing integrated science skills competency through practical work requires a trained observer and individual testing, which poses a problem of time management for the classroom teachers.

In addition, the problem of using such a procedure can be a burdensome task for classroom teachers as it is common to have fifty (50) to sixty (60) students per class during the science lesson in question. Under underqualified and unqualified science teachers, poorly equipped laboratories may undermine the practical approach and resort to a theoretical, invalid, and unreliable scale of assessment.

To circumvent these problems, a paper and pencil format test instrument needs to be developed. The integrated science process skills are measured in junior secondary school class three (JSS III) students using a paper and pencil test format. The test assesses performance on a set of integrated science process skills associated with planning investigations. They include formulating hypotheses, operationally defining variables, identifying and controlling variables, as well as interpreting data. Paper and pencil format is a welcome development because it can measure different types of knowledge, including declarative (factual or known that), procedural knowledge (knowing how, i.e., step by step in investigation), and schematic knowledge (knowing why-knowledge used to reason about).

Paper and pencil test formats produce high levels of reasoning ability since the tests are related to what students and scientists do in the laboratory. Paper and pencil test formats do not only show how students show higher engagement in learning (Obioma, 2016). Paper and pencil achievement test formats demonstrate what students know and can do (Odo, 2012).

The evidence gathered during the performance provides insights into students’ thinking and, at the same time, introduces students to authentic world problems, which allows them to show how they can apply academic knowledge to practical situations.

Many paper and pencil test formats have been developed to assess science process skills for both primary and secondary scholars, but most of the tests were developed and validated outside Nigeria. A review of the literature shows that not much work, if any at all, has been done in the area of test construction and validation for use to assess these specific skills, especially for junior secondary school students, JSSIII. The search for available literature on integrated science process skills showed the need for the development of a test geared towards JSS111 science students.

Even among the developed instruments, the main shortcomings were that most of them were based on specific curricula and evaluated a complete combination of skills rather than specific skills (Onwu, 2012). In addition, the tests were said to have had uncertain validity because of the lack of external criteria by which to judge them. Onwu (2012) and George (2010) created a science process skills (TSPS) test for primary four to six students that focused on inquiry skills.The test was presented in the form of a demonstration. It was considered to be valid but had low reliability. Most of the reviewed tests at the primary levels tend to deal with basic science process skills only. None of them specifically addressed the assessment of higher-order thinking skills.

In an attempt to address some of the identified weaknesses of developed tests, Tobein (2013) further developed a test of integrated science process skills (TSPS). The test was designed to examine primary six pupils' performance in the area of planning and conducting investigations. The test items were used on twelve objectives and they proved to have the ability to differentiate students' abilities in inquiry skills. The few studies available in Nigeria show that researchers have been more interested in finding out the levels of acquisition of science process skills or identifying the process skills inherent in particular curriculum materials (Onwu and Mozube, 1992). Moreover, none of the studies has so far attempted to determine test bias against possible sources such as gender and location of students.

Adopting the existing tests is likely to be problematic. Research has shown that students learn science process skills better when they are taught to see them as important and relevant to their everyday lives (Okra, 2014).

Therefore, the development and acquisition of science process skills has raised concern with regards to the excessive use of unfamiliar materials and conceptual models in Nigeria and African educational systems. Researchers advocate the use of locally developed educational materials that are familiar and meet the expectations of students. This is in agreement with Adesogi (2011) on the methods of scientific instruction in Nigeria and Africa as a whole, that such instructions make us academic foreigners in our own country. Therefore, the use of the existing tests may lead to invalid and unreliable results in Nigeria.

Ugwu (2014) observed that test instruments for assessment of integrated science process skills in schools right now have not been carried out in a comprehensive manner and the assessment instruments were not used to improve the quality of science process skills. Harlen (2016) maintained that without the development of a valid and reliable test instrument for the assessment of science process skills, there will continue to be a gap between what our students need from science and what is taught and assessed. Eze (2014) argued that assessing science process skills is important for formative, summative, and monitoring purposes because the mental and physical skills described as science process skills have a central part in learning with understanding.

Statement of the problem

Nigerian students are generally good at regurgitating facts that have been fed into them. This fact-regurgitating ability is less valuable in today's ever changing economy. Instead, students need to be able to reason, to extrapolate, and to creatively apply their knowledge in novel and unfamiliar settings. Because of this, students need to learn how to use information in creative ways that will help them think critically.

Hence, mastering science process skills is deemed crucial because the skills are required in the process of finding solutions to a problem as well as making decisions in a systematic manner (Curricula Development Centre 2012). Currently, the acquisition of science process skills of each student is assessed through school-based practical work (hands-on-procedures), where teachers expect students to demonstrate the acquisition of science process skills.

Unfortunately, the use of hands-on-procedures to assess skill acquisition by a group of students has enormous practical assessment constraints.

Large class sizes and inadequate laboratory facilities were among the constraints; teachers were less confident in assessing practical work and did not have enough time to do so accurately (Onwu 2012). Another problem is that the use of foreign-developed existing tests may lead to invalid results because the tests have been accused of estrangement and lack of indigenized approaches. The poor students' enrolment in sciences and the overall poor academic achievement of JSS III students in science raise doubts on the efficacy of the developed existing tests in science process skills. To circumvent these problems, it becomes necessary to seek alternative ways of assessing students' competence in science process skills. Hence, the need to develop and use a paper-and-pencil group testing format for measuring students' science process skills competency, which can be administered efficiently and objectively. It does not require expensive resources.

Purpose of study

The main purpose of this study was to develop and validate, a reliable and effective paper and pencil test for measuring science process skills competence effectively and objectively in junior secondary school class three (JSS III).This study specifically intended to;

i. Develop a paper and pencil test instrument of integrated science process skills for JSS III students.
ii. Develop test items that are valid within the acceptable range of value of validity, item discrimination, power and index difficulty levels.
iii. Develop the test items that are reliable within the acceptable range of values of reliability level.
iv. Construct test items that do not favor any particular participants belonging to different school location and gender.

Research Questions

i. What was the item responses pattern according to the performance category and the integrated science process skills measured?

ii. Is the developed test instrument a valid means of measuring students' competence in integrated science process skills in term of discrimination power and difficult indices in the performance category and skills measured?

iii. Is the developed test instrument a reliable means of measuring students' competence in integrated science process skills?

iv. Does the developed test instrument show sensitivity in regard to school location and gender in the different group of students?

v. What is the interacting effect of gender and school location on student acquisition of the science process skills measured?

Statement of Hypothesis

i. $H0_1$: There is no significance ($p \leq 0.05$) difference between mean achievement of urban and rural students on integrated science process skills measured.

ii. $H0_2$: There is no significance ($p \leq 0.05$) difference between mean achievement of males and females of urban students on the integrated science process skills measured.

iii. $H0_3$: The interaction effect of gender and school location on students' acquisition of integrated science process skills competence will not be significant at ($p \leq 0.05$).

Methodology

Item writing was based on the integrated science curriculum for JSS111 in Nigeria; prescribed text books; locally prepared past examinations and tests; standard achievement tests; some teaching materials reviewed; and from day-to-day experiences to ascertain the inclusion of the targeted science process skills and the objectives on which the test items were based. Items for integrated SPS testing and those related to planning investigationsThey include formulating hypotheses, identifying and controlling variables, operationally defining variables, interpreting data, graphing, as well as designing suitable experiments. Answering test items requires conceptual understanding of the science content. Therefore, the construct being measured is confounded by knowledge of scientific content. The pilot study was made up of ninety (90) JSS111 students, forty-five (45) from rural schools and forty-five from urban schools. The population for the main study was three hundred JSS111 students from six (6) public schools in the Nsukka education zone of Enugu state, Nigeria.

In both the pilot and main study, the students were selected through purposive sampling. On the basis of school typicality and locality,

The subjects selected consisted of both male and female JSS111 students from both urban and rural schools for gender and location comparison. The design of the study was casual comparative and ex-post facto.

Initially, a total number of items selected was 60 multiple-choice test items, which were referenced to the stated objectives. Each item has four optional responses. Only one of the four optional responses was correct. These items formed the first draft of the instrument. The first draft instrument was tested for content validity by six evaluators/raters who comprised of two chemistry lecturers, two biology lecturers, and two physics lecturers, all from the University of Nigeria Nsukka. The raters were given the test items and a list of the test objectives, to check the content validity of the instrument by matching the items with corresponding objectives. A high percentage of the raters agreed with the test developer on the assignment of the test items to the respective objectives. The evaluators also provided answers to the test items so as to verify the objectivity and accuracy of the scoring key. The analysis of their responses showed that ninety (90) percent of the raters' responses agreed with the test developer on the accuracy and objectivity of the test item. The validation of the items led to the removal of many unsuitable items. Thirty-one (30) items survived the validation.

On the appropriate dates, the researcher and the assistants administered the developed test instrument to learners.

After the administration of the test, the scripts were scored by allocating a single mark for a correct response and no mark for a wrong, omitted, or a choice of more than one response per item. The raw scores for each subject were entered into a computer for analysis.

The reliability of the test instrument was determined by using the Kuder-Richardson twenty-one method (KR21) for determining the internal consistency of the test items. Comparisons of the performance of the students from different groups (school location and gender) were determined using descriptive statistics. Data from the test of integrated science process skills (TISPS) instrument was analyzed quantitatively using mean and standard deviations, percentage values to answer the research questions. The hypotheses were tested using analysis of covariance (ANCOVA).

Data Analysis

Research Question 1: Scores from all the 300 students involved in the study were used to determine the item response pattern. The item response pattern for all the students who participated in the study was determined according to their performance categories (upper, medium and low scorers). The percentage of the upper scorers was within the range of (42 – 50%) followed by the percentage of the medium scorers which was within the range 28 – 36% and the percentage of the low scorer was within the range of 16 - 26%, for example, from item number 2, 50% of the upper scorers selected the correct option, 33.3% of the medium scorer selected the correct option, and 16.7% of the low scorers selected the correct option

The results suggest that the developed test was able to discriminate between those who are likely to be more competent in science process skills (upper scorers) and those who are likely to be less competent in the skills(low scores). Generally the analyses indicated that the correct option attracted more of the upper scorer because they are extremely intelligent.

Research Question 2: The discrimination indices of the items were organized according to the different performance categories and the integrated science process skills measured.

The discrimination index for each item was determined using the scores of the upper scorers and low scorers. The test instrument is capable of distinguishing between students who possess the trait measured and those who do not. The discrimination indices of the items were further grouped according to the science process skills measured in the study. This was necessary to determine the science process skills which discriminated better than others. All the indices fall within the acceptable range of values of discrimination index (0.3-10) (Ikete, 2018). The difficult indices of the test items were determined according to the performance categories in order to find out the range of values for indices of difficulty. These items were retained in the instrument despite the high indices of difficulty, because they had good discriminating indices. The difficulty indices of the items were further grouped according to the integrated science process skills measured. This was necessary to indentify the process skills which the students found to be more difficult than others. All the indices fall within the acceptable range of value of a test difficulty index (0.30 to 0.70).

Research Question 3: The Kuder-Richardson twenty one (KR21) reliability coefficients was calculated for finding out internal consistency of the 30 items that make up the integrated science process skills instrument and was found as 0.81 by the use of computer. This value is an important proof for the reliability of the test as it shows that questions are consistent with each other. The developed test may therefore be considered reliable.

Research Question 4: Comparison of the performance of students from urban and rural schools.

Location	N	$\overline{X}$	SD
Urban	150	15.42	2.81
Rural	150	9.76	1.08

The performance mean of the students involved (15.42 for urban schools, and 9.76 for rural schools) shows quite a big difference. The mean difference observed in the performance of rural and urban students may be an indication of the discrimination power and sensitivity of the developed test, in terms of its ability to identify students who are more competent in integrated science process skills, and those who are less competent, presumably the urban and rural students respectively.

Research Question 5: Interaction between gender and school location on students acquisition of the science process skill measured.

GENDER SCHOOL LOCATION

	URBAN			RURAL		
	N	$\overline{X}$	SD	N	$\overline{X}$	SD
Male	75	16.69	2.38	75	10.4	2.12
Female	75	14.2	2.65	75	9.2	1.68

Table clearly revealed that there is an interaction between gender and school location in student acquisition of the science process skills measured.

Result above indicated that urban students are more competent in the acquisition of science process skills than the rural students. The mean of male and female students are 16.69 and 14.2 respectively on urban schools which are higher than the mean of male (10.4) and female (9.2) on the rural school.

Hypothesis: Analysis of co-variance (ANCOVA) for students' overall acquisition of science process skills competences by school location and by gender.

Source of Variation	Sum of Squares	d.f	Mean Squares	f.cal	Fcv
Covariate	574.584	1	574.584	134.575	
Main affect	2354.888	2	1177.444	275.772	
School location	79.372	1	79.372	18.590	3.84
Gender	2223.684	1	2223.684	520.814	3.84
2- way interaction	36.987	1	36.987	4.663	3.84
Explained	2966.459	4	741.615	173.695	3.84
Residual	1259.541	295	4.270		
Total	4226.000	299	14.134		

$H0_1$: There is no significant difference ($P \leq 0.05$) between mean achievement of urban and rural students on integrated science process skills measured.
The ANCOVA table shows that the F-calculated value (18.590) is greater than the critical value (3.84) at alpha level of 0.05.
The developer therefore concluded that there is a significant difference in the mean achievement score of urban and rural students on integrated science process skills measured. The researcher therefore rejected the hypothesis
$H0_2$: There is no significant difference (P = 0.05) between mean achievement of male and female students on the integrated science process skills measured. The F-calculated (275. 772) is greater than the F-critical value (3.84) at the given alpha level of 0.05. The researcher therefore concluded that the difference between the male and female students on the integrated science process skills measured is significant. The researcher therefore rejected the hypothesis.
$H0_3$: The interaction effect of gender and school location on students' acquisition of integrated science process skills competence will not be significant ($P \leq 0.05$). The result shows that F-calculated is 4.663 while F-critical value is 3.84 at the given 5% probability level. The researcher concludes that there is a significant interaction between gender and school location on students' acquisition of integrated science process skills competence. The researcher therefore rejected the null hypothesis.

Discussions and conclusions

The findings that urban students outperformed rural students in the acquisition of integrated science process skills support Eze's (2012) finding that urban students outperformed rural students in terms of communicating, classifying, observing, and predicting skills.

The rural-urban differences may be attributed to poorly equipped physical and laboratory facilities, poor language performance levels, and a lack of qualified science teachers. In terms of student population, rural schools have large science classes.The few qualified science teachers are mostly located in urban areas, like cities, etc.

The conditions of teaching and learning science in urban and rural schools are not the same.

Secondly, the observed mean difference in the performance of rural and urban students may be an indication of the discriminating power and sensitivity of the developed test instrument in terms of the ability to identify students who are more competent in the integrated science process skills measured and those who are less competent, presumably the urban and rural students respectively.

It can be concluded generally that JSS3 students have achieved a desirable acquisition level of integrated science process skills based on the pattern in the acquisition level of integrated science process skills. The reason for such achievement remains clear: students' ability in and grasp of thinking skills. According to curriculum development (2012), in order to acquire the science process skills, students have to acquire the thinking skills (knowledge) as well as the skills involved in the mastery of the relevant skills.

The difficulty index was 0**.**5 and the RK21 reliability coefficient calculated for finding out the internal consistency of the 30 items that make up the developed test instrument was found to be 0**.**81. This value is an important proof of the reliability of the test.

The developer concluded that the developed instrument is valid and reliable enough to be used to measure students' competence in the stated science process skills in planning scientific investigations.

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