Assessment of science practical skills for Nigerian secondary schools: Teachers' practices and militating factors

Omaze Anthony Afemikhe[1], Sylvanus Yakubu Imobekhai[1]& Theresa Chinyere Ogbuanya[2]

[1]Institute of Education, University of Benin, Benin City, Nigeria

[2]Faculty of Education, University of Nigeria, Nsukka, Nigeria

Abstract

It is the belief that the teaching of science in Nigerian secondary schools can accelerate technological development which is one of the visions of Nigeria by 2020. Good science instruction involves interplay of experiments, observation and theoretical inferences. Practical work in science has a formative function, of assisting students in understanding science and how scientific ideas are developed. Experiments have to be conducted and the assessment of practical has to be carried out as an important component of grades assignment in certification examinations on completion of secondary school. Teachers play an important role in the preparation of candidates for certification examinations in the delivery of theory lessons and conduct of practical exercises. The question which then has to be answered is what assessment practices are used in preparation of students for the certification examination. In addition, the problems which confront proper integration of practical in the teaching of science were equally explored. Towards this end, this study utilized a survey research method utilizing science teachers in secondary schools in Edo state, Nigeria. A sample of two hundred science teachers was used for data generation and the data were collected using the researchers' designed questionnaire. The data were analyzed using frequencies, mean scores, t-test and ANOVA. The typology of practical practices utilized by teachers was varied as no one method was predominant and militating factors varied between teachers based on school ownership and science subject taught. Based on the results it was recommended that teachers should focus on the teaching approach prescribed by the syllabus. In addition material resources should be provided for teachers use in teaching practical lessons.

Introduction

In Nigeria, Science is taught at all levels of the educational system from pre-primary through primary and secondary school to tertiary levels. At the levels below the tertiary level some components of science are taught to all students before 2011 when science is no longer a part of core subjects; science in primary schools is taught as a component of basic science and technology (Federal Ministry of Education, 2007a; 2007b) infused with approved curriculum innovations in the areas of environmental education, drug abuse education, population and family life education and sex education (Afemikhe & Imobekhai, 2014). At the junior secondary school level science is taught as basic science (Federal Ministry of Education, 2007c). The themes covered at this level include: you and the environment, you and non-living things, science and development and you and energy. At the senior secondary school level, science is taught as chemistry, biology and physics but students are not expected to offer all three of them.

Expectedly, the teaching of science has evolved from teaching science as a product, to teaching it as a process. This has led to focusing on how scientists work in the generation of knowledge rather than on what knowledge has been generated. The expectation in this regard also involves trying to ensure that students imbibe some basic science skills that they can apply as part of their everyday life. The consequence is that achievement in science has metamorphosed into four main ways of knowledge, namely declarative, procedural, schematic and strategic knowledge. These have been seen as knowing that, how, why when, where and how to apply knowledge respectively. They include knowledge that ranges from discrete and isolated content elements, such as terminology, facts, or specific details, to more organized knowledge forms, such as statements, definitions, knowledge of classifications, and categories. The strategic knowledge is most complex as it involves 'navigating the problem, planning, monitoring, trouble-shooting, and synchronizing other types of knowledge'. "Strategic knowledge is used when one encounters ill-defined tasks" (Tsai & Li, 2007:14). How each of these types of knowledge acquisition is cultivated depends on the implementation of the curriculum. Practical activities' use is central in this regard.

Practical work is formative as it helps the students to understand science and how the scientific ideas are developed (Watts, 2013). To achieve the goals of science education, it is imperative that an attempt is made to balance emphasis on both theory and experiments. Experiments in science illustrate the fact that science is not a theoretical abstraction as it describes the real world around us. It also generates interest in science and promotes skills and competencies of doing science (Central Board of Secondary Education, undated). The skills normally emphasized in science practical include procedural and manipulative, observation, drawing and reporting and interpretative skills. According to Watts (2013) the purposes of practical work include:

i. motivation of students;
ii. excitement of discovery;
iii. consolidation of theory;
iv. development of manipulative skills;
v. knowledge of standard techniques;
vi. general understanding of data handling;
vii. development of other skills like analytic, evaluative, planning, applied and mathematical; and developing an understanding of how science works through concept of scientific process, collaborative working, reproducible results and fair testing.

Experiments are the essence of science. In order to assess practical work in science, two approaches have been used: direct and indirect assessment. According to Abraham, Reiss and Sharpe (2013), while direct assessment involves students manipulating tangible objects to demonstrate practical skills, the indirect assessment involves inferring a students' competency from the data they generate and/or reports of the practical work they undertook. Assessment is emphasized as it drives teaching and learning (Pollard, Triggs, Broadfoot, McNess & Osborn, 2000). In the assessment of practical work different typologies have been used. Watts (2013) outlined seven kinds of science practical assessments which include:

i. traditional practical task or examination,
ii. written examination which assesses practical work,
iii. investigations,
iv. projects,
v. skills focused assessments;
vi. portfolio of required assessments, and
vii. classroom-based assessment.

Each of these is expected to yield dependable information about skills possessed by students. Watts (2013) indicated that assessment of practical skills have however focused on skills narrower than what practical work tends to assess.

In Nigeria, the physics curriculum for example recommends that the guided discovery approach be used in the teaching of the subject. The effort is to facilitate the creativity and acquisition of scientific skills and attitudes by the students. Consequently, it is expected that the emphasis should be on engaging students in experimentation, questioning, discussion and problem solving. Unfortunately, it would appear that these have rarely been successful (Afemikhe & Imobekhai, 2014) and most schools wait till a few weeks to the commencement of final examinations before practical activities are given much impetus. Under these circumstances what kind of practical work assessment is predominant in Nigerian schools?

Practical work also requires minimum quantity of equipment and chemicals in addition to having sufficient level of human resources for their conduct. To what extent do teachers see these as affecting the implementation of practical work as part of science teaching in Nigerian Schools? Based on the situation of practical work in Nigerian secondary schools, this study attempted to find answers to the following questions:

1. What assessment approaches are predominantly used by science teachers in Edo state of Nigeria?
2. What factors encumber the teaching of science practical in schools?
3. Are there variations in assessment approaches used by teachers in public and private schools?
4. Do variations also exist in assessment approaches used by biology, chemistry and physics teachers?
5. Are the factors which militate against use of practical in science teaching dependent on subject taught and school ownership (private and public)?

Methodology

In executing this study a cross-sectional survey approach was applied. The population of the study was composed of science teachers in both public and private secondary schools in Edo state, Nigeria. Only teachers who teach the subjects biology, chemistry and physics were utilized in the study. From the population, a sample of two hundred teachers was used. The selection involved sampling of schools and all science teachers in the sampled school were eligible to take part in the study. The teachers were not compelled but were approached to complete the questionnaire after the details of the study had been explained.

A questionnaire titled 'Secondary Schools Science Practical Skills Questionnaire' composed of three sections was used in data collection. Section A of the questionnaire asked respondents to supply some demographic information such as school ownership, science subject taught. Section B itemized some approaches used in the conduct of practical activities in the classroom. This section was based on typology of conducting practical outlined by Watts (2013) and some others specified by City and Guilds (2003). The respondents were to indicate on a three-point scale of 'all the time', 'sometimes' and 'not at all' how often each practical approach was utilized. The validity-evidence of the questionnaire was established using 3 jurors of experts in measurement and evaluation with initial training in science education and they determined the adequacy, comprehensiveness and suitability of the items.

Section C contained some factors which could hinder appropriate implementation of practical activities in science teaching. The respondents were asked to indicate the extent to which each factor made it difficult to achieve the science practical objectives in schools. The respondents were asked to respond on a three point scale of 'great extent', 'small extent' and 'not at all'. Based on the comments and observations of the experts the questionnaire was corrected and copies produced for the determination of the reliability of the scores. The responses provided to section B were scored as 'all the time' = 3, 'sometimes' = 2 and 'not at all' =1. The responses to section C were scored as 'great extent' = 3, 'small extent' = 2 and 'not at all' =1). The reliability of the scores from the instrument on administration to thirty science teachers was determined using Cronbach alpha and section B yielded a value of 0.857, section C a value of 0.688. These values were deemed appropriate for this study. Analysis of the data collected was carried out with means, t-test and ANOVA. The predominant response category for each item was taken as the one that had responses equal to or greater than 50%.

Results and discussions

The total number of respondents was 165 giving a return rate of 82.5%. There were more male (51.5%) than female (47.9%) teachers in the samples used. The number of respondents who teach in private schools were 54 (32.7%) compared to 111 (67.3% who teach in public schools. The distribution by subject taught showed that 68 (41.2%), 57 (34.5%) and 39 (23.6%) teach biology, chemistry and physics respectively.

Using the interpretative norm setup and examining Table 1, it is found that practical assessment approaches that were used all the time include 'Students write their reports on an investigation using data which they have been provided' and 'Teacher observes students undertaking practical work and rates them'. Among those approaches used sometimes are 'Students write their reports on an investigation using their own data', 'Students conduct a practical and write up their apparatus, methods, results and inferences', 'Practical assignments given to students'. There was no consensus in agreement with 'Students are given a theory of practical examination which assesses practical skills (not involving practical work)' and 'A portfolio of experiments detailing methods, results and conclusions is produced by students for assessment' among others.

Table 1: Mean and frequency distribution of assessment practices

Practical work approaches	**Not at all**	**Sometimes**	**All the time**
Students write their reports on an investigation using their own data.	15(9.1)*	**93(56.4)**	56(33.9)
Students conduct a practical and write up their apparatus, methods, results and inferences.	15(9.1)	**89(53.9)**	59(35.8)
Students are given an oral examination based on the practical work.	22(13.3)	**97(58.8)**	45(27.3)
Students write their reports on an investigation using data which they have been provided.	20(12.1)	57(34.5)	**88(53.3)**
Teacher observes students undertaking practical work and rates them.	20(12.1)	54(32.7)	**90(54.5**
Students are given a theory of practical examination which assesses practical skills (not involving practical work).	20(12.1)	84(49.7)	59(35.8)
Teacher assesses the kinds of laboratory skills that science practical work will require	16(9.7)	69(41.8)	74(44.8)
A portfolio of experiments detailing methods, results and conclusions is produced by students for assessment.	28(17.0)	84(49.7)	55(33.3)
Practical assignments given to students.	16(9.7)	**96(58.2)**	49(29.7)
Practical conducted in an environment close to work situation as much as possible.	23(13.9)	**87(52.7)**	52((31.5)

*Numbers in brackets are percentages

The factors which inhibit achieving objectives of practical work to a small extent include 'equipment not available', 'lack of consumable', 'large curriculum content', 'time is limited', 'duration of lesson and 'pupil behavior'. There was no consensus on effect of 'teachers' experience', absence of laboratory', 'health and safety issues in school' and large class size. When percentage of responses for the items for the two response options highly rated are combined for each factor, it is realized that all issues examined are relevant in influencing the attainment of objectives of practical work.

Table 2: Mean and standard deviation of factors which inhibit practical work

Factors inhibiting practical work	**Not at all**	**Small extent**	**Great extent**
Equipment not available	28(17.0)*	**91(55.2)**	44(26.7)
Lack of consumables	29(17.6)	**89(53.9)**	42(25.5)
Large curriculum content	27(16.4)	**90(54.5)**	45(27.3)
Time is limited	30(18.2)	**90(54.5)**	42(25.5)
Pupils' behaviour	28(17.0)	**87(52.7)**	45(27.3)
Teachers' experience	50(30.3)	59(35.8)	51(30.9)
Absence of laboratory	57(34.5)	65(39.4)	41(24.8)
Absence of technical support like attendants	40(24.2)	77(46.7)	46(27.5)
Health and safety issues in school	34(20.6)	72(43.6)	56(33.5)

Large class size	29(17.6)	70(42.4)	63(38.2)
Duration of lesson	27(16.4)	**92(55.8)**	43(26.1)
Principals' being not supportive	66(40.0)	55(33.3)	40(24.2)

*Numbers in brackets are percentages

Table 3 contains t-test results of differences between teachers in public and private school usage of the typology of practical exercises. Significant differences were noticed only in the cases where 'Students write their reports on an investigation using their own data' in favour of teachers in private schools.

Table 3: t-test of difference between means of private and public school usage of approaches

Practical work approaches	School ownership	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Students write their reports on an investigation using their own data.	Private	54	2.44	0.63	2.932	162	.004
	Public	110	2.15	0.58			
Students conduct a practical and write up their apparatus, methods, results and inferences.	Private	54	2.19	0.59	-1.232	161	.220
	Public	109	2.31	0.63			
Students are given an oral examination based on the practical work.	Private	54	2.24	0.58	1.446	162	.150
	Public	110	2.09	0.64			
Students write their reports on an investigation using data which they have been provided.	Private	54	2.57	0.57	2.099	163	.037
	Public	111	2.33	0.74			
Teacher observes students undertaking practical work and rates them.	Private	54	2.52	0.61	1.175	162	.242
	Public	110	2.38	0.74			
Students are given a theory of practical examination which assesses practical skills (not involving practical work).	Private	51	2.25	0.72	.165	159	.869
	Public	110	2.24	0.63			
Teacher assesses the kinds of laboratory skills that science practical work will require	Private	49	2.41	0.61	.552	157	.582
	Public	110	2.35	0.68			
A portfolio of experiments detailing methods, results and conclusions is produced by students for assessment.	Private	54	2.26	0.62	1.240	163	.217
	Public	111	2.12	0.72			
Practical assignments given to students.	Private	53	2.25	0.52	.593	159	.554
	Public	108	2.19	0.64			
Practical conducted in an environment close to work situation as much as possible.	Private	53	2.23	0.64	.638	160	.525
	Public	109	2.16	0.67			
Practical as part of normal work	Private	54	2.35	0.59	1.60	162	.111

Public	110	2.19	0.61

In Table 4, the ANOVA summary of use of typology of practical work by subject taught are presented. Significant differences were only noticed in the case of 'practical assignments given to students'. Table 5 contains the pair wise comparison to show source of difference. From the table, significant differences are observed between Biology (2.33) and Chemistry (2.06).

Table 4: ANOVA summary table of use of practical typology by subject taught

Practical work approaches	Source	Sum of Squares	df	Mean Square	F	Sig.
Students write their reports on an investigation using their own data.	Between Groups	.944	2	.472		
	Within Groups	59.743	160	.373	1.264	.285
	Total	60.687	162			
Students conduct a practical and write up their apparatus, methods, results and inferences.	Between Groups	.711	2	.355		
	Within Groups	61.339	159	.386	.921	.400
	Total	62.049	161			
Students are given an oral examination based on the practical work.	Between Groups	.332	2	.166		
	Within Groups	62.699	160	.392	.423	.656
	Total	63.031	162			
Students write their reports on an investigation using data which they have been provided.	Between Groups	1.418	2	.709		
	Within Groups	78.387	161	.487	1.456	.236
	Total	79.805	163			
Teacher observes students undertaking practical work and rates them.	Between Groups	1.532	2	.766		
	Within Groups	78.260	160	.489	1.566	.212
	Total	79.791	162			
Students are given a theory of practical examination which assesses practical skills(not involving practical work).	Between Groups	.358	2	.179		
	Within Groups	69.195	158	.438	.409	.665
	Total	69.553	160			
Teacher assesses the kinds of laboratory skills that science practical work will require	Between Groups	.486	2	.243		
	Within Groups	68.223	155	.440	.552	.577
	Total	68.709	157			
A portfolio of experiments detailing methods, results and conclusions is produced by students for assessment.	Between Groups	.156	2	.078		
	Within Groups	78.399	161	.487	.160	.852
	Total	78.555	163			
Practical assignments given to students.	Between Groups	2.265	2	1.133		
	Within Groups	55.928	157	.356	3.180	.044
	Total	58.194	159			
Practical conducted in an environment close to work situation as much as possible.	Between Groups	.511	2	.256		
	Within Groups	68.619	158	.434	.589	.556
	Total	69.130	160			
Practical as part of normal work situation.	Between Groups	.680	2	.340		
	Within Groups	59.504	160	.372	.914	.403
	Total	60.184	162			

Table 5: Scheffe multiple comparison of means of significant typology

Dependent Variable	(I) Science subject taught	(J) Science subject taught	Mean Difference (I-J)	Std. Error	Sig.
Practical assignments given to students.	Biology	Chemistry	.27381*	.10860	.044
		Physics	.11783	.12121	.624
	Chemistry	Biology	-.27381*	.10860	.044
		Physics	-.15598	.12590	.466

Table 6 contains t-test results based on school ownership. Significant differences were noticed in the following cases: large curriculum (private = 2.27, public = 2.04), teachers' experience (private = 2.34, public = 1.84), absence of technical support (private = 1.81, public = 2.15), Health and safety issues in school (private = 2.32, public = 2.05) and principals not being supportive (private = 2.06, public = 1.74).

Table 6: t-test of difference between means of factors by school ownership

Factors inhibiting practical work	School ownership	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Equipment not available	Private	53	2.15	0.60	.708	161	.480
	Public	110	2.07	0.69			
Lack of consumables	Private	53	2.21	0.74	1.705	158	.090
	Public	107	2.02	0.61			
Large curriculum content	Private	52	2.27	0.69	2.121	160	.035
	Public	110	2.04	0.63			
Time is limited	Private	53	2.06	0.66	-.233	160	.816
	Public	109	2.08	0.67			
Pupils' behaviour	Private	52	2.17	0.55	.876	158	.382
	Public	108	2.07	0.72			
Teachers' experience	Private	53	2.34	0.73	3.885	158	.000
	Public	107	1.84	0.78			
Absence of laboratory	Private	53	1.81	0.68	-1.040	161	.300
	Public	110	1.95	0.81			
Absence of technical support like attendants	Private	53	1.81	0.79	-2.804	161	.006
	Public	110	2.15	0.68			
Health and safety issues in school	Private	53	2.32	0.73	2.261	160	.025
	Public	109	2.05	0.73			
Large class size	Private	52	2.15	0.70	-.674	160	.501
	Public	110	2.24	0.74			
Duration of lesson	Private	52	2.08	0.65	-.292	160	.770
	Public	110	2.11	0.65			
Principals' being not supportive	Private	51	2.06	0.73	2.422	159	.017
	Public	110	1.74	0.81			

From Table 7, significant difference is noticed only in the case of pupils' behaviour. In Table 8, two clusters are observed; physics and biology are not significantly different while biology and chemistry are also not significantly different.

Table 7: ANOVA summary table of factors affecting practical work by subject taught

Factor inhibiting practical work	**Source**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Equipment not available	Between Groups	1.127	2	.564	1.308	.273
	Within Groups	68.484	159	.431		
	Total	69.611	161			
Lack of consumables	Between Groups	.978	2	.489	1.120	.329
	Within Groups	68.117	156	.437		
	Total	69.094	158			
Large curriculum content	Between Groups	1.451	2	.726	1.673	.191
	Within Groups	68.536	158	.434		
	Total	69.988	160			
Time is limited	Between Groups	.398	2	.199	.445	.642
	Within Groups	70.707	158	.448		
	Total	71.106	160			
Pupils' behaviour	Between Groups	2.702	2	1.351	3.097	.048
	Within Groups	68.492	157	.436		
	Total	71.194	159			
Teachers' experience	Between Groups	.320	2	.160	.250	.779
	Within Groups	99.680	156	.639		
	Total	100.000	158			
Absence of laboratory	Between Groups	.288	2	.144	.238	.788
	Within Groups	96.132	159	.605		
	Total	96.420	161			
Absence of technical support like attendants	Between Groups	1.074	2	.537	1.019	.363
	Within Groups	83.772	159	.527		
	Total	84.846	161			
Health and safety issues in school	Between Groups	.334	2	.167	.307	.736
	Within Groups	85.927	158	.544		
	Total	86.261	160			
Large class size	Between Groups	.256	2	.128	.240	.787
	Within Groups	84.563	158	.535		
	Total	84.820	160			
Duration of lesson	Between Groups	.330	2	.165	.383	.682
	Within Groups	68.080	158	.431		
	Total	68.410	160			
Principals' being not supportive	Between Groups	1.008	2	.504		
	Within Groups	100.767	157	.642	.785	.458
	Total	101.775	159			

Table 8: Scheffe multiple comparison of means of significant students behaviour

Science subject taught	Subset for alpha = 0.05		
	N	1	2
Physics	39	1.9487	
Biology	67	2.0597	2.0597
Chemistry	54		2.2778
Sig.		.699	.254

The results with respect to typology of practical approaches indicated that teachers use approaches where ‘Students write their reports on an investigation using data which they have been provided’ and ‘Teacher observes students undertaking practical work and rates them’ are not unexpected as experience shows that practical are usually not conducted as regular part of learning science (Afemikhe & Imobekhai, 2014), but as final examinations approach. Under such circumstances the ‘fire-brigade’ approach may be adopted leading to teaching to the test. The fact that factors which inhibit achievement of objectives of practical include equipment, consumables, curriculum, etc is indicative that material resources for teaching science are in short supply. Under such circumstances, conduct of practical work may be very difficult. Consequently, implementation of science programmes dependent on use of practical as a formative tool would be lacking. This will not augur well for realization of objectives of science teaching. Pupils’ behaviour is also a factor implicated in the proper teaching of practical in science teaching and it is an important factor in any teaching learning situation. When the pupils are uncooperative learning would not take place; otherwise the objectives of teaching and learning are easily realizable. These material resources factors and pupil factor could have possibly led to achievement in the sciences in public examinations not being very encouraging (Okonkwo, 2006).

Differences in ‘Students write their reports on an investigation using their own data’ in favour of private schools could be attributed to private schools involving their students in practical as a way of getting more patronage. Differences between giving practical assignment by biology and chemistry teachers in favour of biology could be because of ease of getting materials for biology when compared to chemistry. With respect to teachers experience the factor was more in private schools. This is unexpected as turnover rate in private schools is usually very high because of the low wages they offer. Technical support was more problematic in public schools as governments are really not engaging the services of this category of staffers at the moment.

Conclusion and recommendations

The results of this study are indicative of teachers using a multiplicity of forms of practical approaches in schools with the most predominant being **‘**Students write their reports on an investigation using data which they have been provided’. Material resources are inhibiting factors in achieving objectives of practical work. Variations were noticeable in the typology of practical approaches between public and private schools.

Based on these results, it would appear that practical work is given some place in the scheme of science teaching in Nigerian schools. Whatever typology is applied by teachers should be such that takes into cognizance teaching approaches as recommended in curriculum in place. Teachers should not wait till it is time for examinations before practical activities are carried out. This can however be strengthened by ensuring that relevant material resources are provided.

References

Abraham, I., Reiss, M.J., & Sharpe, R.M. (2013). The assessment of practical work in school science. *Studies in Science Education*, 49(2), 209-251.

Afemikhe, O. A. & Imobekhai, S. Y. (2014). ‘Nigeria’. In B. Vlaardingerbroek and N. Taylor (Eds). *Issues in Upper secondary science education: Comparative perspectives* (161-174). New York: Palm grave Macmillan.

Central Board of Secondary Education (undated). *Assessment of practical skills in science and technology Class X.* New Delhi: Authors.

City and Guilds (2003). *Guide to the assessment of practical skills in intermediate vocational qualifications.* London: City and Guilds of London Institute.

Federal Ministry of Education (2007a). *9-year basic education curriculum: basic science and technology for primary 1-3.* Abuja: Nigerian Educational Research and Development Council.

______ (2007b). *9-year basic education curriculum: basic science and technology for primary 4 -6.* Abuja: Nigerian Educational Research and Development Council.

______ (2007c). *9-year basic education curriculum: basic science for JSS 1-3*. Abuja: Nigerian Educational Research and Development Council.

Okonkwo, C. A. (2006). Curriculum trend and performance in physics at SSS level: A review. *African Journal of Historical Sciences in Education*, 2(1), 135-143.

Pollard, A., Triggs, P., Broadfoot, P., McNess, E., & Osborn,M (2000). *What pupils say: Changing policy and practice in primary education.* London: Continuum.

Tsai, M. T., & Li, Y. H. (2007). Knowledge creation process in new venture strategy and performance. *Journal of Business Research*, 60(4), 371-381.

Watts, A. (2013). *The assessment of practical science: A literature review.* Cambridge: Cambridge Assessment.