TOWARDS OPTIMAL ENHANCEMENT OF PRACTICAL WORK AND ACTIVITIES IN SCHOOL SCIENCE

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Abstract

Science and science education occupy core positions in the technological development of any nation. The duo is capable of producing skilled human resources needed for transformation into national prosperity only when there is quality. Qualitative science education requires that the mode of delivery is action-packed and learner-centered through valuable practical work and activities, and must be applied at all levels of education. The discussion paper explored ways of enhancing practical work and activities in school science regardless of the level of education; primary, secondary or tertiary. The paper navigates the pathways for achieving quality practical work with focus on the concepts of science and science education, meaning and purpose of practical work and activities, the place of the laboratory in science teaching, obstacles to good quality practical work and activities, ensuring standards in the quality of practical work and activities in school science and basics for achieving quality practical assessment.

Key words: Optimal, Enhancement, Practical work, Practical activities, School science

Introduction

Science can in simple terms be described as the intellectual, systematic and strategic attempt to explain and control the natural world. It entails dynamic and determined interaction with the universe through search and verification. Science education is unique because search and verification combine with transfer whereby scientific knowledge, skills and principles are acquired, tested and transmitted. Science education is the engine that drives science and technology. While the interplay of the trio guarantees sustainable development and global survival, the modes of science delivery play predominant roles. Science is activity and must be presented as such at all levels. It is taught through task- based and learner-centered methods giving cognizance to valuable practical work and activities. Meanwhile, only certain important practices guarantee optimal enhancement of practical work and activities in school science.

Science and Science Education Concepts

Science is the act of doing and it is more concerned with intellectual and investigative processes and activities. Science relates to developing, acquiring and controlling knowledge, skills and attitude about the natural environment, while science education involves the strategic and professional processes involved in acquiring, transferring and demonstrating science knowledge, skills and attitudes. Science education involves the in-depth study of science.

In simple perspective, science education deals with sharing science content and process with individuals, learners (children, youths and adults) or the general public and it makes one relevant in the scientific community. The field of science education mainly involves work in science content and process (the scientific method), analysis of science product, and science pedagogy. Science education leads the path and opens the gate to sustainable development (economic, society and environmental development). Through science and science education, individuals are empowered to be scientifically literate, and because the utility values are overwhelming, the trend worldwide is to produce scientifically literate citizens through science education. The foregoing thus imposes and impresses it upon Nigeria to give consideration to productive science education, and the foremost way of achieving this is by placing science teaching procedures in right perspectives.

Qualitative science education assures human and national survival and self-sufficiency. The Nigerian National Policy of Education recognizes the significance of science and places premium on effective science teaching and learning at all levels of education (FRN, 2013). The move to transform a nation into a self-sustaining economy can be achieved through science and technological growth, but a number of issues concerning functional and qualitative science education should be addressed. Evidences abound that many problems militate against the development of science education in developing countries including Nigeria. (Omotayo, 2005; Alebiosu & Ifamuyiwa, 2008; Omoregbe & Ewansiha, 2013; Okoli, Obiajulu & Ella, 2013; Jacob, 2013). However, It is not enough to dwell on problems and challenges, the concern is that science education must be taken to higher stride and due attention given to practical work. Doing quality and effective practical work is a significant index of a worthwhile science education programme and it is very critical for teachers to adopt laboratory and action-packed or activity-laden dynamic and valuable teaching methods.

Meaning and Purpose of Practical Work and Activities in School Science

Practical work is a distinctive feature of science education and it plays a key role in the teaching of evidence, provided the type of practical work is selected carefully with a clear purpose in mind. It is an attempt to describe the working of the real world around us and it helps to facilitate and improve the learning of science. It gives students the appreciation of the spirit and methods of science. Practical work serves two major functions. Firstly, it consolidates theoretical understanding and converts apparently dry and uninteresting science facts and theories into real experiences. Secondly, it develops and promotes skills and competencies of doing science.

Specifically, according to Alebiosu (2003), practical work serves the following purposes:

- Promotes long term memory in students
- Enhances pupils development of the ethical dimension of science
- Instills the spirit of collaboration and active participation in learners
- Exposes learners to scientific experiences that could ultimately help them in developing scientific attitude, skills and values e.g longing to know, questioning all things
- Trains the mind in the understanding of the world.
- Enhances the acquisition of scientific attitude, skills abilities and competencies for the effective learning of science
- Equips students with the need to face future challenges in the modern age of science and technology
- Inculcates in the student the spirit of inquiry and scientific mode of thinking.
- Consolidates teacher's thinking and learner's understanding.
- Stimulates students' interest and under-standing.
- Leads to perfection of skills of doing
- Enables the evaluation of student's learning.

Aside from these broad functions, there are specific functions and objectives of practical activities in the different school subjects. Some of these according to Alebiosu (2000) are;

In Physics, it develops experimental and problem solving techniques in ability to take records and observations, measurements and estimates with due regard to precision, accuracy and units.
In Chemistry, it familiarizes students with skills and principles in preparation, dilution and standard solutions, filtration and so forth. In Biology, it enables students obey instructions make accurate observations and drawings.

The report and proposal for strategic frame work for enhancement of practical work in school science in the UK presented by the body representing the UK's foremost science education organisations: Science Community Representing Education (SCORE) (2008), classified practical activities into three viz; core activities, directly related activities and complementary activities.

The report explained these activities with the following break- down;

Core activities include investigations, laboratory procedures and techniques and fieldwork. Directly related activities entail designing and planning investigations, data analysis using ICT, analyzing results, teacher demonstrations, and experiencing phenomena, while complementary activities are associated with science related visits, surveys, presentations and role play, simulations including use of ICT, models and modeling, group discussion and group based text-based activities. (SCORE, 2008).

The Place of Laboratory in Science Teaching

The laboratory is a major resource for science teaching. It is an integral part of any school where science is studied as a subject (Alebiosu, 2003). The laboratory is a place of experimentation, and is simply any place where scientific investigation takes place. A make shift or temporary place set up to meet certain needs and requirements of science teaching at particular time can serve as laboratory. E.g students may be taken for field trip and in the process engage in serious and complex investigations. Such an environment at that particular time is regarded as laboratory. Laboratory activities have been used in science teaching to support theoretical science instruction over the years.

Certain facilities are most essential if the school science laboratory is to be functional, relevant and productive. Apart from the adequacy of the laboratory human and material resources, there are required specifications for the design of each of the physics, chemistry, biology or any other science subject's laboratory. According to Alebiosu (2003), factors to be considered for ease of and efficiency in laboratory practical work include; the class, size and age group of the student, the nature of the students' interests, mood, readiness etc, the nature of experiences, the time slated for the practical activity and, the form in which the practical work is done. Teachers and students must be protected from internal and external hazards, accidents or crises in the laboratory hence rules and regulations must strictly be adhered to while improvisation should be taken seriously. The specific roles and expectations of the teacher among others entail that he/she;

- Plans practical work with specific learning objectives in mind.
- Specifies outcomes
- Practices and masters the activities ahead of the class (behind the scene).
- Provides outlines and needed materials for the exercise
- Guides students through the activities

Well planned and effectively implemented practical work is very potent at stimulating and engaging students' learning at varying levels of inquiry; challenging them mentally and physically. It is expedient that the teacher gives cognizance to the following specific activities for optimal enhancement of practical work and activities in school science.

- Actively participating in the class such as; moving round the class, ensuring students ask questions to be sure they understand what is being done, encouraging and helping students and so forth.
- Ensuring the class recognizes the purpose of the experiment being performed.
- Giving full guidance on the procedure of the experiment such as handling of apparatus, observation, description, measuring, taking readings, graphs, calculations etc.
- Conducting experiments in such a way as to make students think and talk.
- Instilling the spirit of accuracy in students while experiment is being conducted
- Making sure conclusions are drawn only from the evidence obtained from the experiment.
- Controlling the appropriate use of simple and complex apparatus as required.
- Developing resourcefulness in learners such that they can design their own experiments.
- Encouraging and guiding students to apply the purpose of the experiment and experiences derived to everyday life situations, problems and challenges.
- Demonstrating serious Commitment and confidence

Obstacles to Good Quality Practical Work and Activities

Effective science teaching involves a creative interplay of experiments, observations and theoretical inference, hence practical activities cannot be marginalized in schools. There is outcry on impediments to the ability to achieve good quality practical work and activities in school science. Related literature particularly emphasized issues relating to unavailable necessary infrastructure and weak assessment procedures (Alebiosu & Bamiro, 2007; Okoli, Obiajulu, & Ella, 2013; Omoregbe & Ewansiha, 2013, Cossa & Uamusse, 2015) and that weak assessment procedures particularly confront quality practical work in developed countries (Shiksha, n.d; SCORE, 2008; Abraham & Saglam, 2010; Cambridge News-Department of Education, 2013).

Main actors in the barriers to effective practical work are as presented in figure 1.

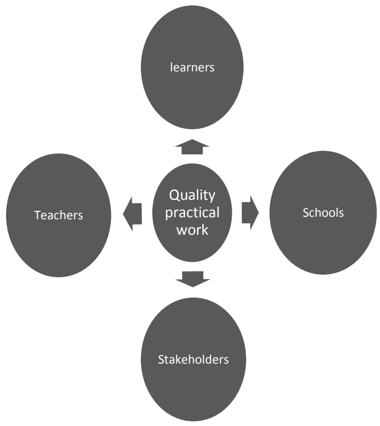

Figure 1: *Barriers to Effective practical work Issues emanating from these main actors can be teased out as presented in table 1.*

Table 1: Classification of Barriers to Quality Practical Work in Science

Stakeholders	**Teachers**
Inadequacy of resources and facilities	Teachers' incompetence
Inadequacy of text materials	Lack of professional expertise
Insufficient funding	Teachers' non diligence
Lack of home support	Lack of motivation for science teachers
Parent's non- challant attitude	Job dissatisfaction
Parent's level of education	Inadequate in-service training
SCHOOL	LEARNERS
Lack of school support & short school time	Insufficient student cooperation
Large class size	Shallow student's understanding of procedures
Limited amount of time slated for science lessons	Lack of student's interest
Wrong scheduling of time in the school time table	Student's fear of touching materials
One shot practical examination syndrome	Student's carelessness in handling resources
Unclassified assessment procedures	Peer influence
One-time assessment procedure practices	

Ensuring Standards in the Quality of Practical Work and Activities in School Science

Science is a practical-oriented discourse, which driving force is science education. Practical work and activities allow students to share their scientific understandings and explanations with one another. It is imperative for science education to give significant consideration to providing opportunities that are rich in practical activities. The importance of practical work is widely accepted and it is acknowledged that quality practical work promotes the engagement and interest of students as well as developing a range of skills, science knowledge and conceptual understanding. (SCORE, 2008).

The value of practical work and activities lies in its being used to accomplish variety of cognitive, affective and psychomotor objectives. Cognitive objectives refer to learning of scientific concepts, developing problem solving skills and increasing the understanding of scientific methods while psychomotor objectives refer to developing skills and performing science investigations, analyzing data, communicating and skills in working with others. Affective objectives refer to enhancing motivation towards science and positive perceptions of ability to understand the environment. (Alebiosu, 2003).

In Nigeria, the Universal Basic Education Commission (UBEC) has integrated some positive measures into existing practices at the Basic education level. Teaching texts and workbooks are loaded with practical activities that can easily be carried out in the class (FGN/UBEC, 2014). This has significantly revolutionized the study of Junior secondary school science. For example; to teach the topic "sense organs", the teaching text specified the following stepwise activities;

"Make a small dot on a piece of white paper, place the paper on the table, stand back two meters away from the paper, use a meter rule to point to the dot with your two eyes open. Repeat the activity with one eye open. Explain what you notice in the two cases"

(FGN/UBEC, 2014. pg 57).

The new joint schemes of work for senior secondary schools in Oyo State is very comprehensive, detailed and explicit in weekly teaching exercises, content and practical activities. The document categorically stated the practical activities for all the learning materials in a tabular form. (Oyo State Government, n.d). It is almost certain that similar documents are used in other States. Nevertheless, it is pertinent, logical and obvious that certain conditions are important and salient initiatives have to be put in place in order to entrench standards in practical work and activities in school science. Some of these include;

1. Enforcing improvisation
2. Strong commitment to high quality practical work among teachers, technicians and stakeholders
3. Teachers and students should be able to refer to common materials supporting practicals.
4. Using ICT driven strategies and technology -enabled pedagogy.
5. Giving students chances to evaluate their individual actions
6. Mentoring of inexperienced teachers
7. Good knowledge and practice of health and safety measures.
8. Supportive leadership and management
9. Adequate supply of technical support
10. Attaching importance to professional expertise in practical work
11. Giving high priority to resource allocation and supply.
12. Provision of adequate teaching time frame.
13. Ensuring stakeholders remain informed through research and evidence
14. Employing appropriate assessment pract-ices

Basics for Achieving Quality Practical Assessment

There is no doubt that assessment practices in science practical work calls for transformation because current assessment practices both damage and restrict practical science. Assessment of practical work and activities and the assessment of skills in practical work and activities are not the same. Prevailing assessment procedures align with the assessment of practical work which tends to concentrate on a written product of an inquiry produced by an individual. The processes of constructing arguments, planning, observing and formulating conclusions are neglected. There is the need to align the aims and objectives of doing practical work with the actual practical activities and assessment practices and procedures. Quality assessment would facilitate quality teaching in that assessment outcomes afford the teacher the opportunity to appraise how well the students have learned specific learning material in the context of the objective of doing the work as well as how effectively he/she (the teacher) performed.

The need to overhaul assessment procedure of practical science has received the attention of science educators and researchers globally. Many assessment procedures in Nigeria have been reported to be faulty because the measure of skills are side tracked (Alebiosu, 2000; Omotayo, 2005; Afemikhe, Imobekhai, & Ogbanya, 2015). Tan & Towndrow (n.d) expressed displeasure with assessment procedure in Singapore schools and recommended peer digital video evaluation mode. The study advocated "giving students a voice in practical science assessments". Abrahams & Saglam (2010) studied teachers' views on practical work in secondary schools in England and Wales and recorded teacher's notable support for Science Investigation (Sc1) format assessment criteria that cover a wide range of assessments.

It is in the light of global moves to reform modes of practical assessment in schools that Abrahams, Reiss & Sharpe (2013) reviewed Direct Assessment of Practical Skills (DAPS) and Indirect

Assessment of Practical Skills (IAPS) and recommended the former. The Council for Science and Technology U.K commented on the loss of laboratory experiments in school science while advocating for reforms in practical work assessment as follows:

> "The current methods of assessing practical work in science based on continuous assessment and internal marking do not work. They fail in both of their main objectives: to provide a fair assessment and to encourage and promote good quality practical work in schools. They are time consuming, prescriptive and repetitive, and they undermine both the relationship between teachers and pupils and the professional integrity of teachers. They encourage 'teaching to the test'."

(Cambridge news, 2013. Retrieved from http:// www. cambridge-news.co.uk/)

In Nigeria, the most common assessment mode is the paper and pencil test or the alternative to practical mode. Even the certificate examinations that claim to do real test of practical is the 'one-shot' practical examination that only uses 'one-time' practical assessment. It is the 'teaching to the test' type. An example of a practical question is shown;

Question:

A student used magnesium oxide to prepare magnesium nitrate. The magnesium nitrate was then heated to re-form magnesium oxide. The object of the experiment was to determine whether the mass of the magnesium oxide produced was the same as the amount used initially.

Some magnesium oxide was put into a weighed evaporating dish. The dish was re-weighed.

Mass of dish + magnesium oxide = 14.70g

Mass of dish = 8.90g

a). Calculate the mass of magnesium oxide used

Answer: *The mass of magnesium oxide = 5.8g*

b). An acid was slowly added until all the magnesium oxide had dissolved. Magnesium nitrate was produced. What acid was produced?

Answer: *Tetraoxonitrate V acid.*

c). The solution was evaporated to dryness and the resulting solid was heated in a fume cupboard. The following reaction took place.

$2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$

After cooling, the dish was weighed. It was then heated again, cooled and re-weighed. The final mass of the dish contents was 14.40g.

i). Why was the heating done in a fume cupboard?

Answer: *Nitrogen IV oxide (NO_2) is a poisonous gas.*

ii). Why was the dish reweighed?

Answer: *To ensure decomposition was complete.*

iii). Calculate the mass of magnesium oxide obtained.

Answer: *14.40 - 8.90 = 5.5g.*

d). Using your answers to (a) and (c) (iii), calculate the percentage yield of magnesium oxide.

Answer: *5.55/5.8 X 100% = 98.8%.*

c). Suggest one reason why the experiment did not produce the same amount of magnesium oxide as was at the beginning of the experiment.

Answer: *Some of the magnesium oxide could have been lost during heating*

(Culled from: Ugenyi, 2011).

The illustrated example shows that knowledge-based questions are translated into practical activity questions and students regurgitate the experiences gained from the teaching phenomenon. There is no provision for interaction and practice with real materials and with one another. In addition, there is no room for demonstration and measure of practical skills. Another example is shown in Figure 2. Diagram illustrating the experiment is given and questions are asked.

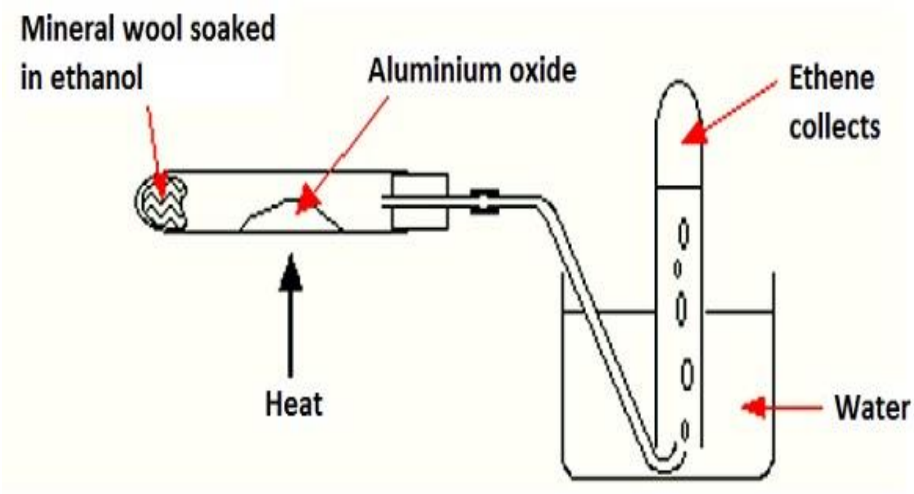

Figure 2: *Dehydration of ethanol to form ethene*

Question:

Ethanol vapour is dehydrated over a heated catalyst (aluminium oxide) to produce ethene

a). What is the purpose of the mineral wool?

Ans: *For lagging the test tube to prevent it from cracking*

b). What is the type of chemical reaction called?

Ans: *Catalytic cracking*

c). Give a test for ethene

Ans: *Add a few drops of bromine dissolved in tetrachloromethane (CCl_4); the bromine solution is decolourized*

d). What precaution should be taken in the experiment when the heat is removed?

ANS: Ethene should be collected quickly so that petroleum products of lower boiling points do not contaminate it. Hence the delivery tube must be removed before the heat is turned off.

(Adapted from: Ugenyi, 2011).

Alebiosu (2003) classified assessment forms as follows;

i). Direct observation and reporting using assessment schemes in which various tasks, skills and skill areas are identified and highlighted to be observed and graded during practical work. E.g open –ended schedule, intermediate schedule and the check-list schedule

ii). Written reports in which students write reports on completion of the investigation and submit for teachers to assess.

iii). Paper and pencil test in which questions are asked without recourse to the demonstration of particular skills and attitudes, but the focus is the skills in the cognitive domain.

It was garnered from literature (Reiss, Abrahams and Sharpe, 2012), that a merger of direct observation and reporting using assessment schemes and written reports constitute two new categories; Direct Assessment of Practical Skills (DAPS) and Indirect Assessment of Practical Skills (IAPS). The two examples earlier illustrated in the paper align with IAPS form and is the more dominant assessment mode.

According to Reiss, Abrahams and Sharpe (2012), DAPS, refers to any form of assessment that requires students, through the manipulation of real objects, to directly demonstrate a specific or generic skill in a manner that can be used to determine their level of competence in that skill, while IAPS relates to any form of assessment in which a student's level of competency, again in terms of a specific or generic skill, is inferred from their data and/or reports of the practical work that they undertook. The researchers' comparison of the two modes is presented in table 2;

Table 2: Comparison of DAPS and IAPS

	DAPS	IAPS
What is the principle of the assessment?	A student's competency at the manipulation of real objects is directly determined as they manifest a particular skill.	A student's competency at the manipulation of real objects is inferred from their data and/or reports of the practical work they undertook
How is the assessment undertaken?	Observations of students as they undertake a piece of practical work	Marking of student reports written immediately after they undertook a piece of practical work or marking of a written examination paper subsequently taken by students
Advantages	High validity, encourages teachers to ensure that students gain expertise at the practical skills that will be assessed.	More straightforward for those who are undertaking the assessment.
Disadvantages	More costly, requires teachers or others to be trained to undertake the assessment, has greater moderation requirements	Lower validity, less likely to raise students' level of practical skills

Source: Reiss, Abrahams and Sharpe (2012)

To ease the use of the direct assessment of practical skills (DAPS), the use of a scheme is more convenient and appropriate and hereby suggested. Such is the scheme developed by Alebiosu (2000), presented in Table 3.

Table 3: Skill Area and specific tasks

Skill Area	Specific Tasks
Planning and Designing	Ability to plan instructions and select techniques. Planning and designing procedures in the experiment clearly, concisely and correctly
Manipulative skills	Ability to work methodically, manual dexterity, confidence, obedience and orderliness in carrying out activities within stipulated time.
Observing and Recording	Ability to promote, describe, report and record observations and measurements, draw, analyse and present results precisely, correctly, neatly and clearly within stipulated time
Interpretation of data and Formulation of generalizations	Ability to transform results precisely and correctly. Accuracy in experimental data, units, decimal places, formulae, equations of reactions and calculations. Neatness and accuracy of graphs, lines, scales, diagrams, drawings and labels. Ability to draw valid conclusions from observations made.
Application	Ability to predict, evaluate and infer from results obtained as well as the ability to state and explain necessary precautions and possible improvements for the experiment.
General attitude to work, orderliness and tidiness	Students self-confidence, interest, enthusiasm and orderliness to work within stipulated time and do it well.

***Source:** Alebiosu (2000)*

Questions are drawn to cover these practical skill areas and the teacher assesses them by observing students and awarding scores on their actions and performances.

The following should be considered in the planning of quality practical work assessment in school science:

- There should be access to rich resources (human and physical).
- Give attention to the cognitive, affective and psychomotor domains.
- Incorporate feedback. Science learning and retention are encouraged and enhanced when students receive feedback about their learning progress.
- It is strictly objective and content directed.
- Focus strictly on specific and precise skills and activities.
- It is not examination driven.
- It has sufficient time frame. The time given for assessment is adequate
- Single out every aspect of the activity.
- Consider learner individual differences and learning difficulties
- Embrace a measure of student's individual and collaborative work
- Do not discriminate against gender

Conclusion

Students learn better when they experience science for themselves, not as abstract material for 'rote learning' but as real experiments to be designed, executed and evaluated. Science is doing. The old adage 'Tell me and I shall forget, show me and I shall remember, involve me and I shall understand' holds true. It is in view of this that practical work is considered an essential component of school science at every level of education.

Schools should be sensitive to the efficacy of practical work and activities, procedures of doing them and assessment forms. Practical work and activities in science should be embedded in the professional life of the science teacher and should be conducted appropriately. The teacher, at any level whatsoever has no justification for not arranging practical experiences for students or denying them of rich and proper practical experiences. The survival of any nation truly depends to a large extent on development in science and technology, but it is a function of the strength of science education.

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