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MICROSCALE EXPERIMENTS IN SENIOR SECONDARY SCHOOL PRACTICAL CHEMISTRY: A PANACEA FOR IMPROVING STUDENTS' ACHIEVEMENT AND REDUCING COST

Ifepe N. U.[1] & Anekwe C. E.[2]

Department of Science Education, Nnamdi Azikiwe University, Awka[1]

Department of Science Education, Chukwuemeka Odumegwu Ojukwu University, Uli[2]

Email: ifepenjidekauche@gmail.com[1] & akristo116@gmail.com[2]

Abstract

This paper examined how the integration of Microscale experiments in senior secondary school practical chemistry could serve as a panacea for improving students' achievement and reducing cost. Chemistry is a branch of science which helps in the understanding of the universe. This is effectively achieved using the theoretical and practical aspects of Chemistry. The poor achievement of Chemistry students generally and in practical aspect of the subject specifically have reinforced the vigour with which practical work is being pursued in the implementation of senior school Chemistry curriculum. However, the efforts appear to be thwarted by the problem of lack of equipment, facilities and reagents for the teeming population of Science students in Nigerian schools. The use of Microscale experiments in teaching of practical Chemistry in senior secondary school was advocated. This innovation involves conducting chemical experiments on a much smaller scale with the use of minute quantities of reagents, modified techniques, equipment and instruction. The benefits, potentials and possible limitations of Microscale experiment were also analysed. Finally, based on its cost-effectiveness, user friendliness, safety, scientific literacy and efficiency, Microscale experiments were recommended to Chemistry teacher for use in implementation of practical Chemistry lessons. Science teacher educators were also encouraged to buy into the strategy and include it in teacher education programmes in the colleges and faculties of education as well as in retraining activities. Also, the government should create or invest in the production of micro kits for chemistry and other science-related subjects.

Keywords: Microscale, Experiments, Chemistry, Science.

Introduction

Chemistry is a branch of science that deals with the study of matter, its structure, composition, properties and the changes it undergoes (Ojukuku, 2010). Chemistry provides the major part of manpower needs of a nation. Chemistry is essential for understanding much of the natural world and central to many other scientific disciplines, including astronomy, geology, biology and medicine. The important aspect can be seen in modern medicine, manufacturing industries, food, etc. (Science Rising, 2016). It explains life and industrial processes such as cooking, medicine, cleaning and environmental issues. The activity-based nature of Chemistry as one of the core sciences is in line with minds-on and hands-on activities that science portrays. This agrees with the position of Holman (2013) on welcome trust, that hands-on practical work is seen as a vital part of school science all over the world. The knowledge and understanding of chemistry help man make informed decisions about many issues that affect him, his community and the world. Therefore, Chemistry is important in our everyday life and our collective understanding of both the biological realm and physical world.(Averill and Eldredg,2017). The importance of Chemistry in economic, scientific and technological development cannot be overemphasized. Hence, a solid foundation is needed for an effective and efficient chemistry education especially in our secondary schools.

Chemistry is one of the subjects in school that is of utmost importance for the development of an economically and technologically sound country. The teaching of chemistry in senior secondary school is expected to enable students acquire basic theoretical and practical knowledge, acquire basic STEM knowledge and skills, develop reasonable level of competence in ICT applications that will engender entrepreneurial skills, apply skills to meet societal needs of creating employment and wealth, be positioned to take advantage of numerous career opportunities offered by chemistry, be adequately prepared for further studies in Chemistry.etc,(FME, 2011). Despite these laudable objectives of chemistry at secondary school level, the students' achievement in both internal and external examinations has been a thing of concern to major stake holders in education particularly chemistry educators. In line with that, Adeoye and Abimbola (2016) lamented that the yearly dwindling of Nigeria senior school students' achievement in external examination such as the West African senior school certificate examinations (WASSCE) has been an issue of concern to all and sundry. Carter (2016) referred to students' achievement as a measure of the amount of academic content a student learns in a determined amount of time.

Achievement is an important factor that has been identified to be subjective by teacher qualities. Academic achievement refers to the accomplishment of academic goals or the extent to which a student, teacher or instructor has achieved the stated educational objectives (Aniaku, 2013). Academic achievement is generally used to determine how well an individual can defend, recall and assimilate the knowledge of what they have learnt. Students' academic achievement is linked to students' completion of a task after much effort must have been utilized. Aniodoh and Egbo (2013) showed concern towards the problem of students' persistent underachievement in chemistry. The researchers stated that the unimpressive academic achievement in chemistry at the secondary level in Nigeria if not nipped in the bud, will have adverse consequences on the students and the society at large, given the importance of chemistry in Nigeria's scientific and technological development.

Available evidence from West African Examination Council (WAEC Chief Examiner's Report, 2011-2016) on students' achievement in chemistry showed a percentage credit pass of 49.54%, 43.13%, 72.34%, 62.49%, 60.60% and 57.74% respectively. This indicates that during the years reviewed, the average percentage credit pass was 57.64% which is still on a lower side. Regrettably, in 2018, the candidates' mean score was 24 which are worse than that of 2017 with a mean score of 26. This implies that in as much as the set of 2017achieved slightly higher than those of 2018, it could be deduced that the achievement of the two sets of students is below average and too low to be termed good achievement.

The Chief Examiner stated some weakness that affected the students' achievement most of which are caused by inadequate experimental experiences. They include; non-adherence to instructions especially concerning stepwise test, cancellation/alteration of titre values to agree with that of their teacher, arithmetical errors in volume of acid used, poor mathematical skills, poor knowledge of S.I units of mass concentration and molar concentration, test on solids instead of solutions, lack of knowledge of laboratory set up and names of laboratory apparatus, poor knowledge of solubility of gases in water, assigning wrong charges on ions, inability to make simple inference from observation recorded, recording of volumes of burette to one place of decimal instead of two places of decimal, (WAEC Chief Examiners' report 2011-2018).

From the Chief Examiner's report, it is obvious that poor practical chemistry, precisely, acid-base titration and identification of ions highly contributes to students' poor achievement. In solving the issues related to experiments, it was suggested that students should be exposed to experimental work. However, studies have reviewed that most schools are faced with poor laboratory conditions or absence of laboratory conditions or absence of laboratory, chemical hazards, risk and environmental pollution (Tesfamariam, Iykknes and Kvittingen 2014; Onasanya and Omosewa, (2011); Njoku and Ezinwa, 2014; Edomwonyi and Avaa, 2011). These make the chemistry teachers resort to teaching Chemistry more theoretically than using practical activities. Chemistry has always had its practical side because it is an experimental science. Whatever was learnt about substances and their behavior during the past centuries came from observation, practical experience and analytical techniques. According to Madhu (2018), practical chemistry can be grouped into qualitative and quantitative analysis. Qualitative analysis gives the presence or absence of different chemical components in a sample. It indicates different elements, or groups of elements such as functional groups, e.t.c. present in the sample. Therefore, a qualitative analysis of a sample can be used to determine whether a particular component is present in a sample or not. However, this analysis does not provide any information about the quantity of that chemical component. The qualities in the sample that are often considered in the analysis are colour, odour, melting point, boiling point, reactivity, precipitation, etc. Whereas quantitative analysis in chemistry gives the amount of different chemical components present in a given sample. The quantity can be given as a mass, volume, concentration, relative abundance.

Chemistry educators believe that practical chemistry is indispensable in chemistry teaching and learning process (Achimugu, 2012). The experiment allows the students to explore their environment and at the same time construct meaning from the experiences gotten from interaction with the environment. Also, the practical activities stimulate curiosity, acquisition of manipulative skills, imagination, critical thinking, etc., it keeps the lessons exciting and captivating and helps in understanding of the theoretical aspect of chemistry.

Muhammad (2013) speaking on the importance of practical in all science subjects of which chemistry is one of them, maintained that it is very important because it serves as the backbone of sciences. Notwithstanding the implication of practical chemistry, there have been challenges in carrying out the activities. Some factors have been attributed to the causes of inadequate practical activities in schools. High cost of equipment and chemicals, this might lead to ill-equipped laboratory or absence of laboratory in some schools, chemical hazard risk and environmental pollution, poor teaching method, contributes to inadequate practical activities (Edonwonyi & Avaa 2011; Onasanya & Omosewo (2011); Njoku & Ezinwa 2014; Tesfamariam, Lykknes & Kvittingen, 2014).

Chemistry is a physical and practical subject, not just theory, and most schools and colleges do not have adequate equipment to do the physical and practical experiments (Mylab, 2015). Tesfamariam, Lykknes and Kvittingen, (2014), further explained that practical work requires more time and the presence of qualified and experienced teachers and technical assistants; as a result, it is frequently missed from the real curriculum in schools around the world, especially where resources are scarce. Onasanya and Omosewo (2011) reported that there were inadequate resources for the teaching of chemistry and other related science subjects in secondary schools in Nigeria and that where there are few resources in good condition, the challenge will be in limited number compared to the number of students that need them. Chemistry as an inquiry-based science is resource-based. To this end, to achieve the desired outcome, adequate resources are required. Considering standard experiment for quantitative analysis (acid-base titration), it requires the use of standard equipments like pipette of 20/25cm^3 for a babe, burette of 50cm^3 for acid, beakers and conical flasks of various volume, test tubes, droppers, etc. This demands that each student will use at least 100cm^3 of the acid and 50cm^3 of the base. In the standard experiment, it turns out that the chemicals will be used in a large quantity, while the apparatus will be in large scale and expensive (Igoro, Adjivon, 7 Oyelakin, 2011; Pesimo, 2014; Tesfamariam, Lykknes & Kvittingen, 2014). In such situation, the inadequacy of the resources will hinder the standard experiment or resort to the grouping of the students. Grouping the students, on the other hand, might hinder opportunity of active participation by all students as there might be some students that will dominate the activities (Njoku as cited in Nzewi 2010) which may also lead to poor achievement.

Since experimental work involves high consumption of expendables, use of equipment and apparatus which in most cases are costly, an alternative method that may enhance students' practical activities at an affordable price should be considered. The use of Microscale experiment in teaching and learning of chemistry will go a long way to achieving effective teaching and learning of chemistry especially in schools that lack adequate funding of the laboratory equipment, apparatus and expendables without affecting the experimental procedures and results.

Microscale experiments also referred to as small scale experiments is the process of experimenting by reducing the size, mass and volume of experimental quantities (Caro, Farmer and Wilson as cited in Igaro, Adjivon and Oyelakin, 2011). This is done by the use of micro kits without affecting the experimental procedures and results when compared with the macro counterpart and without jeopardizing the overall learning achievement. Many of the experiments associated with general chemistry can be carried out in simpler equipment like injection bottles, dropper bottles, syringes, well plates, plastic pipettes which are cheaper than the traditional glassware in a laboratory. Research and Development in Mathematics, Science and Technology Education (RADMASTE) Center, University of Witwaterstand, South Africa, introduced the use of micro kits to address the problem of science practical work in schools of disadvantaged communities in the 1990s. Mylab small scale science kits were also designed in South Africa in 2001 by Corried Toit and his colleague (Tesfamariam, Lykknes, Kvittingen, 2014). Maylab small scale kits are purpose-built small scale apparatus to aid teachers and learners to enjoy science subjects through the hands-on use of the kits and by carrying out the experiments themselves (Mylab, 2015). One that experiments using the kits can experiment in a large scale laboratory confidently. Properties of the small scale chemistry kit include; - all the experiments are done with small amount of chemicals thereby cutting costs, pollution and the danger of explosions; the kits can be used in ordinary classrooms, very little storage space is needed and the kit is a cost-effective alternative to a full-scale science laboratory. This enables the expansion of the laboratory experiences of students in large classes and introduces laboratory work into institution too poorly equipped for standard type work.

Teaching chemistry at Microscale level is an innovative teaching strategy that does not just save time and effort but solve problems and issues on the high cost of chemicals and apparatus (Pesimo, 2014). Wilson as cited in Igaro, Adjivon and Oyelakin, (2011), introduced a technique whereby the volume size or mass size of chemicals is scaled down thus, ensuring in the long run that the quantity of material employed by a student for a macro-experiment is equivalent to the amount employed by at least ten students for micro-experiment.

Microscale experiments reduce the amount of chemicals necessary to perform experiments to a fraction of what was historically used. In addition to decreasing the quantities of chemicals purchased and amount of chemicals waste generated, Microscale techniques have proven to be safer and more cost-effective than traditional experiments, (Pesimo, 2014). It can reduce the cost of laboratory supplies and minimize chemical waste without affecting the learning outcomes of the students. Microscale experiments provide the students' the opportunity to discover new concepts at minimum cost and wastage of materials. Nevertheless, one should be careful in the bid to cut cost as sustainability is very important to avoid temporary savings and permanent damage. This paper believes that Microscale experiment will positively affect the senior secondary school students' achievement and provide necessary practical experience required for solving life problems.

Statement of the Problem

The Chemistry curriculum aims at producing active learners. To this end, students are given ample opportunities to engage in scientific investigations through hands-on activities and experiments. The inquiry approach, incorporating thinking skills, thinking strategies and thoughtful learning, should be emphasized throughout the teaching and learning process. The science laboratory has always been regarded as the place where students should learn the practical aspect of chemistry and the process of science. Ideally, each student should be wholly responsible for conducting the experiments from start to finish. While practical work in Chemistry is considered essential in chemical education, it is frequently absent from the real curriculum in schools around the world. However, inadequate exposure to practical chemistry has been attributed to students' poor achievement in chemistry among secondary school students. Available evidence from West African Examination Council (WAEC Chief Examiner's Report, 2011-2016) on students' achievement in chemistry showed a percentage credit pass of 49.54%, 43.13%, 72.34%, 62.49%, 60.60% and 57.74% respectively. This indicates that during the years reviewed, the average percentage credit pass was 57.64% which is still on a lower side. Regrettably, in 2018, the candidates' mean score was 24 which are worse than that of 2017 with a mean score of 26. This implies that in as much as the set of 2017 achieved slightly higher than those of 2018, it could be deduced that the achievement of the two sets of students is below average and too low to be termed good achievement.

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Notwithstanding that it is possible to perform Microscale experiment in Chemistry, it is important to ascertain its effectiveness in learning outcome. Therefore, there is a need to provide an opportunity that will engage all students in the learning process. However, standard experiment due to its expensive nature might not provide such opportunity especially in schools that lack adequate laboratory or have an ill-equipped laboratory. The use of Microscale experiment in chemistry, on the other hand, provides opportunity for each student to actively participate in practical chemistry thereby offer the chance to improve the learning outcome and better understanding of concepts. Hence, the paper seeks to examine how the integration of Microscale experiments among senior secondary school students could improve students' achievement and reduce cost in practical chemistry.

Issues Relevant to the topic

Standard experiment or microscale experiment: a panacea for improving students' achievement and reducing cost.

A Standard experiment in chemistry is carried out on a large scale in the laboratory. The chemicals to be used are always in large quantity, and the apparatus are large scale and expensive (Pesimo, 2014). It requires the use of standard equipment such as pipette of $20/25cm^3$ for base and burette of $50cm^3$ for acid among others (Onasanya and Omosewo, 2011). Hence, each student is expected to have at least $150cm^3$ each of the acid and base for an experiment. This is not achievable because of inadequate resources in most of the secondary schools in Nigeria which includes Anambra state. Thus, teachers resort to grouping of the students. This may hinder the active participation of students in the learning process and may affect achievement and acquisition of science process skills (Njoku as cited in Nzewi, 2010).

On the other hand, Microscale experiment in chemistry is carried out on a reduced scale quantity of chemicals. Positive difference in examination result can be increased by doing science and then learning science of which microscale experiment can ensure (Mylab, 2015). Microscale chemistry experiment uses small quantities of chemicals and simple equipment.

Advantages of Microscale Experiment

- Reducing costs

- Reducing hazards and allowing many experiments to be done quickly and sometimes outside of the Laboratory (STEM, 2016).
- The use of Microscale experiment ensures that all students are engaged in the practical work as scaled-down materials are used.
- Microscale experiments maintain students' interest towards a subject, increase the possibility of science inquiry, hands-on activities, opportunities for students to practice and hence promote active participation of learners during teaching and learning (Orna, 2010).
- Microscale experiment in chemistry as an exploratory approach in teaching of science which can lead to the students' high level of thinking and manipulative skills (Pesimo, 2014).
- Using Microscale equipment and procedures means that chemicals are needed in very small quantities, which are safer to work with and easier to dispose of properly.
- Microscale experiment also makes it economically feasible to do experiment with very expensive chemicals, such as gold, platinum, and palladium salts.
- Reduced reliance on intensive ventilation systems.
- Easy to use and environment-friendly (Poppe, Markic & Eilks, 2011).
- Enhances students' understanding of scientific concepts.
- Help address many of the challenges that teachers face when planning practical work including the shortage of equipment and chemicals, lack of laboratory space, lack of laboratory assistants, shortage of time, and lack of confidence by teachers (Orna, 2010).

Disadvantages of Microscale Experiment.

According to Abdullah, Mohammad and Ismail (2009), the following are the limitation of Microscale experiments.

- Difficulties in getting accurate results for quantitative experiments
- Problems in handling some of the apparatus
- Difficulty in seeing what is happening during an experiment. For example, you may need a magnifier to examine a precipitate (Thompson, 2008).

Microscale experiment can be applied in teaching and learning of chemistry by the use of micro equipment. In using the micro equipment for experiments, the volume of chemicals used is greatly reduced while the equipment used is micro equipment which is cheaper than the standard ones. For instance, in volumetric analysis, the standard experiment requires that each phase of the experiment will utilize not less than 100-120cm^3 of the acid and base 75-100cm^3 of the base while in Microscale experiment, each phase of the experiment will utilize not more than 10-20cm^3 of the acid and 8-10 cm^3 of the base. It implies that the quantity of acid and base required to carry out one phase of standard solution can be used to perform several phases of Microscale experiment. This will make it possible for the experiment to be carried out where there is a lack of adequate materials/resources. Where resources are available, the teaching and learning of science will be based on practical activities and has the students experimenting, solving problems, discussing with each other and are involved in hands-on activities. This approach stimulates curiosity, imagination and critical thinking. It keeps the lessons exciting and captivating. Validity of the concepts learned by the students can be tested by experimentation. This satisfies the basic human desire of the knowledge of what, how and why things (Mallick, 2012). Microscale experiments enhances participatory learning which makes learning accessible and offers open participation, unbounded progression, through different stages of achievement (Sen,2012).

The focus of activity is on wider, long term goals and also the immediate objectives of that particular activity. Sen (2012) stated that learning begins at a place which participants can understand, relate to and get involved in. Success lies in offering opportunities to each individual so that transitions are understood and supported ensuring progress towards more complex or difficult tasks leading to deeper levels of trust and responsibility. Fatokun, Egya, and Uzoechi (2016), stated that the conventional method does not encourage meaningful student-teacher, student-students and student-material interaction. It also hinders activities for developing scientific reasoning and skill processes. The researchers added that chemistry lessons should be activity packed, because merely teaching the chemical concepts in the class may not be enough to achieve the desired mastery of the concepts. Omilani, Ogunleye, Modupe and Okoduwa as cited in Omilani, Ochanya, and Aminu, (2016) also maintained that chemistry at the senior secondary school level as recommended by the curriculum should be taught as an experimental science irrespective of laboratory inadequacy and availability. Therefore, the use of alternative method like Microscale experiments which promotes direct experiment, participation at reduced cost is important.

Significance of the Study

The paper has both theoretical and practical significance. Theoretically, the study is anchored on these theories namely: John Dewey's learning theory (1916), Jean Piaget constructivist theory (1967) and Lev Vygotsky constructivist theory (1962). These theories stressed active participation of the students in teaching and learning processes, hence, the theories could be strengthened by the findings of the study.

Dewey views teaching and learning process as a situation where the students are engaged in hands-on activities. Dewey believes that students learn by actively participating in learning experiences. For Dewey, learning by doing enables students to develop problem solving skills and consequently apply it in their future lives. Microscale experiment gives students more chance to perform experiment and encourages students' interaction with the environment, hence giving them the opportunity to learn by doing. Therefore, the paper advanced the theory of learning by Dewey.

Piaget asserts that learning occurs by active construction of meaning, rather than by passive recipients. Piaget's theory of constructivism argues that people acquire knowledge and form meaning based upon their experience. Piaget further stated that two of the key components which create the construction of an individual's new knowledge are accommodation and assimilation. Assimilating causes an individual to incorporate new experiences into the old experiences. This causes the individual to develop new outlooks, rethinks what were once misunderstandings, and evaluate what is important, ultimately altering their perceptions. Accommodation, on the other hand, is reframing the world and new experiences into the mental capacity already present. Individuals conceive a particular fashion in which the world operates.

These experiences can only be possible when students are engaged in minds-on and hands-on activities and Microscale experiment offer the opportunity for all hands to be on deck during teaching and learning. The findings of this work, therefore, could form a base that encourages students' participation in teaching and learning, thereby, advancing the theory.

Vygotsky believes that learning occurs through participations in the social or culturally embedded experiences and that students should be engaged in meaningful experience as the essence of learning. Microscale experiment ensures that students are engaged through learning activities that serve as interactive bridges to get them to construct and interpret information on their own understanding. Therefore, the work could advance the social constructivist theory by Vygotsky.

Practically, the findings of this study could be of great benefits to the students, teachers, researchers, government and education policymakers. The findings of this study will provide the students more opportunity to perform experiments, which makes active participation in the teaching and learning process possible and consequently lead to high level of thinking, acquisition of scientific process skills and enhancement of academic achievement, hence eliminating rote learning and memorization. This is obvious because Microscale experiments involve the active participation of the learner and are capable of arousing the curiosity of the learner as the learner manipulates certain practical skills. This will be achieved when copies of the paper are made available in the school libraries, and on-line.

To the teachers, the findings of the study will solve the teachers' need for instructional materials. This will be achieved through workshops, periodic training of the teachers, researcher's participation presentation of papers based on the study in conferences and publishing the work as articles in journals.

The findings of this study will add to the body of knowledge regarding the Microscale experiments and thus become a primary source of literature to future educational researchers. When the study recommendations are taken into consideration, future researchers will find a basis for further investigation. The future researchers will derive these benefits when the study is disseminated through the university library and repositories, by publishing the work as articles in journals, research exhibitions and internet by the researchers.

The findings of this study will reveal to the government and education policymakers, the cost-effectiveness of Microscale experiments. Therefore government and education policymakers can purchase equipment and materials for performing practical activities in chemistry with little fund. Chemicals purchased can be used at several phase of experiment since all experiments are carried out with little quantity. This will be achieved when the findings are disseminated through workshops, participating in conferences, presenting papers based on the study, internet posting and publishing the work as articles in journals.

Summary

The paper was presented under the following sub-headings: introduction, statement of the problem, issues relevant to the topic, significance of the study, summary, conclusion and recommendation. The introduction explores the concept of chemistry with a special touch in practical chemistry, achievement, Microscale experiments and how these concepts are interrelated. The paper revealed that despite the importance of chemistry, students' achievement in the subject still remains poor. This was attributed to among other things, absence of or inadequate supply of laboratory apparatus and chemicals, expensive nature of chemicals/reagents or equipments, lack of interest by the students and the ineffective teaching methods adopted by chemistry teachers in teaching practical chemistry. Thus, researchers have continued to search for the best way to improve students' achievement and reduce cost. The paper suggested the use of Microscale in teaching practical chemistry. Since, it reduces cost and could improve students' achievement because of the involvement of students in the practical experience.

The significance of the study was done under two sections; the theoretical significance and practical significance. Under the theoretical significance, three theories were reviewed and its relationship to the topic explained. The theories are: John Dewey's learning theory, Jean Piaget constructivist theory and Lev Vygotsky social constructivist theory. These theories stressed the need for active participation and direct experience of the students in teaching and learning, which forms a strong part of Microscale experiments. The Practical significance of the study to the students, teachers, researchers, and government and education policymakers was also highlighted.

The paper concluded by proffering strong recommendations for the government to invest in Microscale experiment, as it will help to reduce cost and waste and ensure that the students are directly involved in practical chemistry section. Hence, improving their general achievements in the subject.

Conclusion

The paper which was on the integration of Microscale experiment among senior secondary school practical chemistry: a panacea for improving students' achievement and reducing cost deduced the following as its conclusions:

- ✓ Microscale experiments in chemistry ensure active participation and enhance students' achievement. This active participation is in line with the hands-on, minds-on approach of science teaching and learning as stipulated in the National Policy on Education(Ezeudu, Chukwudi, Nwafor & Agugu, 2019)
- ✓ It also has the advantage of reducing cost, damage and waste, as small amount of chemical are used in Microscale experiments. This cost effectiveness can be seen on the aspect whereby the cost of reagents, breakage of glass materials and the quantity of products and reagents are reduced. All practical activities are carried out using small amount of chemicals/reagents. In addition, the cost effectiveness of Microscale experiment revealed by this paper makes the purchase of the apparatus/chemicals affordable by school administrators and government.
- ✓ It also avails all students' direct practical experiences and can be used in the absence of or inadequate supply of laboratory apparatus and chemicals.

Recommendation

The paper proffers the following recommendation:

1. Practical activities in chemistry should not be neglected even in the phase of inadequate laboratory apparatus and chemicals. However, Microscale experiment which has been identified to facilitate practical activities in miniaturized form should be utilized.
2. Since the effectiveness of the Microscale experiment in chemistry has been revealed in this paper, teachers can adopt the strategy especially where standard experiment is not feasible.
3. Stakeholders in Chemistry educations like Ministries of Education, Science Teachers' Association of Nigeria (STAN), education commissions, school principals and state school management board should organize seminars, workshops and conferences where teacher in the field would be trained on the use of Microscale experiment on practical chemistry.
4. Government should create/invest in the production of micro kits for chemistry and other science related subjects.

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