ESUT Journal of Education (EJE)

Vol. 6 Issue 1, May 2023

Laboratory Method: A Key to Effective Science Teaching in Emerging Technologies for Achieving Sustainable Goals.

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ABSTRACT

The laboratory method is essentially thought of as a hands-on and minds-on approach in science instruction in which students have the opportunity to gain some experience with phenomena associated with their course of study. Laboratory method is a unique source of quality teaching and learning in science because science students are able to observe and manipulate materials to demonstrate certain aspects of the subject matter which has been learnt in class through lectures, discussions and textbooks. Hence, it provides students with opportunities to engage in processes of investigation and inquiry which is believed to enhance quality education. Here, the students learn by actual doing rather than by observing the practical work. As they do it by themselves, the experience is impressed more firmly in their minds. Thus, this method is psychologically sound as it satisfies the natural urge for activity and broadens interest and curiosity of the students. For learning of science through laboratory method to be meaningful to science students, they should be encouraged to use the emerging methods that scientists use to arrive at knowledge i.e. the basic and integrated science skills. Scientific process skills are not necessarily a set of rules for discovering new scientific knowledge, rather they are general procedure that scientists usually follow in finding solutions to problems. Therefore, the inculcation of these ideals in science students by the science teachers becomes necessary to enable them excel in laboratory teaching and learning techniques. This paper essentially x-rays the principles of adoption of laboratory method vis-à-vis the utilization of emerging technologies such as virtual technologies (computer application) in science instruction to achieve sustainable development goals in quality science education. The problems associated with laboratory method in science instruction as well as possible solutions for its effective utilization for quality science education are also highlighted.

Keywords: Laboratory method, Science teaching and learning, Emerging technologies, Computer-based learning, Sustainable development goals

INTRODUCTION

Science is an important subject in school curriculum because man's future depends to a great extent on the scientific advancement/development of productive activity. Therefore, it is imperative to teach science in school curriculum. Introduction of science in school is basically done with the view to developing in students' scientific attitudes and temperament, critical thinking, active inquiry as well as independent work and understanding of the physical world for sustainable growth. So it is a powerful means of developing attitudes of critical inquiry, respect for truth, adaptability and systematic work which are a pre-requisite for initiating the process of social change and of national development. For any nation to develop, it must have adequate human capital which is essentially obtained through sound education. According to Mbajiorgu (2022), education is an investment in human capital and the ultimate aim of education is to enhance human capital of the nation. Sound education therefore leads to human development and this can positively

influence standard of living and overall nation's development.

Quality education has been the subject of debate/discussion everywhere over the years. In any nation, emphasis has always been on how to provide quality education which usually rests on science and technology that help to facilitate national development. This has practically led to the formulation of educational policies and their implementation, one of which is good quality science education. Mbajiorgu (2019) posited that one of the major tasks of science education is to assist individuals come to terms with the correct conception of science. Science is of two dimensions – the product and process. Being a product represents the accumulated facts, knowledge and information resulting from the activities of the scientists through their scientific processes which are utilized to produce the product. Science in schools therefore, must be taught in such a way that will give the quality education required for individual development as well as nation's overall development in the areas of science and technology.

The best approach to impact science to students should be a big concern to any government as well as other stakeholders. It is believed that education is a pivotal part of human development, and can positively influence standards of living, health and governance. Schools handle the important responsibility of imparting education to students and developing them into responsible and enterprising citizens. This can only be achieved when the quality of education provided is the top priority of every government and the school in particular (Salmi in Hamidu, Ibrahim & Mohammed, 2014). Most governments in developing nations have set of good guidelines and policies on science education, but what is lacking rests on improper implementation of the required approaches to teaching and learning of science in schools (Sally in Hamidu *et al.*, 2014). As all science subjects taught in schools are practically oriented, it becomes vital to fashion out the best techniques to go about science instructions in achieving sustainable development goals in educational sector, and one of which is laboratory method. Practical work, including laboratory work, has been part of science education for more than a century, and is considered an essential component of science teaching.

In embracing laboratory method in science instruction, it is necessary to utilize emerging technologies to enhance meaningful and lifelong learning. Regarding lifelong learning as part of United Nations' initiative of the role of emerging technologies in sustainable development goals (SDGs) for the year 2030, Montoro, Colon, Moreno & Steffens (2019 emphasized the need to adopt innovative ideologies in improving education. For instance, they recognized the importance of application of virtual laboratories as well as hybrid and ubiquitous learning and collaborative environments in both primary and secondary education. That emerging technologies such as robotics, artificial intelligence and mixed reality, which are part of the recommendations for SDGs by the United Nations, should be considered quite relevant in improving teaching and learning at all levels of education (Montoro *et al*, 2019). According to Day & Schoemaker as cited in Rotolo, Hicks & Martin (2015), emerging technologies have assumed increasing relevance in the context of policy-making for their perceived ability to change the status quo (i.e. traditional method of instruction). Therefore, if laboratory method of science instructions is effectively utilized with the appropriate emerging technologies, it will go a long way in providing the quality education for SDGs in any nation.

Concept of Science Laboratory

Laboratory is a facility that provides controlled conditions in which scientific research, experiment and measurement may be performed. This implies conduct of practical or experiment following scientific methods. According to Hamidu *et al.* (2014), laboratory has been described as a room or a building specially built for teaching by demonstration of theoretical phenomenon into practical terms. With the laboratory experience, students will be able to translate what they have read in their texts to practical realities, thereby enhancing their understanding of the learnt concepts. There is a popular saying that 'seeing is believing'; and it is the effect of using laboratories in the teaching and learning of science and other science related disciplines that enable students to understand and recall what they see more than what they hear. Laboratory is very important and essential to the teaching of science, and the success of any science course is much dependent on the laboratory provision made for it.

For the past several decades, educational researchers have suggested that laboratory courses are beneficial and make unique contributions to science education. Science educators have designed laboratory activities with the intention of promoting student learning in cognitive and affective domains such as understanding scientific concepts, interest and motivation, scientific practical skills, scientific inquiry, and understanding the nature of science (Freedman; Henderson; Hofstein & Lunetta in Silvia *et al*., 2012). Lending credence to this statement, there is a general consensus among science educators that laboratory occupies a central position in science instruction. It could be conceptualized as a place, where theoretical work is practicalized; and practical in any learning experiences involve students in activities such as observing, counting, measuring, experimenting, recording and carrying out fieldwork. It provides opportunity for individual and group learning, and not only simplifies abstract scientific concepts but develops scientific skills in students. The lab activities cannot be easily carried out where the laboratory is not well equipped. There is usually a strong move to emphasize the dependence of science teaching on the existence of a well-equipped science laboratory.

A successful science laboratory is the result of extensive planning, collaboration, and coordination between the design team and all impacted stakeholders (Brader & Bartlett, 2017). Since teaching and learning in the contemporary society is student-centred and task-based for meaningful learning, there is need for a paradigm shift from the traditional laboratory setting to modern design. According to Ogunsola-Bandele & Adeoye (2014) and Ogunsola-Bandele (2006), the modern laboratory design termed Power Lab.8 (octagonal workstation) is an ideal as it has a complete science laboratory system made of adaptable to different approaches of science instruction designated with both teachers and students in mind. The new facilities provide safe, spacious work areas and convenient preparation rooms adaptable to different approaches of science instruction. The octagonal workstation encourages cooperation, hands-on learning while allowing the teacher to move freely about the room in order to observe groups of students and assist them as needed. It lends itself to more formal instructional approaches and permits various configuration or arrangement in modern laboratory. As against traditional lab design where most students, especially those at the rear find it extremely difficult to observe practical demonstration, with the Power 8 design in place, the entire room becomes the teacher's domain and students are able to get personal attention through the various arrangements that can take place in the

laboratory (Ogunsola-Bandele, 2006). The modern workstation of Power 8 design is flexible, and so can be re-arranged in various shapes, namely; crescent, triad, single pod and U-shape according to the specific room layouts and space requirements.

The Power Lab.8 provides attractive innovative appearance that can generate students' enthusiasm for science learning. Students will enjoy working in a modern learner-centred environment, where they have plenty of space to move around and can easily engage in team activities. Power Lab.8 facilitates effective interactions by having students sit where they can easily collaborate with their fellow students. This flexibility (Ongunsola-Bandele, 2006) allows for the creation of an optimal laboratory configuration in which the teacher and students can work safely in an open and in uncluttered area. This spacious work surfaces encourages focused, hands-on experimentation and plenty of group interaction. The quality and durable components ensure that the laboratory look good and serve well for years.

A good science laboratory is therefore seen as a well-designed room/building meant for teaching by demonstration or otherwise practicalizing theoretical concepts discussed in the class. In the laboratory, both the learners and teachers need an education that prepares them to be successful in an ever-changing technical world. Laboratory work is exciting, collaborating and promotes group interaction among the learners for knowledge gain. Tetsuo (2017) describes term laboratory work as any activity related to the learning or teaching of science (whether carried out individually or in a small group) in a school laboratory and that primarily involves observation, experimentation, and investigative work. According to the author, this contrasts with practical work which entails fieldwork, as well as observation, experimentation, and manipulation of the objects/materials being studied, and other scientific activities (e.g. investigations inside or outside of the laboratory for the purpose of teaching/ learning science). Hence, laboratory work is an essential part of practical work. As science laboratory is essential for students to learn and explain scientific facts and theories, it offers various opportunities for students to think creatively, develop techniques, and explore their interests. Science laboratory enhances the application of principles of science; promotes intellectual honesty, scientific attitude, co-operation and resourcefulness as well as provide better training in handling laboratory equipment.

Further benefits of the science laboratory for students are highlighted as follows:

1) Gives learners hands-on experience: a science lab is a place where students get hands-on experiences of the experiments they have learnt from the textbooks as well as their teachers. In this way, they get an idea of how an experiment is done and what its result would be. They also explore other techniques that have been used for performing the experiment.
2) Helps students formulate their own ideas: A science lab gives students an opportunity to formulate their ideas and make them workable in the real world.
3) It fosters curiosity: students usually have an innate curiosity about the world around them. The science lab encourages this curiosity because it gives students a chance to test and experiment with their surroundings. As they investigate and discover new things, they develop their thinking skills and gain knowledge about the world around them.
4) Encourages creativity: students in the science lab are encouraged to come up with hypotheses and experiments around

a particular topic. This teaches them how to solve problems and think critically. It also encourages creativity, as they have the opportunity to use their imagination during experiments.

5) Self-directed learning: science lab classrooms allow students to direct their own learning because the experiments are usually open-ended. Students have an opportunity to test out theories, ask questions and make observations. They can then use the information from these experiments in future studies or projects.
6) Help improve memory: experimenting in a science lab helps students' better memory power. There is always an active involvement of both hands and mind while experimenting as oppose to rote memorization of facts. When students have an understanding of concepts, there is no longer any need to remember what they read or heard.
7) Students become more focused: when students are involved in experiments, they become more focussed as compared to when they do theoretical studies. This improves concentration and also helps them develop better analytical skills.
8) Better concentration levels: science experiments involve hands-on work to engage students more and make them concentrate better. The result is that they get better grades and their overall academic performance improves.
9) Improved vocabulary: the terminology used in science classes is different from what one learns in normal classrooms. Through science experiments, students learn about new concepts and words which expand their vocabulary.
10) Develops critical analysis skills: science labs promote critical analysis skills by putting forth various points of view from which one can draw conclusions. This improves their analytical skills and prepares them for future challenges outside the classrooms.

The science laboratory therefore makes teaching of science more meaningful and interesting as well as enhancing co-operation and resourcefulness among students. In the laboratories, the students learn about facts and laws of different branch of science and check their truthfulness and learn to make practical use of them. In this method, the learners become very active and learn by themselves. In short, it involves minds-on, hands-on activities and it's learner-centred. According to Hamidu *et al.* (2014), laboratory experiences have been reported to promote central science education goals including the enhancement of students' understanding of concepts in science and its applications; scientific practical skills and problem solving abilities; scientific 'habits of mind'; understanding of how science and scientists work; interest and motivation.

What is Laboratory Method?

The term laboratory as indicted earlier simply means a workroom where certain activities are carried out such as observing, testing, measuring and experimenting, and by extension, formulating, interpreting and predicting data/event utilizing laboratory method. Laboratory method of teaching is viewed as the activity involving a two-way approach carried out by the teacher through the exercise and experimental approaches both of which are useful in science teaching. According to Omiko (2015), the laboratory exercises include experiments and other activities which help the students in acquiring scientific skills. Laboratory method teaches the professional skills of the field of study of sciences at all levels of education. Laboratory experiences allow students to learn and practice those skills in controlled environments where such skills are secluded, and distractions highly minimized. As laboratory experiences demand a high degree of student involvement, they are undeviating, first-hand experiences which place the student

face-to-face with the problem being explored or the task being performed. Laboratory experience if well planned and properly motivated will minimize the student's role as a passive observer. In other words, laboratory method should be student-centred.

As teaching and learning of science is best achieved through laboratory methods, careful consideration should be given to those aspects of the science curriculum that can best be taught through a laboratory experience. Making the content meaningful by giving students hands-on experiences will bring the science curriculum alive and solidify the concepts in the students' brains. Omiko (2015) posited that "hands-on experience" encourages students to develop a spirit of inquiry and allows them to acquire scientific skills and the right attitude to handle scientific tools and materials. When using the laboratory method, science processes should be utilized. Those processes are: observing, communicating, comparing, organizing, relating, inferring, and applying, as pointed out earlier.

Essentially, the study of science can properly be applied to the laboratory study of the subject which is basically what laboratory method is all about. In order to know what the facts of science are, they must be seen and handled directly on the laboratory tables. Science teaching and laboratory always go together, and almost in all the methods of teaching, especially in heuristic, demonstration and laboratory method of teaching. Practical activities and experiments are unavoidable assets to a science lesson and knowledge. Laboratory method is almost universally approved by the science teachers everywhere. However, to large extent, it is pertinent to note that the text book method of teaching in the classrooms prevails in most institutions to such an extent that laboratory work is incidental, inefficient and in most cases omitted altogether. Suffice it to emphasize the obvious that laboratory teaching develops in the students the ability of interpreting what he/she sees in the light of experience and makes him/her thus an observer later. Laboratory work is unquestionably of value in the cultivation of the mind. It brings the teacher and students in close contact and thus the personality of the teacher influences the character of the students in a way. With the guidance of the teacher, the students are able to explore facts in science through the laboratory activities.

Literature has shown various methods of teaching laboratory method of sciences viz: self-preparation, right explanation, starting experiments, handling instruments, explaining observations, writing reports and lab safety self-preparation. **Self-preparation:** the preliminary planning in the utilization of laboratory methods by the instructor is quite ideal. In that regards, keeping the following concerns in mind during the preliminary planning will greatly increase the probability of success. Under this arrangement, the teacher/instructor should address the followings:

1. **What are the resources available?** Conscious of the fact that laboratory method is a hands-on activity, the instructor should check out if
   - there are sufficient quantities of materials required
   - some of the materials should be ordered or improvised
   - there are adequate funds to permit purchasing of these materials
   - the supplies and equipment maybe borrowed from other schools.

2. **Proper time schedule for the conduct of the laboratory work**
   Here, the instructor needs to find out whether there is going to be an assembly or other programme scheduled that will

decrease the length of the period or eliminate it entirely.

3. **Pre-laboratory activity before the students try it.** The 'Try test' goes with a lot of merits in that it allows the instructor:
   - the chance to try-out all the experimental procedures, so as to ascertain if all the procedures are workable and can be accomplished during a given timeframe. Oftentimes, some teachers underestimate the time needed to complete a laboratory work. 'Try test' equally reassures the teacher of the right procedure/steps to be taken.
   - to identify all the pitfalls the students may encounter and modify the procedures to avoid them.
   - sufficient time for the assembling of all required equipment and materials and modes of delivery during the actual lab work: whether the equipment and materials are best assembled beforehand by the teacher or whether they should be assembled by the students during the lab session. Should the students assemble the equipment and materials, they need to be given clear and concise instructions.

4. **Determine the most efficient and effective size of student participants**
   The pre-lab test enables the instructor to assess if the lab work should be done individually or in a group. Ideally, the amount of materials and equipment available will pre-determine group size.

5. **Determine how the materials and equipment should be distributed to the students.**
   The teacher is expected to work out how the materials are be brought to the students: whether in bulk or in pre-organized trays; how are the materials to distributed at work stations or lab benches; and who does the transporting of materials and equipment–the teacher, a designated student from each group, or the lab assistants?

6. **Determine how materials and equipment will be handled after lab work**
   The teacher determines whether the equipment and materials are to be left out in the work area safely and undisturbed for use the following day; should they be used by another set of the class on the same day for the lab experience, which of course would save the materials and set-up time and preparation.

7. **Consider safety precautions and the safe disposal of materials**
   The teacher is expected to pre-determine any potentially hazardous or difficult techniques to be encountered by the students while performing the lab work, and also provide possible solutions beforehand such as wearing of protective goggles when working with potentially hazardous materials. The students should be given instructions on the location and use of safety equipment in the lab area as well as shown the facilities for safely disposing of waste materials and unused materials.

Starting Laboratory Work: Learning by doing is a cardinal principal of teaching science, and so practical work stands out to be an essential component of learning science. There are different ways to start with. The best is to explain the process orally once, explaining the methods as written in the procedure. The students may be asked to follow the procedure before handing the instruments. This way they will learn the correct procedure for performing the experiment.

Right Explanation: The teacher's value is always judged by students. A teacher should know the proper and effective way of teaching students the experiments in the easiest way. Teacher should be able to share the right knowledge with the students. The correct and right steps involved in the lab work for the science topic should be carefully explained to the students, giving reasons for the scientific cause behind any observation. As the students are curious and interested to know, the teacher should be ever ready to address any questions arising from the practical work confidently.

Handling Instruments: As mishandling of instruments during the lab work may lead to accidents and breakage of expensive lab supplies, the teacher should know the right way of handling the instruments. For instance, the students should be shown how to hold the test tubes, light burners or handle any instrument as the case may.

Explaining Observations: Upon completion of the experiment, the teacher should be to explain to the students the reasons behind the observations as well as the conclusion in details, so that no doubt remains in their mind. Relate the observation with the text they have learned in their theory classes. Getting the correct results is essential for the success of an experiment.

Writing Reports: There are different ways to write lab reports. The students should be taught the correct sequence for writing a particular lab report. The typical structure of the lab reports begins with the aim of the experiment, the requisite and then the detailed explanation of the process, methods and the precautions required. At last, the observation along with a good conclusion is written. Diagrams, flow charts, formulas, are important part of the report.

Lab safety rules: As an important aspect of laboratory work, the teacher should be able to provide the appropriate safety guides, rules and regulations to the students orally and/or typed-written.

Categories of Laboratory Method

Laboratory method is demonstrative, explanatory and practical, and it can involve new teaching technique that focusses on cognitive and behavioural thinking as well as the development of new patterns of learning which are learner-centred, and teachers/instructors acting as facilitators paving the way for the students to learn by providing the necessary resources and support. Laboratory method has been recognized as one of the important methods of teaching science and it forms an integral part of effective science teaching. Under this method, teacher encourages the students to derive various scientific laws and principles on their own by getting personally involved in the experiment work. For this, provision of a well-equipped laboratory is made by the teacher. Along with such materials and facilities, proper instructions are being provided by the teacher to the students by which they can carry out their experiments self-independently. They carry on the experiments and record the observation properly, on the basis of which, they infer their results or draw conclusions. Entire work of the students is being supervised and controlled by the teacher, as a result of which, the probability of meeting with any kind of accident reduces to considerable extent. Not only that, students can perform their work without encountering much mistakes. Thus the principles of laboratory method of instruction can be outlined as follows:

a) It follows the principle of learning by doing.
b) It follows psychological principle, where students' interest and learning ability is taken into consideration.

c) The work should be pre-organized and pre-selected.
d) Teacher must see that, students are allowed to work independently without much interference.
e) The teacher must ensure that apparatus and equipment should be checked properly before hand
f) Teacher must see that students are able to follow instructions and record their observation properly.

For effective science teaching, according to Himanshu (2012), laboratory method is used to maximum possible extent by the teachers, as a result of which, some experts have divided it into various categories, some of which are as follows:

a. Inductive laboratory method: Through this method, students get the opportunity to form various scientific concepts and principles on their own as in this method they have to take part in various project functions.
b. Verification and deduction method: Through this method, teachers illustrate various scientific concepts, principles and laws in front of students.
c. Technical skill oriented method: This method stresses to acquire various kinds of manipulative skills which involve the development of hand-eye coordination.
d. Science process oriented method: Through this method, teachers develop the science process skills of various kinds in the students.

In another dimension, laboratory method of science instruction can be applied by utilizing Guided and Unguided Discovery methods of teaching and learning. The Unguided Discovery method is that in which learners are provided neither with general principles nor the solution to the problem under study. This is said to have pure discovery. In Guided Discovery method, the learners are provided with just the general principles but not solution to the problem under study, i.e. it is by deductive process. Here, the teacher guides the learner to discover what had earlier been discovered. However, the above techniques constitute part of the traditional method of laboratory method of instructions which have been in use for ages.

Thus, any form of laboratory method can be used by the teacher. But, it is very necessary to plan and organise laboratory activities carefully. Pre-laboratory instructions should be provided by the science teacher well in advance of time as through it, students will get prepared for taking active part in laboratory activities. Through such kind of pre-laboratory instructions, students will become oriented to the objectives to be attained and the procedures or methods to be adopted. Necessary directions for actual laboratory work should be provided by the teacher to the students, which should highlight the precautions which they are required to be observed. Teacher can provide the instructions to the students either in written form or orally. If these are provided in the written form, then there should be proper provision of black-board and instruction cards in the classroom, as without it, this function cannot be performed properly (Himanshu, 2012).

It is interesting to note that any laboratory techniques applied, presents its peculiar learning experiences to the students. Some of the concrete experiences offered by laboratory activities are highlighted in table 1.

Table 1: Types of Laboratory Experiences

Type of Lab. Activities	Laboratory Experiences
Type I Activity	This develops such skills as measurement and observation. It may not require formal reasoning, and so teaches important skills used in subsequent lab work
Type II Activity	This verifies the concepts or principles previously studied in a textbook or presented in a class discussion. Students can replicate an experiment already performed by someone else. The problem is stated, results predicted, and the procedures are specified. Students should pool their data, discuss trends, and draw conclusions, and may be asked to explain how they verified the principle or concept. A Type II lab usually follows the teacher's presentation of a concept or principle
Type III Activity	The experiences here are guided discovery activities; students practice finding relationships in their data. They get directions from the teacher or the book, but they do not know what results or conclusions to expect. A Type III lab serves as an introduction to a concept or principle. The discovery process takes more time, and fewer commercially prepared materials are designed in this fashion, but the benefits are worth the extra time and efforts. However, this lab activity should not be relied upon as it may be frustrating for students to have to "discover" all things expected.
Type IV Activity	This involves problem-solving activities. Students are presented with a problem, and they develop their own methods for collecting data. Students can practice such data collecting skills as measuring, identifying, and controlling variables at the same time they uncover a scientific concept or principle. In a Type IV lab, a student acts like a scientist scouring out the solution to a problem. This is time consuming and frustrating for students as well, and so requires patience and flexibility.
Type V Activity	This places the entire burden of an investigation on the student, who must formulate both the problem and the method of data collection. In addition, he/she must interpret the data and arrive at a conclusion. The problem can be a logical extension of a class discussion or an idea generated by the student's own experience. This is a true research project. The most difficult task may well be that of limiting the scope of the problem to fit each student's stage of cognitive development. In order for Type V investigations to be successful, students must be knowledgeable and skilful, and the teacher must be comfortable with the role of a resource person, rather than the source of knowledge.

Laboratory Method as Emerging Technologies for Achieving Sustainable Goals

Literature has it that the Sustainable Development Goals (SDGs) established by the United Nations in 2015 consist of 17 global goals with 169 targets aimed at transforming the world by the year 2030. According to Berawi (2017), these include actions to end poverty, improve health and education, and promote prosperity and well-being by considering environmental sustainability. The researcher further noted that the SDGs cover multiple dimensions of development, including social welfare (e.g. education, health, poverty), economic growth (e.g., production and employment, clean energy, industries and infrastructure), environmental sustainability (e.g. ecosystem, water and sanitation, climate change), and effective regulatory rules and governance (e.g., accountability, justice). The 2030 Agenda principle of a "no one will be left behind" philosophy requires global partnership and participation in an integration of environmental, social, economic, and governance dimensions in the process of development. Technology development plays a significant role in achieving SDG targets by improving the efficiency and effectiveness of new and more sustainable ways of development. The creation of new technologies that foster research and stimulate innovation is thus required. These processes can be boosted by strengthened knowledge-sharing and collaboration amongst stakeholders in both national and international contexts (Berawi, (2017). As it affects education in particular, SDG is expected to ensure inclusive and equitable quality education in all ramification. With internet connectivity for instance, students can access learning resources and opportunities even in remote or low-income areas. Teachers can prepare for classes anytime or anywhere. Information and communication technology (ICT) as emerging technology opens up access to education to underserved populations for whom improved educational opportunities lead to improved economic opportunities.

Emerging technologies have generated plenty of debates within the academic spheres, becoming the central subject of many initiatives and political discussion forums (Rotolo *et al*., 2015). According to Montoro *et al.* (2019), emerging technologies refer to those new technologies that are being continuously developed or will be developed during the next five or ten years. However, Rotolo *et al*. (2015) identified five attributes that feature in the emergence of novel technologies as radical novelty, relatively fast growth, coherence, prominent impact and uncertainty and ambiguity. The combining attributes, Rotolo *et al*. (2015) conceived emerging technology as:

> 'a radically novel and relatively fast growing technology characterised by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes. It's most prominent impact, however, lies in the future and so in the emergence phase is still somewhat uncertain and ambiguous'.

Minwuyelet (2019) elaborated that emerging technology is a term generally used to describe a new technology and/or the continuously development of existing technology which is expected to create significant socio-economic effects in the near or specific time future. It is therefore paramount to consider the application of the

relevant emerging technologies in improving the quality of education especially in the areas of science and technology. The continuous and rapid progress of technology has made the academic and scientific world, especially in the field of education, focus on studying the advantages and disadvantages of the use of ICT in classrooms, as well as the use of different types of emerging technologies that are computer based. Mbajiorju (2019) posited that the current technological development, perhaps for future expected sustainable development goals, demands that a teacher possesses the practical skills to use ICT facilities, noting that some ICT tools aid in the analysis, processing and presentation of information, modelling, measuring and control of external events which are very relevant for progress in science activities of laboratory work is part of. As pointed out by Ghavifekr & Rosdy (2015) also the ICT assists teachers to the global requirement to replace traditional teaching methods with a technology-based teaching and learning tools and facilities. In Malaysia, they posited that ICT is considered as one of the main elements in transforming the country to the future development.

The emerging technologies such as virtual laboratories: computer-based, as well as hybrid and ubiquitous learning and collaborative environments, which seem to be in vogue in recent times, appear to be all perspective profound learning techniques prominently emerging in primary and secondary education (Montoro *et al*., 2019). Other emerging technologies, apart from virtual reality, worthy of mention which are prevalence in adaptive learning environments in schools in some countries include robotics, artificial intelligence, augmented reality and mixed reality. According to Minwuyelet (2019), the fundamental idea of augmented reality is to combine or mix the view of the real environment with additional virtual content that is presented through computer graphics, and that its convincing effect is achieved by ensuring that the virtual content is aligned and registered with the real objects. As an individual moves in an environment and their perspective view of real objects changes, the virtual content should also be presented from the same perspective. Therefore, augmented reality can be regarded as emerging computer-generated content in the real world. Augmented reality is quite relevant in laboratory teaching techniques as it appears to be a live view of a physical real-world environment whose elements merged with augmented computer-generated images in mixed reality.

Use of Computer in Laboratory Method of Science Instruction

With the technology advancement in the world (Ogunsola-Bandele & Adeoye, 2014), computers are gradually gaining access into the science laboratory to help the students with their practical and the staff with the organization and management of the laboratory which includes filing, record keeping, and their link with account. The emerging technique of laboratory method of teaching and learning of science subjects should incorporate the application of computers to achieve sustainable goals in the development of science and technology in any nation. The use of computers in laboratory work is quite necessary and achievable, since it stands the chance of addressing so many inherent problems associated with laboratory activities ranging from dangers in handling some practical works, lack of laboratory raw materials (e.g. reagents) and equipment, well trained laboratory personnel as well as lack of required infrastructural facilities for the desired laboratories in schools. With the technology advancement in the world, computers are gradually gaining access into the science laboratory to help the students not only with their practical, but with the

staff as regard organization and management of the laboratory which includes filing, record keeping and their link account. Modern techniques require the use of computers in the organization and management of the laboratory work, apart from the real integration of the computer soft wares into the practical exercises.

Oftentimes, certain practical works are skipped due to none availability of chemical reagents and apparati for the students. There are various soft wares in CDs and the likes (computer simulations) that are available to perform such practical with the computer with ease. Such CDs now exist on Chemistry, Biology and even Physics practical. For instance, in Biology, there are various CDs that can take the students through the whole human body to learn such internal organ systems like human skeletal, muscular, cardiovascular, reproductive systems and lot more. The computer software helps the students to be able to set up the titration process, filling in the acid in the right apparatus, identifying the right indicator and actually seeing the experiment take place and recording their result. Thus, such CDs help the students to learn about various internal body system with the use of computers. The smart search or Google also directed students to the part of the body under study. The detailed animation bring the intricate function of the body to life. These innovations make practical real fun for the students and help in situations where materials, apparati or chemicals are not sufficient or even non-available to carry out real practical work.

Although hands-on experimentation is usually the main focus in any science laboratory, the usefulness of integrating the computers into recording and interpreting scientific results have been recognized. That is apart from the computer helping the students in their practical works, recording the results and interpreting is another aspect that the students might be finding difficult. With the computer integration, students can immediately interpret the results of their experiment by performing the hands-on work and simultaneously entering the data into analytical software on a nearby computer. They can also perform an experiment using one set of variables and run a computer simulation using another set of variables. Integrating hands on experimentation with computer based activities in these and other ways can significantly enhance the students' learning opportunities without taking up a lot of valuable class time or using costly laboratory resources.

Still dwelling more on significance of the application of computers in science lab, computer can also be used to carry out certain practical (through simulation) that may be dangerous to perform in real situation/physical laboratory work, e.g. demonstration of predation of lion on antelope in wildlife. Under this arrangement, apart from cost-efficient, the virtual laboratory by use of computer allows the students to conduct experiments without the risks associated with laboratory work such as chemical, biological, physical and electrical hazards. On the other hand, the use of computer to demonstrate certain life activities such as germination and growth of seedlings saves a lot of time and constraints, apart from excitement and motivation it could generate on the part of the students. Medical laboratory tests are now done with computers with ease and resuts interpreted quickly and accurately.

Integration of ICT in education refers to the use of computer-based communication that incorporates into daily classroom instructional process. In conjunction with preparing students for the current digital era, teachers are seen as the key players in using ICT in their daily classrooms (Ghavifekr & Rosdy, 2015). There are two major uses of

computer-based technology in school laboratory activities viz: direct instruction of laboratory concepts by simulation using traditional computer-assisted instruction (CAI) and using the microcomputer for data analysis and or input of data with laboratory instrumentation interfaced to the microcomputer. Computer can also help students to record the results and interpret the recorded results of certain practical work done with ease. With the computer integration, students can immediately interpret the results of their experiment by performing the hands-on work and simultaneously entering the data into analytical software on a nearby computer. They can also perform an experiment using one set of variables and run a computer simulation using another set of variables. Integrating hands-on experimentation with computer based activities in these and other ways can significantly enhance students learning opportunities without taking up lot of valuable class time or using costly laboratory resources.

However, certain constraints associated with the application of computers in schools especially in the laboratories are eminent and well-known. Some of the problems are itemized as follows:

1. Cost implications for the acquisition of computer and software
2. Non-supply or irregular supply of electricity to most schools and the need for stand-by generators.
3. The science teachers have to be trained in the use of the computers and software for practical work
4. There is need to employ computer experts
5. The school has to beef-up its security if computers are in the laboratory
6. Temptation not to supplement computer with hands-on experimentation is there
7. Inability to conduct real practical in external examinations such West African Secondary School certificate examination (WASSCE) and the likes.

Role of Laboratory Method in improving Quality of Science Education

The science learning goals of laboratory experiences include enhancing mastery of science subject matter, developing scientific reasoning abilities, increasing understanding of the complexity and ambiguity of empirical work, developing practical skills, increasing understanding of the nature of science, cultivating interest in science and science learning, and improving teamwork abilities. It is known fact that laboratory experiences will be more likely to achieve these goals if they (1) are designed with clear learning outcomes in mind, (2) are thoughtfully sequenced into the flow of classroom science instruction, (3) integrate learning of science content and process, and (4) incorporate ongoing student reflection and discussion (National Research Council, 2006).

Laboratory activities have long had a distinctive and central role in the science curriculum and science educators have suggested that many benefits accrue from engaging students in science laboratory activities (Hofstein & Lunetta in Hamidu *et al.*, 2014). At the beginning of the twenty-first century, a new era of reform in science education is being entered. Both the content and pedagogy of science learning and teaching are being scrutinized, and new standards intended to shape and rejuvenate science education are emerging (National Research Council in Hamidu *et al,* 2014). The National Science Education Standards reaffirm the conviction that inquiry in general and inquiry in the context of practical work in science education is central to the achievement of scientific literacy and quality education. Inquiry-type laboratories have the potential to develop students' abilities and skills such as: posing scientifically oriented questions (Hofstein &

Mamlok-Naoman in Hamidu *et al.*, 2014), forming hypotheses, designing and conducting scientific investigations, formulating and revising scientific explanations, and communicating and defending scientific arguments. Tobin (1990) indicated that laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science. The author also suggested that meaningful and quality learning is possible in the laboratory if students are given opportunities to manipulate equipment and materials in order to be able to construct their knowledge of phenomena and related scientific concepts. Gilbert & Hodson in Yara (2010) also lent credence to the significance of laboratory method in the learning of science. In their submission, they identified six major significance of laboratory method in promoting quality and effective learning of science and these are as follows:

i. Motivating students by stimulating interest and enjoyment
ii. Teaching laboratory skills
iii. Assisting concept acquisition and development
iv. Developing and understanding of scientific inquiry and developing expertise in conducting inquiries
v. Encouraging social skills development
vi. Inculcating the so-called scientific attitudes.

Adeyegbe in Yara (2010) listed laboratory adequacy as one of the factors that affect the learning outcomes of students. In terms of academic achievement, Adeniran in Yara (2010) indicated that laboratory instructional strategy gives a new approach to science teaching and learning because it provides a non-threatening, realistic and concrete approach to learning of science as opposed to the difficulty encountered in learning the formal, abstract treatment of the typical textbook. Oyedeji in Hamidu *et al.* (2014) discovered that students taught with science laboratory instructional strategy performed significantly better than use of traditional lecture and text book method. The most effective vehicle by which the process of inquiry can be learned appears to be a laboratory method where the student experiences, first-hand, the inquiry process. Laboratory method has also been demonstrated to be effective means for comprehension, understanding and application of scientific knowledge. Laboratory experiences provide opportunities for teachers to model best practices in the study of scientific concepts, including application of scientific methodologies, respect for life and the environment, inclusion of learners of all abilities, and consistent adherence to safety standards. Thus, study in a laboratory is an integral and essential part of science courses. Typically, the terms have meant experiences in school settings where students interact with materials to observe and understand the natural world. Some laboratory activities have been designed and conducted to engage students individually, while others have sought to engage students in small groups and in large-group demonstration settings. Teacher guidance and instructions have ranged from highly structured and teacher-centered to open inquiry (Hofstein & Mamlok-Naaman in Hamidu *et al.*, 2014).

Strategies for Effective Use of Laboratory Method

The following strategies may be adopted as they relate to laboratory method of teaching science particularly in secondary school: As it relate to laboratory demonstrations, it begins by demonstrating key techniques or equipment operation or describing the location and handling of special materials. The students are gathered close to focus them on what the teacher is doing and to ensure that everyone can see and hear.

Again, they are focused on the key terms and functions that are in the procedures, and use the demonstration to generate excitement about the laboratory. The teacher should not attempt to demonstrate equipment he has not practiced using. If the teacher made mistake during his demonstration, it is instructionally important to describe how he/she made the mistake, it is good to familiarize him with the equipment operation prior to the demonstration (Allen in Hamidu *et al.*, 2014).

With respect to laboratory instruction, a good science teacher should maintain an active role and consistent pace of interaction throughout the laboratory period so that students learn what to expect from him/her as an instructor. The teacher should include several moments of whole class instruction at key points in the laboratory. When the teacher is asked the same question three times to three groups that have the same problem, it is likely that other groups will have the same question or problem as well. The teacher should gain everyone's attention and use this moment to provide targeted "just in time" instruction or feedback for everyone. During the class, the teacher should move around the room to make himself accessible to students, focusing equal time on groups that ask and those that don't ask for help. He should be aware of the progress of all student teams, address students by name whenever he get the chance, and listen to what is being said in groups to help him anticipate and diagnose instructional problems. He should not assume that since a group is quiet, they know what they are doing. He can diagnose a laboratory problem early on by observing what is being done or said in seemingly on-track groups. It is always useful, and never unappreciated, for a teacher to approach a group and prompt them with "he should tell them what he is doing" to find out if they are on the right track (Allen in Hamidu *et al.*, 2014).

A good teacher should be able to display sound classroom attitude. He should have the ability to set the tone for the entire class and how students will treat each other. He should not patronize, criticize or be sarcastic with students about their prior knowledge or current interests even as a joke. The teacher is there to help them develop and get them interested in learning more through encouragement and support. In terms of classroom diversity, the teacher should choose to embrace the diversity of students in the lab, recognizing that everyone comes to the institution setting with different social and cultural history. The teacher should use both visual and verbal approach to address students' problems. The practical work should commence and end on time. Prompt commencement of work would discourage lateness and naturally promote the importance of arriving on time in the subsequent work. The teacher should introduce the laboratory using a brief, but well organized overview of the important concepts for the current subject and the lab procedures that will help the student successfully complete the experiment. "Lab Tips," or notes should be created on the board or in a hand-out with suggestions for achieving success. Consistently, the teacher should provide short overviews that are focused on making links between the class concepts and the necessary lab skills to get started. This approach will help convince the students that the lab overview is relevant and useful and that they should pay attention to it. The teacher is expected to start class by demonstrating key techniques or equipment operation or describing the location and handling of special materials.

The teacher should use the whiteboard/chalk board to clearly organize the key information for the day, as it is important for an instructor to provide visual cues to

support verbal information and directions. The information should be organized on the board using boxes for important ideas or key formulas and number procedural items to make them easy for reference throughout the laboratory. The key points on the board should be left for students as reference point during class. These points can aid the instructor when answering students' questions later in the laboratory class. The teacher should maintain an active role and consistent pace of interaction throughout the laboratory period so that students learn what to expect from him as an instructor. During the class, the teacher should move around the room to make him accessible to students, focusing equal time on groups that ask and those that don't ask for help. The progress of all student teams should be paramount; students should be addressed by names at the slighted chance; and each group should be listened to in order to anticipate and diagnose instructional problems. The teacher should not assume because a group know what they are doing, it is always useful and never unappreciated, to approach a group and prompt them with "tell me what you are doing…" to find out if they are on the right track. A good teacher should remind the students that he has a role to play as an instructor, i.e. being there to facilitate their learning. This means the teacher will push them to take responsibility for their own learning; he may answer a question with a question to get them to think about an idea, or he may tell them "try and see what happens…" to foster learning. The teacher, therefore, should remind them that he is doing this to help learning and to develop their own expertise, not just to be difficult. Sometimes, a mix of guided support be provided by the teacher (Nord, Harper & Nam, 2009).

The measures that enhance effective utilization of Laboratory method of science can be summarized thus:

i. Adequate supply of instruction materials and guidance by the instructor
ii. Every experiment should be tried out by the teacher alone first with same resources the learners will eventually use in the experiment
iii. The teacher before any laboratory exercise or experiment should make adequate planning, preparation and provision
iv. While doing the exercise, learners should be properly supervised and assisted
v. Purpose and objective of the exercise should be clear to teacher and learners
vi. General discussion during which errors and mistakes should be pointed and corrections be effected
vii. Correct conclusions/inferences should be highlighted and explained at the end
viii. Unanswered questions should form the beginning of the next theory or practical class
ix. The practical can be carried by the students in batches in a large class
x. Safety measures and other laboratory ethics should be pointed out

Problems facing Effective Use of Laboratory in Teaching Science

The teaching of science in the laboratories has been a controversial issue. Laboratory work is both time consuming and expensive compared with other methods of instruction. The use of the laboratory method in teaching science has become a dogma among science educators and teachers. On one hand, they extolled the importance of the use of the laboratory method in science teaching while on the other hand, they only pay "lip service" to its use in practice. Science teachers do not usually find it convenient to make laboratory work the centre of their instruction. They usually complain of lack of materials and equipment to carry out practical work. At the same

time, it is possible that some of these materials and equipment may be locked up in the school laboratory store without teachers being aware of their existence. The conditions under which many teachers function do not engender any enthusiasm to use the laboratory method of teaching science even where they know that these materials and equipment are available. Apart from insufficient practical materials and equipment, other problems militating effective use of laboratory method in science instructions include size of the class, lack of motivation on the part of the science teachers, inexperienced and unqualified teachers, negligent by the government, and lack of maintenance culture in most schools.

Class size in urban schools is getting larger and this does not usually encourage teachers to use the laboratory method to teach science. In some states of the country, teachers go for months without salary owing to shortage of funds. Also, teachers are no longer being paid science allowance which goes a long way to motivate them carrying these hazardous tasks. Science teachers who fall in this category cannot reasonably be expected to give off their best to their students. Higher institutions in Nigeria charged with the responsibility of training science teachers at all levels, are increasingly turning out teachers without requisite laboratory experience. A common reason usually given is shortage of laboratory facilities. Such not well-trained science teachers usually lack the necessary confidence to conduct practical classes with their students. It is only accreditation exercises that are improving this situation in Colleges of Education and Universities at present. This can only be achieved if the government is willing to do the needful in terms of giving up on the capacity and responsibility to equip the school laboratories. Most often, teachers employed/engaged to teach science subjects in secondary schools are not specialists as they did not undergo training in education. Therefore, lack of enthusiasm and competency among teachers (perhaps due to poor motivation and proper training respectively) with respect to managing laboratory work which is time-consuming (Isozaki, 2012) is a strong handicap to effective utilization of laboratory technique in science instruction.

Governments' inability to accord all secondary schools the status of science based and oriented one by supplying adequate manpower and the required resources has its own negative impact. Instead of doing the needful, they have therefore resorted to designating selected schools as "science schools" which are even poorly equipped with their meagre resources. In addition, most laboratories in schools lack maintenance culture for the few available equipment and machines meant for carrying out practical. Some labs are not equipped with work tables that have sinks, water supply, natural gas and electrical outlets. Abimola & Danmole as cited in Hamidu *et al*. (2014) stated that often times, some schools display no approved guidelines for the safe use, maintenance storage and disposal of laboratory materials.

Other limitations of the laboratory method of science instruction are itemized as follows:-

1. It is expensive and uneconomical.
2. It is time consuming as it takes much time in some experiments to come to conclusion.
3. It expects a lot from students and teacher.
4. It does not guarantee that, students would be equally efficient in solving problems outside laboratory.
5. All students cannot be expected to be skilled workers.
6. Most of the students are either not ready or lack to ability to undertake original work.

Conclusion

Laboratory method is a unique source of quality teaching and learning in science because science students are able to observe and manipulate materials to demonstrate certain aspects of the subject matter which has been learnt in class through lectures, discussions and textbooks. Hence, laboratory method provides students with opportunities to engage in processes of investigation and inquiry which is believed to enhance quality education. Quality education is achieved when science laboratory and the laboratory in the context of teaching and learning science is made relevant regarding research, developmental and implementation issues. The science learning through laboratory method of instruction brings about the mastering of the subject matter and development of scientific skills i.e. inculcating scientific attitudes and developing practical skills. It also arouses students' interest, curiosity and motivation; and brings about meaningful learning and retention as well as improving team work among students and resourcefulness.

The application of laboratory method by adopting emerging technologies such as use of virtual technologies (computer) in science instruction is a unique source of quality teaching and learning in science. Application of computers in laboratory method (through simulation) is quite relevant especially where certain practical works may be too dangerous to carry out in the laboratory. However, the inherent problems associated with laboratory method of science instruction such as inadequate laboratory facilities in most institutions due to insufficient funding, large class of students, lack of enthusiasm and interest among teachers due to poor motivation, lack of competency of instructors due to poor training etc. should be addressed. For effective utilization of laboratory method, adequate lab facilities as well as well-educated teachers should be provided. The teachers should provide all required enabling environment for the practical exercise and also ensure full class control as well as proper supervision.

Recommendation

It is recommended that

1) Teachers, laboratory technicians and attendants be made to attend, at regular intervals, relevant workshops, seminars, conferences and short courses that will update and upgrade their knowledge and experiences from time to time in laboratory activities.
2) There should be emphasis on the availability, functionality and accuracy of laboratory equipment in other to achieve the aims of using the laboratory.
3) Government should provide adequate infrastructural facilities, enough fund for the procurement of raw materials as well as curriculum development that will enhance the use of laboratory method and improve the quality of science instruction in schools.
4) The teachers and other personnel involved in laboratory method should be properly remunerated with prompt payment of salaries and science allowances.
5) Laboratory method should be combined with other instructional methods such as demonstration method, experimental and discovery/inquiry method of teaching. All of which should be focused on learner-centred; hands-on and minds-on acquisition of knowledge.
6) Relevant laboratory staff (Technicians and Attendants) should be provided

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