

Laboratory-Based Learning and Academic Achievement in Physics, Chemistry, and Biology Education

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Abstract

The purpose of this research was to examine how incorporating hands-on laboratory experiences into secondary school science classes affected students' performance in physics, chemistry, and biology. Study methodology included a quasi-experimental pretest-posttest with a control group. A grand total of 120 tenth graders took part, with 60 being assigned to the experimental group and 60 to the control group. In contrast to the control group, which got more conventional lecture-based education, the experimental group learned in a laboratory setting. In order to gauge academic progress, students were given achievement exams both before and after the six-week intervention. The statistical tools used for data analysis included the independent samples t-test, standard deviation, and mean. It appears that the groups were initially equivalent, as there was no statistically significant difference in the pretest findings. On the other hand, the experimental group showed markedly improved performance in all three areas on the posttest. Students that were given the opportunity to learn in a laboratory setting showed much more improvement, according to the gain score analysis. The results indicate that students gain a better grasp of concepts, do better in school, and are more invested in their science classes when they learn in a laboratory setting. The research concludes that science classes in secondary schools should include more hands-on learning opportunities.

Keywords: Laboratory Based Learning, Academic Achievement, Science Education, Physics Education, Chemistry Education, Biology Education

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1. INTRODUCTION

Modern pedagogy places a premium on student engagement and hands-on learning experiences that foster analytical reasoning, problem-solving skills, and conceptual comprehension. For students to truly grasp the concepts taught in scientific classes, especially those pertaining to physics, chemistry, and biology, it is believed that hands-on activities must be combined with

classroom theory. As a method of instruction, laboratory work helps students make connections between theoretical and practical aspects of science. This study compares the effectiveness of laboratory-based training to that of more conventional lecture-based ways of teaching and investigates whether students learn more effectively through controlled practical interaction.



Figure 1: School Science Lab

1.1 Background Information

The advancement of technology, new ideas, and society as a whole are all based on scientific education. Biology looks at living things and how they function, chemistry at how compounds are made and changed, and physics at how matter and energy work. To become an expert in these fields, you need to know the theory behind them, but you also need to know how to put that theory into practice¹.

Traditionally, many classrooms have used lecture-based instruction, in which lecturers present material and students listen and take notes. This approach facilitates the completion of lengthy course modules in a condensed time frame, but it frequently places an emphasis on rote memory rather than critical thinking. Some students may memorize definitions, responses, and formulas without really understanding how they work².

On the flip side, students have more chances to interact directly with scientific phenomena when they learn in a laboratory. Students actively build their knowledge through doing experiments, taking measurements, observing, and analyzing data. A more tangible and participatory kind of learning is achieved through the use of laboratory equipment, carrying out studies, and analyzing experimental outcomes. Engaging in this kind of experience learning helps to fortify mental connections and facilitates a more thorough understanding³.

Furthermore, scientific curiosity is fostered through laboratory activities. Students do research by making predictions, testing those predictions, analyzing the results, and drawing conclusions. Analytical reasoning, accuracy, teamwork, and problem-solving skills are honed through such procedures. In today's fast-paced, technologically-driven society, these skills are crucial for academic achievement and for fostering scientific literacy⁴.

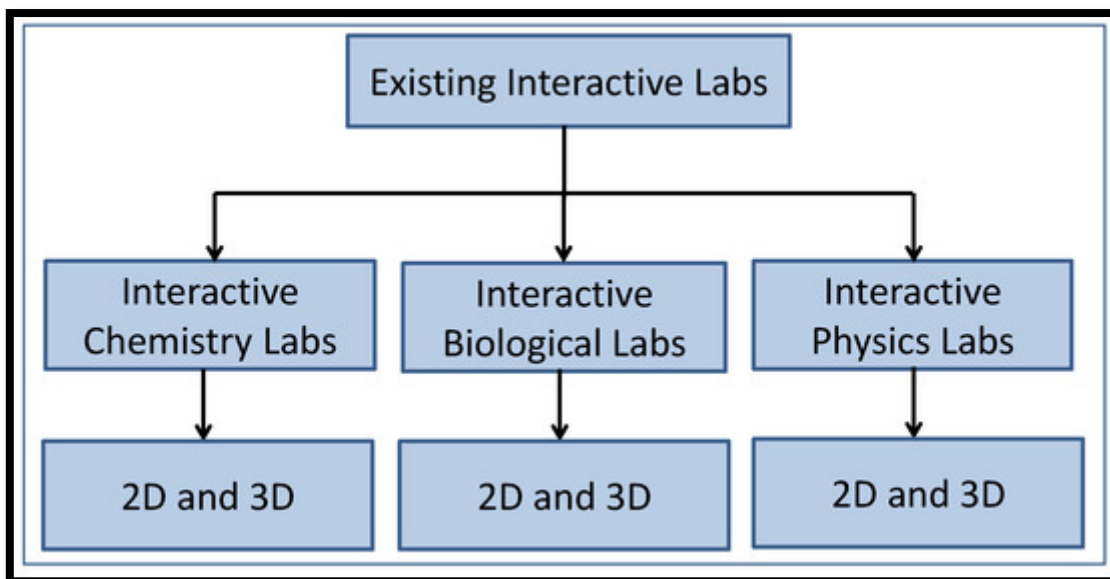


Figure 2: Interactive Laboratories for Science Education

However, not all schools use laboratory-based learning despite its many advantages. Realistic learning may be hindered by a lack of resources, outdated facilities, inadequate time management, or excessive class numbers. The need of conducting empirical studies to determine the impact of laboratory-based learning on academic attainment in core science topics cannot be overstated.

1.2 Statement of the Problem

Lab work is a required part of most science courses, although teachers don't always follow the rules when they assign it. Sometimes, instead of actively learning from each other, students just sit through teacher demonstrations or participate in mindless procedural exercises. Because of this, chances to think for oneself and explore ideas are limited⁵.

This causes pupils to do well on written exams that test their theoretical understanding of science, but they may have a hard time applying what they've learned to actual problems or scenarios. Concerns over the efficacy of conventional teaching approaches in promoting holistic comprehension are prompted by the disparity between theory and practice. Examining whether or not students' performance in Physics, Chemistry, and Biology is substantially improved by laboratory-based learning as compared to conventional lecture-based teaching is the main objective of this research. Although experiential learning is backed by educational theories, further research is needed to find out how it really affects students' performance⁶.

1.3 Objectives of the Study

1. To examine the effect of laboratory-based learning on students' academic achievement in Physics.

2. To analyze the impact of laboratory-based learning on academic performance in Chemistry.
3. To determine the influence of laboratory-based learning on achievement in Biology.
4. To compare the academic performance of students taught through laboratory-based instruction with those taught through traditional lecture-based methods.
5. To evaluate the overall contribution of practical learning experiences to science education outcomes.

2. METHODOLOGY

This section details the research methodology used to determine whether or whether students' performance in Physics, Chemistry, and Biology improved after engaging in laboratory-based learning.

2.1. Research Design

Two groups, one serving as an experimental group and the other as a control group, were utilized in the study using a quasi-experimental design. The experimental group learned in a lab setting, whereas the control group sat through classroom lectures. Prior to the educational session, both groups were given a pretest to gauge their starting academic level. Following the instructional period, they were given a posttest to gauge the learning outcomes. After that, we compared the posttest scores to see how much of an impact lab instruction had on the students' final grades⁷.

2.2. Participants / Sample

One hundred twenty students from different secondary schools took part in the study, all of whom were in the tenth grade. Each of the two groups consisted of sixty students: sixty in the experimental group and sixty in the control group. For the sake of objectivity and group comparison, the participants were hand-picked from students with comparable academic backgrounds. The pupils' ages varied from fifteen to sixteen⁸.

2.3. Instruments and Materials Used

The research relied on the following instruments for its data collection process. Each of the three science subjects had its own set of achievement examinations that evaluated students' knowledge and skills via the use of multiple-choice, short-answer, numerical, and application-based questions. These assessments served as both the pretest and the posttest, with minor adjustments made to prevent redundancy. In addition, the experimental group employed industry-standard scientific kits and equipment to conduct their research. To make sure that both the traditional and laboratory-based approaches covered the same material, we also created structured lesson plans for each⁹.

2.4. Procedure and Data Collection

Over the course of six weeks, the research was carried out. All participants, including those in the control group, took a pre-test covering basic concepts in biology, chemistry, and physics

before the study began. Students in the experimental group learned through hands-on experimentation, data collection, and analysis during the intervention period, whereas those in the control group learned through more conventional means, such as classroom lectures and textbook assignments. To maintain consistency, both groups were exposed to the same curriculum at the same time. Two weeks later, both groups were given a posttest to gauge how much progress they had made in their studies. The results of the pre- and post-tests were subsequently recorded and submitted for analysis¹⁰.

2.5. Data Analysis Techniques

Simple statistical approaches were used to examine the given data. For the purpose of comparing the two groups' overall performance, we computed the mean (average) and utilized the standard deviation to quantify the variation in the students' scores. To find out whether there was a significant difference between the two groups, an independent samples t-test was used. In order to test the hypotheses, a significance level of 0.05 was used¹¹.

3. RESULTS AND ANALYSIS

The results of the study, derived from the experimental and control groups' pre- and post-test scores, are presented in this section.

3.1. Pretest Results

The pretest was conducted to check whether both groups were equal before the intervention.

Table 1: Pretest Mean Scores

Subject	Experimental Group	Control Group
Physics	45.2	44.8
Chemistry	46.5	45.9
Biology	47.1	46.7

There was no statistically significant difference between the groups before treatment since none of the t-values were greater than the 0.05 level of significance.

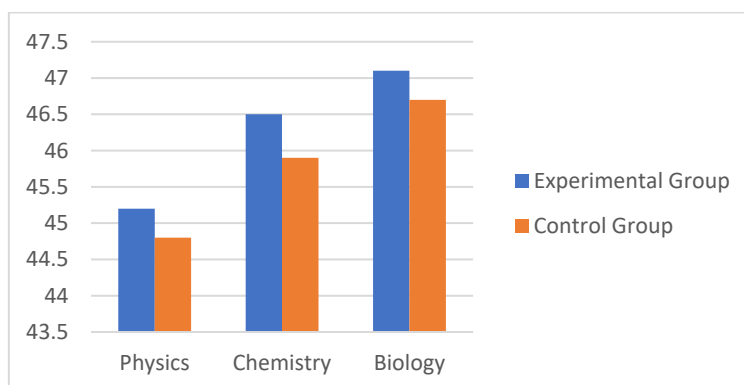


Figure 3: Comparison of Pretest Mean Scores Between Experimental and Control Groups

Both groups will have nearly equal bars on the graph, suggesting they were at comparable academic levels prior to the intervention.

3.2. Posttest Results

There was a posttest administered following the sixth week of class.

Table 2: Posttest Mean Scores

Subject	Experimental Group	Control Group
Physics	72.4	63.1
Chemistry	75.6	64.8
Biology	78.2	66.3

Statistical Analysis (Independent t-test):

Subject	t-value	Significance
Physics	5.82	$p < 0.05$
Chemistry	6.45	$p < 0.05$
Biology	7.10	$p < 0.05$

There is a statistically significant difference between the groups because p is less than 0.05.

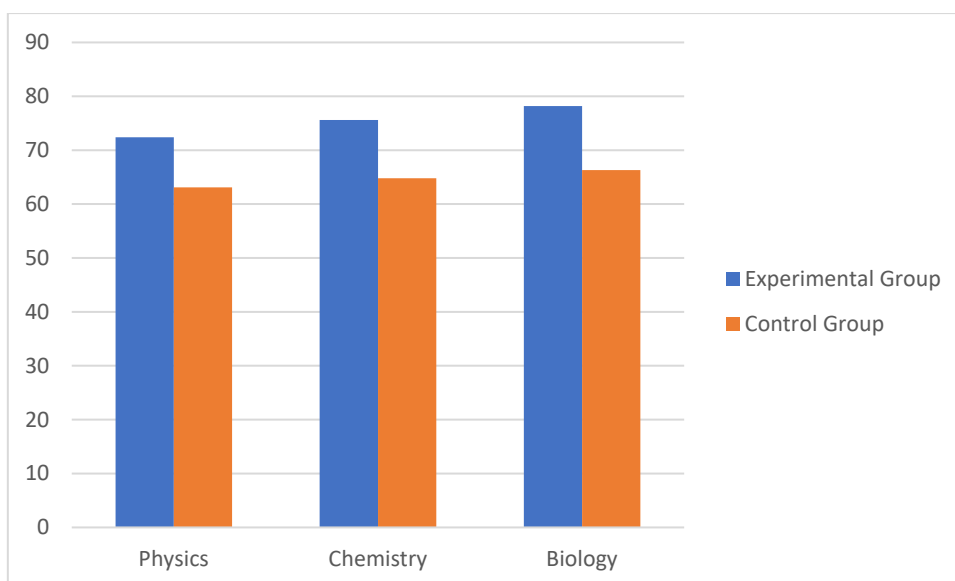


Figure 4: Experimental and Control Group Posttest Mean Score Comparison

When comparing the two groups, it will be easy to see that the experimental group outperformed the control group in terms of academic performance.

3.3. Gain Score Analysis

Gain score = Posttest – Pretest

Table 3: Mean Gain Scores

Subject	Experimental Group Gain	Control Group Gain
Physics	27.2	18.3
Chemistry	29.1	18.9
Biology	31.1	19.6

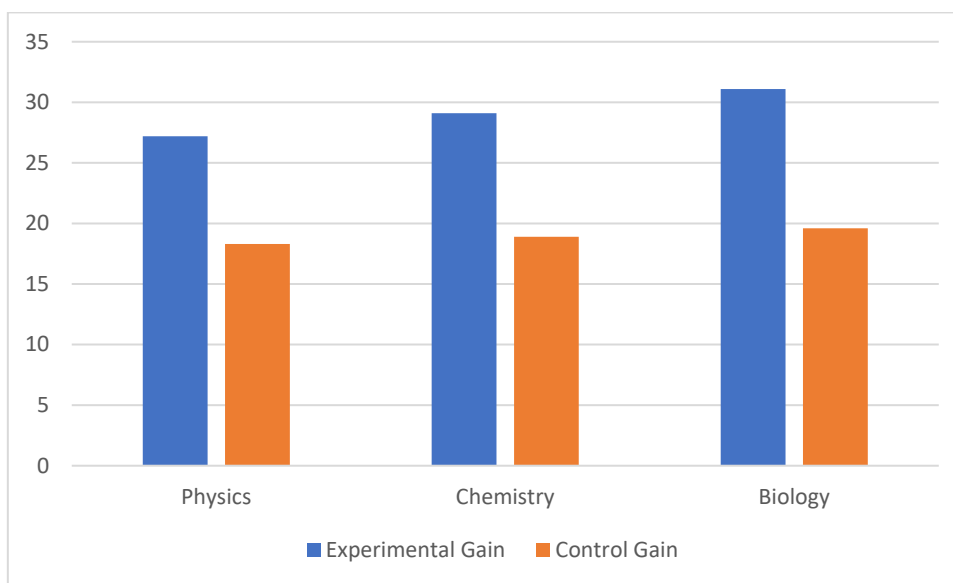


Figure 5: Comparison of Gain Scores Between Experimental and Control Groups

The experimental group will exhibit substantially better improvement on the graph, proving that learning in a controlled environment is beneficial.

3.4. Summary of Statistical Findings

1. Pretest results showed no significant difference between groups.
2. Posttest results showed significant improvement in the experimental group.
3. Gain scores were higher in the laboratory-based learning group.
4. t-test analysis confirmed that the difference was statistically significant at 0.05 level.

4. DISCUSSION

This part provides an analysis of the study's results, draws parallels to other studies, explains what those results mean for education, and then moves on to talk about the study's limitations and potential future research paths.

4.1. Interpretation of Results

The primary goal of this research was to find out how much better students did in Biology, Chemistry, and Physics classes that had laboratory instruction. Students who were taught through laboratory-based learning outperformed those who were taught through more conventional lecture techniques, according to the data¹².

Both the experimental and control groups performed similarly on the pretest. This proves that prior to the intervention, both groups had comparable academic performance. The results of the posttest can be reasonably attributed to the teaching approach, as a result.

Across the board, the experimental group outperformed the control group on the posttest. Students who were able to participate in lab-based learning also fared better in the gain score analysis. At the 0.05 level of significance, the t-test findings validated the discrepancies.

The results indicate that students are more engaged, retain more information, and have a better grasp of concepts when they learn in a laboratory setting. Active participation in experiments and direct observation of scientific phenomena increases the likelihood that students will comprehend and successfully apply abstract notions¹³.

4.2. Comparison with Existing Studies

Previous research in science education has shown results that are in line with this study's. Students' academic performance and comprehension of scientific topics are both enhanced by hands-on practice, according to numerous prior research. In contrast to sitting passively during lectures, students learn more when they participate actively in experiments¹⁴.

Experiential learning improves analytical and problem-solving capacities, according to several research in the field of education. Students that participated in laboratory activities had higher success scores, which is supported by the present study's results.

Having said that, research has shown that unstructured and poorly directed laboratory work may not necessarily boost achievement. One possible explanation for the strikingly good results is the utilization of organized laboratory sessions and well-planned lessons in this study¹⁵.

The results corroborate what is already known from studies on science education: that students perform better in school when they use active learning tactics, such as hands-on labs.

4.3. Implications of the Findings

Several significant consequences for science education stem from this study's findings:

1. **Teaching Practices:** Teachers should incorporate regular laboratory activities into Physics, Chemistry, and Biology lessons rather than relying solely on lectures.

2. **Curriculum Development:** Curriculum planners should ensure that practical work is meaningfully integrated into the syllabus with sufficient time allocation.
3. **School Infrastructure:** Educational institutions should invest in well-equipped laboratories and necessary materials to support effective practical learning.
4. **Student Engagement:** Laboratory-based learning can increase student interest and motivation in science subjects, which may lead to long-term academic improvement.
5. **Skill Development:** Beyond academic achievement, laboratory activities help develop observation skills, teamwork, analytical thinking, and scientific reasoning.

These implications highlight the importance of experiential learning approaches in improving science education outcomes.

4.4.Limitations of the Study

Although the study produced significant findings, certain limitations must be acknowledged:

1. The study was conducted with a limited sample size of 120 students.
2. The intervention only lasted for six weeks, so the results might not be applicable to the long run.
3. The study was limited to Grade 10 students and may not be generalizable to other grade levels.
4. External factors such as teacher effectiveness and student motivation were not deeply examined.

These limitations suggest that the findings should be interpreted with caution.

4.5.Suggestions for Future Research

The following recommendations for further research are made in light of the study's limitations and results:

1. Conduct studies with larger and more diverse samples across different regions.
2. Implement long-term studies to examine the sustained impact of laboratory-based learning.
3. Compare traditional laboratories with virtual or digital laboratory methods.
4. Investigate the effect of laboratory-based learning on different age groups and academic levels.
5. Explore additional variables such as student motivation, gender differences, and teacher competency.

To further understand the significance of lab-based learning in science education, further study is needed in these areas.

The debate provides further evidence that students' academic progress in Physics, Chemistry, and Biology is positively and statistically significantly impacted by laboratory-based instruction. Results show that students' conceptual knowledge and performance are both improved when science lessons include organized practical tasks.

5. CONCLUSION

This section presents the overall findings of the study and highlights the importance of laboratory-based learning in science education. It summarizes the major outcomes and provides final recommendations based on the results.

5.1. Summary of Key Findings

This study looked at how secondary school students' performance in physics, chemistry, and biology changed once they started learning in labs. To compare students taught using laboratory-based instruction against those taught using standard lecture methods, a quasi-experimental design was utilized.

According to what the research found:

1. The pretest results showed no statistically significant difference between the control and experimental groups, suggesting that their pre-intervention academic levels were comparable.
2. After the teaching period, the experimental group showed significantly higher posttest scores in all three subjects compared to the control group.
3. The gain scores demonstrated that students exposed to laboratory-based learning showed greater improvement in academic achievement.
4. The t-test, a statistical tool, verified the significance of the differences at the 0.05 level.

These results clearly indicate that laboratory-based learning positively influences students' academic performance in science subjects.

5.2. Significance of the Study

The findings of this study add to our knowledge of what works in science classrooms as a teaching tool. It provides empirical evidence that practical, hands-on learning enhances students' understanding and academic achievement in Physics, Chemistry, and Biology. The significance of the study lies in the following aspects:

- It stresses how important it is to incorporate hands-on learning into traditional classroom lessons.
- It promotes a change in emphasis from instructors to students in the classroom.

- It emphasizes the role of experiential learning in improving conceptual clarity and retention.
- It provides useful insights for teachers, curriculum planners, and educational administrators in improving science teaching practices.

5.3.Final Thoughts and Recommendations

The study's conclusions suggest that science educators should stop viewing hands-on experience as an extracurricular activity and start including organized laboratory activities into their lesson plans. Successful experimentation requires well-appointed labs, enough supplies, and enough time, all of which should be provided by educational institutions. To guarantee the effective implementation of laboratory-based instruction, teacher training programs should also prioritize the development of practical teaching abilities. When it comes to raising the bar for science education and raising student performance in the classroom, laboratory-based learning is indispensable.

REFERENCES

1. Ogiga, E., & Alu, B. D. (2025). Laboratory-Based Instruction and Academic Performance of Chemistry Education Students in Universities in Rivers State. Faculty of Natural and Applied Sciences Journal of Mathematics, and Science Education, 6(3), 40-46.
2. Bazie, H., Lemma, B., Workneh, A., & Estifanos, A. (2024). The effect of virtual laboratories on the academic achievement of undergraduate chemistry students: Quasi-experimental study. JMIR Formative Research, 8(1), e64476.
3. Libata, I. A., Hassan, H., & Muhammed, R. (2025). Evaluating The Effectiveness Of Laboratory-Based Instruction On Female Students' attitude And Academic Performance In Chemistry In Kontagora, Niger State, Nigeria. Fudma Journal Of Sciences, 9, 92-96.
4. Okam, C. C., & Zakari, I. I. (2016). Impact of laboratory-based teaching strategy on students' attitudes and mastery of chemistry: An experimental study. Journal Of Creative Writing (ISSN-2410-6259), 2(2).
5. Kyakuwa, J. (2017). The effect of laboratory exposure on students' academic achievement in practically based subjects in secondary schools in Wakiso District.
6. Ijaz, M., Ali, S., & Javid, M. A. (2023). Investigating Academic Achievements in Chemistry at the Secondary School Level through a Laboratory-Centred Instructional Approach. Journal of Educational Research and Social Sciences Review (JERSSR), 3(3), 21-28.
7. Ogiga, E. (2025). Effects of Laboratory-Based Instruction on Retention Among Chemistry Education Students in Universities in Rivers State. Faculty of Natural and Applied Sciences Journal of Mathematics, and Science Education, 7(1), 50-57.
8. Chikendu, R. E., & Okoli, C. S. (2025). EFFECT OF HANDS-ON LABORATORY PRACTICAL ACTIVITIES ON SECONDARY SCHOOL STUDENTS' ACADEMIC

- Achievement In Chemistry In Awka Education Zone. South Eastern Journal Of Research And Sustainable Development (Sejrds), 18(1), 51-66.
9. Avwiri, H. E., & Odiri, O. E. (2025). Effects of Using Virtual Laboratory Experiments on Students' Achievement in Chemistry. ETDC: Indonesian Journal of Research and Educational Review, 4(2), 275-284.
 10. Ghandi, I. G., & Deghilipulu, U. (2025). The Effect Of Equipped Biology Laboratories On Students' Academic Achievement In Secondary Schools In Yenagoa, Bayelsa State, Nigeria.
 11. Sabri, K. S., & Emuas, A. H. M. (1999). The relationship between school laboratory experiments and academic achievement of Palestinian students in introductory university science courses. Research in Post-Compulsory Education, 4(1), 87-96.
 12. Ojediran, I. A., Oludipe, D. I., & Ehindero, O. J. (2014). Impact of laboratory-based instructional intervention on the learning outcomes of low performing senior secondary students in physics. Creative Education, 5(4), 197-206.
 13. Akani, O. (2015). Laboratory Teaching: Implication on Students' Achievement in Chemistry in Secondary Schools in Ebonyi State of Nigeria. Journal of Education and Practice, 6(30), 206-213.
 14. Salisu, A. D., & Samuel, I. R. (2025). Effect Of Laboratory Approach on Interest and Achievement of Students in Energy Concepts in Keffi, Nasarawa State Nigeria. International Journal of Modeling and Applied Science Research.
 15. Akeem, A. A., Ojochide, O. J., Omonogu, O. E., Ndanusa, K. B., & Joseph, T. O. (2025). Fostering Students' performance and Interest In Quantitative and Qualitative Analyses of Chemistry Practicals Through Laboratory-Based Strategy In Secondary Schools In Kogi State, Nigeria. African Journal of Educational Management, Teaching and Entrepreneurship Studies, 15(2).