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IMPACT OF LABORATORY-BASED INSTRUCTIONAL LEADERSHIP ON CHEMISTRY TEACHERS' PEDAGOGICAL EFFECTIVENESS AND STUDENTS' PERFORMANCE IN SECONDARY SCHOOLS IN NIGERIA- A LITERATURE REVIEW

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ABSTRACT

This review investigates the link between laboratory-based instructional leadership, chemistry teachers' pedagogical effectiveness and students' achievement in secondary schools in Nigeria. It uses a narrative literature review method, drawing on concepts and empirical studies relevant to the problem. The literature was synthesized comparatively to identify commonalities, areas of convergence, and gaps across the research strands. Based on the review, the most significant findings are that the efficacy of laboratory instruction has an impact on students' conceptual understanding, science process skills, attitudes, and the academic achievement of the students, and the obstacles that must be overcome are: the inadequacy of laboratory facilities, the weak science process skills in utilizing resources, the weak pedagogical competence and the weak science process skills in supporting students' instruction. It also suggests that principals' instructional leadership, specifically in setting goals, monitoring, supervising, providing professional development, and managing resources, can enhance teachers' pedagogical effectiveness. The review's most valuable contribution is bringing together previously disjointed aspects of the literature to create a new concept of instructional leadership in the laboratory and clarifying the path for empirical evidence linking school leadership, teachers' pedagogical effectiveness, and students' chemistry learning outcomes. The review therefore laid the foundation for empirical testing of the conceptual basis and for enhancing chemistry instructional practices, laboratory management, and leadership practice in secondary schools in Nigeria.

Keywords: Laboratory-Based Instructional Leadership, Chemistry Education, Pedagogical Effectiveness, Laboratory Instruction, Student Performance, Secondary Schools

1.0 INTRODUCTION

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Science plays a crucial role in every country's educational goals because scientific knowledge and skills underpin technological development, industrial productivity, and national welfare. Nigeria's National Policy on Education reflects this belief, highlighting science subjects in school curricula as an intentional policy to drive technological and economic development (Hashimi, 2018). Chemistry is generally considered a core basic science and an essential tool for a country's socioeconomic and technological development, especially in relation to national development (Uwague, 2019). It is found in nearly every aspect of life in the country, including industries, agriculture, health care, manufacturing, and so on (Shamsuddin et al., 2017). Chemistry education therefore plays an important role in development by building human capacity, developing the skilled human resources needed for modernization, and empowering people to participate meaningfully in a knowledge-based economy (Ayodele, 2018). However, despite producing many scientists and engineers, Nigeria still relies heavily on science and technology experts from outside the country, partly because of weaknesses in the foundation laid at the secondary school level (Ayodele, 2018). The above scenario makes chemistry education in secondary schools in Nigeria a national concern, and the chemistry teacher a pivotal player in whether the foundation is built or broken. Because chemistry is an empirical and practical field of study, the quality of chemistry teaching is also linked to the quality of laboratory activities. In chemistry, knowledge claims are confirmed through observation, experimentation, measurement and manipulation of materials. Through these activities, students develop science process skills that characterize meaningful scientific literacy (Jack, 2018), namely: observing, classifying, measuring, inferring, predicting, and interpreting data. Evidence from the laboratory shows that laboratory work supports conceptual understanding and improves achievement in science education (Ogunkunle & Akinsola, 2020). For example, Shana and Abulibdeh (2020) found that students taught through intensive practical work improved significantly in attainment scores compared with students taught through traditional methods, and they recommended that secondary schools provide sufficient opportunities for students to attend practical lessons. Likewise, in Tanzania, students who learned chemistry through practical work achieved higher scores than those who did not; thus, practical engagement is important for understanding chemistry concepts (Afyusisye & Gakuba, 2022). In addition, science education research shows that other school-level factors, including laboratory adequacy and instructional materials, are linked to students' achievement in science subjects (Sibomana et al., 2021).

This also aligns with the Nigerian context. Niger State, Nigeria, in Kontagora, a study showed significant improvement in the performance and attitude of female students who were educated through a laboratory approach compared to those who were educated through a conventional approach (Libata et al., 2025). A laboratory-based teaching strategy also enhanced students' problem-solving skills, rate of learning, and approach to scientific enquiry compared with those taught using the conventional approach in Ekiti State (Famuwagun et al., 2024). All this indicates that the laboratory is not an adjunct to the teaching of chemistry but a tool through which meaningful chemistry learning takes place. Students have more opportunities to develop

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the conceptual and practical skills essential in chemistry if such laboratories are functional, well-equipped, and well exploited.

Unfortunately, some secondary schools in Nigeria have weak laboratory facilities that are non-functional or poorly utilised. Igwe and Okeke (2023) evaluated the correspondence between chemistry laboratory facilities and equipment in secondary schools in Anambra State and the required standard, based on an assessment of 79 equipment items; 41 did not correspond, while 38 did. Although facilities like running water, proper electricity supply, chemical storage rooms, preparatory rooms, and fume cupboards were insufficient, the studied schools lacked dark room facilities.

An assessment of material resources available for teaching chemistry in Rivers State revealed that some secondary schools had limited science materials and that the available resources were not utilised effectively (Arokoyu & Ugonwa, 2012). These issues are also reported in other science subjects. Materials for the Biology laboratory in Ilorin were available only to some extent and were used to a limited extent (Alabi et al., 2025), and for the Physics laboratory, materials were also available and used to a limited extent (Tamunoiyowuna & Omeodu, 2022). One challenge teachers in Ohafia Education Zone, Abia State, face is an inability to improvise in teaching and a lack of manipulative skills (Obiyo & Inyama, 2019). Laboratory facilities were reported to be inadequate in Ibadan Less City; students' achievement in chemistry practical was also low, while laboratory facilities were not found to be good predictors of students' learning outcomes ($\beta = .022$, $p > .05$) (Ogundiji, 2025). This problem has been reported elsewhere. For instance, Pareek (2019) found that the schools that were studied lacked adequate laboratory resources, and Safani et al. (2025) reported that gaps in laboratory availability and utilization affected science learning in Kenya. The findings show that limited laboratory facilities remain a barrier to effective practice in practical science.

The failure to teach and learn chemistry has cumulative effects, as shown by students' inconsistent performance in public examinations. The performance pattern of students in Chemistry, based on the results of the WASSCE, was unstable, as observed from the analysis of this result on the senior school certificate examination (SSCE) of West African examinations over a Period of 21 years (1999 – 2019), the number of students who enrolled for the examination got about 50.84% credit pass and above. Earlier examination data for the May/June WASSCE between 2005 and 2011 showed credit-level performances in chemistry of 50.94%, 44.90%, 45.96%, 44.44%, 43.69%, 49.65%, and 48.68%, respectively (Gambari et al., 2016). Likewise, data analysed by Ezeliora et al. (2021) showed that the proportion of candidates receiving credit passes in Chemistry was less than 50% for 2007–2012, except in 2011. In some later years, the proportion of candidates with difficulties in the subject decreased, but over many years, it remained high. Ezeliora and others (2021) also reported weaknesses among Chemistry students in concepts such as acids, bases, acid-base reactions, titration, and calculations using molar and mass concentrations. Earlier Chief Examiners' reports also

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showed a lack of skills in data interpretation, numerical calculations, inferences, recording scientific observations, and conducting qualitative chemical analysis (Jack 2018). These competencies are very much linked to meaningful exposure to laboratory-based instruction.

Efforts have been made to account for why students have difficulties with chemistry. The issue is partially blamed on teaching practices and teacher professional competence. Nbina (2012), for instance, attributed low performance and negative student attitudes to the way chemistry is taught and stressed the need for qualified, professional teachers to produce competent students. Other studies have identified inadequacies in science resources, school conditions, and instructional arrangements as factors that affect students' achievement in chemistry (Nja et al., 2022). Broader evidence also identifies teacher quality and the availability of appropriate learning resources as factors influencing students' achievement in science subjects (Sibomana et al., 2021). The common denominator in these explanations is that the teacher translates what is available into meaningful learning experiences. The chemistry teacher needs to plan laboratory activities, make improvisations as needed, direct students in laboratory tasks, and make pedagogical decisions that affect the acquisition of science process skills.

This puts emphasis on the question of the pedagogical effectiveness of chemistry teachers, as their ability to identify learning needs of students, choose learning activities that are pedagogically appropriate, and organize learning activities that meet the instructional goals (Malik et al., 2025). Studies show that teachers need the necessary professional knowledge, pedagogical skills, and academic competence and should be academically and professionally equipped to carry out instructional processes effectively (Ololube, 2006). It is also found that teachers' pedagogical competence affects students' attitudes toward science (Adegbola, 2019). Additionally, PD can enhance teaching methods, boost teacher confidence, and enhance student participation and performance in science education (Fakai et al., 2024). The pedagogical effectiveness of chemistry teachers should not be seen as a single quality, but as a quality to be evaluated within a framework of dialogue about the teaching of chemistry. The pedagogical effectiveness of chemistry teachers should therefore not be understood as a property of the teacher alone. Institutional and occupational conditions in schools, such as principals' instructional leadership, can also reinforce or restrict it.

Instructional leadership is important here. Instructional leadership is the set of behaviours school leaders use to facilitate teaching and learning, including designing learning objectives, supporting teachers, coordinating teaching activities, supervising teaching, and providing conditions for effective learning (Malik et al., 2025). Hallinger and Murphy (1985) developed the most influential conceptual model of instructional leadership. Their model is based on three main professional areas of instructional leadership: setting the school mission, organizing the instructional programme and establishing a positive school learning climate. These include framing and communicating school objectives, supervising and evaluating instruction, coordinating the curriculum, monitoring student progress, safeguarding instructional time,

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fostering professional development, keeping the school visible, and incentivizing teachers and students (Hallinger & Murphy, 1985). This framework eventually became the basis for the Principal Instructional Management Rating Scale and has been widely used in instructional leadership research globally (Al Sharafat et al., 2024; Hallinger et al., 2020; Shava et al., 2021).

Extensive empirical research links instructional leadership practices to teacher effectiveness and other educational outcomes. Instructional leadership has demonstrated a positive and significant link with teachers' effectiveness in Pakistan, with the head teachers' instructional leadership accounting for a significant portion of the variance in teachers' effectiveness (Malik et al., 2025). In Nigerian secondary schools, principals' instructional leadership related to school mission, instructional programmes, and learning climate was positively correlated with teachers' effectiveness among teachers in public secondary schools in the North Central geopolitical zone (Bada et al., 2024). Similarly, in private secondary schools in South East Nigeria, instructional supervision and curriculum implementation were strongly positively correlated with teacher effectiveness (Ezumah et al., 2025). Ahmad and Rizvi (2026) also reported relationships between instructional leadership, teacher effectiveness, and student academic resilience at the secondary school level. Moreover, principals who give clear instructional guidance, monitor teaching, foster teacher cooperation, and pay attention to student learning have been linked to better teaching effectiveness (Zeb et al., 2025).

However, when the focus narrows to science instruction, the leadership challenge becomes more complex. Science reform-oriented principals were also found to have limited understanding of science practices and were sometimes aware of good science teaching only in the context of general hands-on activities that lack attention to the science practices characteristic of authentic science learning, as per McNeill et al. (2018). The researchers thus stressed the need to build school leaders' understanding of scientific practices so they can supervise science learning effectively. Based on this, Avwiri and Okey (2022) suggested that conventional personnel supervision might not be enough for science teachers to achieve the goals of science teaching because it fails to address science process skills, subject specialization, teacher creativity, and the products of scientific activities. They therefore offered a Scientific Supervision Model which emphasizes the special characteristics of science teaching.

Despite the above, principals are key stakeholders in successful curriculum implementation because they encourage, supervise, and lead the curriculum (Chala, 2019). However, empirical evidence suggests that not all implementations of effective practical work in schools meet the expected quality (Chala, 2019). Research on principals' supervisory practices in Nigeria also indicates that while care taken in teachers' attendance, preparation of lessons, and records of work are often emphasized, the provision of instructional materials, giving professionals feedback, providing teachers with reference materials, and systematically reviewing the activities may receive comparatively less attention (Ayeni, 2012). However, positive links have

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been reported between principals' management practices and their teachers' service delivery (David West & Kaegon, 2017). Dimensions of teacher professional autonomy have also been linked with instructional leadership (Ay & Boz, 2022).

Together, these studies reveal three significant but distinct avenues of research. First, laboratory-based teaching can enhance students' achievement, attitude and chemistry practice (Famuwagun et al., 2024; Libata et al., 2025; Shana & Abulibdeh, 2020). Secondly, laboratory facilities at secondary schools in Nigeria are often in poor condition and poorly equipped (Arokoyu & Ugonwa, 2012; Igwe & Okeke, 2023; Obiyo & Inyama, 2019). Third, teacher leadership relates to teacher effectiveness and other educational outcomes (Bada et al., 2024; Malik et al., 2025; Zeb et al., 2025). However, the integration of these strands has not been discussed in depth in the context of instructional leadership specifically targeting the laboratory aspect of chemistry teaching. Previous research has focused on instruction broadly, laboratory resources alone, or teacher effectiveness, without attention to the specific leadership requirements of practical chemistry instruction. Conceptualization and empirical investigation of the role of instructional leadership in the lab are thus needed, including the setting of goals for practical science, organizing the delivery of the practical science curriculum, supervision and evaluation of lab instruction, practical science-related professional development, support of lab provision and management, and development of practical competencies.

The gap is significant because it shows that the context in which chemistry teachers teach, and students learn, partly depends on decisions made at the school leadership level. The aforementioned issues extend beyond just teachers and students; they highlight challenges in the use of laboratories in Nigerian schools that affect students' science process skills as well as the fluctuation in WASSCE chemistry performance (Arokoyu & Ugonwa, 2012; Obiyo & Inyama, 2019; Jack, 2018; Ezeliora et al., 2021; Obafemi & Ugonwa, 2025). School priorities, resource allocation and management, supervision of instruction, professional development, and monitoring of laboratory activities can affect the quality of practical chemistry teaching. In view of this, the present study examines the role of instructional leadership in chemistry teachers' pedagogical effectiveness and students' performance in secondary schools in Nigeria, aiming to provide evidence-based information to enable principals, education planners, and policymakers to strengthen the leadership aspect of practical science education.

2.0 REVIEW OF RELATED LITERATURE

The review critically summarizes the conceptual and empirical literature on laboratory-based instructional leadership, the pedagogical effectiveness of chemistry teachers, and student performance in secondary schools in Nigeria. The eight strands of literature reviewed below are mutually related: instructional leadership provides the framework for administering and supervising science teaching, the curriculum is implemented in the laboratory, and academic achievement is the outcome of interest. The strands are examined, taking into account international evidence and the Nigerian specificity.

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a. Laboratory-Based Instructional Leadership

The traditional meaning of instructional leadership refers to practices in which school leadership sets the school mission, aligns curriculum and instruction, and oversees teaching and learning (Heck et al., 1990). In the context of the science laboratory as a place of instruction, these practices can be viewed as what might be called "laboratory-based instructional leadership," which is an emergent construct in which laboratory resources are provided and managed, practical work is coordinated, lab-based teaching is supervised, and teachers' competence in conducting experiments is developed. While the construct is not yet a distinct body of literature, some emerging literature on science Heads of Department and Principals in Africa draws on its content.

The science Head of Department case studies are examples of the type of instructional leadership that takes place in science labs. In Lesotho, some HoDs indicated that they very often used science goal planning, communication, curriculum coordination, monitoring learners' progress, teaching time management, and the availability of instructional resources as pedagogical activities. Pedagogical activities reported as less frequently used included classroom observation, formal written feedback, and systematic evaluation of teacher learning, suggesting a preference for administrative over pedagogical instructional leadership (Lisene et al., 2026). Similar outcomes were observed in South Africa, where science HoDs' instructional leadership capacity was limited by a lack of differentiation between curriculum management and instructional leadership and insufficient time spent on leadership roles (Malinga et al., 2021). In low-resource settings, the laboratory aspect of this leadership is especially demanding because most of the sampled schools in South Africa did not have a laboratory or a well-equipped one; practicals needed to be conducted in schools equipped with less-than-ideal apparatus, such as relying on equipment from neighbouring schools for use (Malinga et al., 2021). In distributed leadership contexts, science and mathematics HoDs also served as instructional leaders, subject specialists and classroom leaders, and leaders responsible for learners' performance in their subject area/school/science and mathematics department (Malinga et al., 2021; Munje et al., 2020).

Leadership in Nigeria is similar, comprising principals, vice principals, head teachers, assistant head teachers and heads of department; the principals are responsible for the day-to-day operations of schools (Bush et al., 2021). This relationship has been shown at scale, using data from 248,620 students and 9,370 principals in 35 countries from the PISA 2015 assessments, principals' more positive leadership (in the sense of vision, instructional management, professional development, and empowerment) was found to be related to the higher science resources, greater students' enjoyment and interest in science, and higher science achievement in schools (Tan, 2023). In areas where laboratories are not well equipped, principals have devoted their leadership to advocating for budgets, increasing access to teaching materials, and maintaining communication with stakeholders (Mariani & Suyud, 2024). In addition,

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principals play a critical role in implementing the curriculum, such as practical work, as schools that support innovation are likely to have teachers who are more active in their practical teaching (Chala, 2019). Meanwhile, a lack of positive leadership commitment (with dysfunctional school culture, inadequate funding, and a lack of a shared vision of high-quality instruction) is cited as a significant challenge to improving teaching quality in secondary schools in Nigeria (Onyekwelu, 2024). The present study addresses this gap by investigating whether laboratory-based instructional leadership is a viable – and largely unexplored – pathway by which science teachers can influence scientific outcomes.

b. Instructional Leadership

Instructional leadership theory states that school leaders can affect students' achievement mainly by creating a positive teaching climate and enhancing teachers' motivation and capability (Hou et al., 2019). In an early study, Heck and colleagues showed that three latent dimensions of principal instructional leadership (school governance, instructional organization and school climate) were related to student achievement after accounting for contextual variables (Heck et al., 1990). More recent reviews also have found that instructional leadership has a mostly indirect impact on achievement, and that achievement effect sizes differ across cultural contexts (Hou et al., 2019).

Empirical evidence for the achievement effects of instructional leadership exists only in science. Instructional leadership was found to have moderate positive relationships with Physics, Chemistry and Biology achievement in 6 districts of Balochistan, Pakistan, where it explained 46% of the variance in Physics achievement, 38% of the variance in Chemistry achievement, and 49% of the variance in Biology achievement (Yasmeen, 2023). The head teacher effectiveness pathway is also clear, as teachers' effectiveness was significantly correlated with head teachers' instructional leadership ($r = .65$), and head teachers' instructional leadership explained 48% of the variance in teachers' effectiveness at the secondary level (Malik et al., 2025). Instructional leadership practices and teacher effectiveness among school heads in public secondary schools in Karachi were found to be significantly and positively related to pupils' academic resilience (Ahmad & Rizvi, 2026). The results point to the same mediation process: better classroom teaching leads to better student outcomes, which leads to better instructional leadership.

In sub-Saharan Africa, however, policies and practices are at odds. Bush and colleagues noted that, at the leadership level, principals in countries like Sierra Leone, Sudan, Zambia, and Zimbabwe are characterized as instructional leaders, but there are unclear expectations of middle leaders in some systems, and in some schools, teachers think heads are expected to be more involved in administrative tasks than in teaching. (Bush et al., 2021) This context highlights the ambiguous nature of school leadership in Nigeria in relation to administrative compliance and instructional coordination and calls for empirical study of the effects of leadership behaviours on the science classroom.

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c. Chemistry Teachers

Chemistry teachers are key to implementing chemistry education, serving as the link between students and content; they are directly involved in the teaching and learning process and responsible for implementing the content. A correlational study was conducted in Adamawa State, Nigeria, involving 35,525 SS II students and 834 chemistry teachers, which revealed that the teachers had moderate pedagogical skills, which were significant in predicting the academic performance of the students, while the subject matter knowledge and instructional competence of the teachers were found to be critical factors in determining students' performance in chemistry (Bakari et al., 2025). Similarly, there was a strong positive correlation between teacher effectiveness and chemistry achievement in Pakistan ($r = .846$), which accounted for 71.5% of the variation in chemistry achievement (Akram & Kamran, 2025). The qualification of chemistry teachers and years of experience had a significant effect on academic achievement of students in Bayelsa State (Cleopas & Onwuchekwa, 2024); whereas, a study conducted in Kwara State, indicated that the effect of the chemistry teacher on the academic performance of the students was significant in terms of academic qualification, but not significant in terms of gender (Omosholape & Atinuke, 2022).

Chemistry teachers' roles are unique. Many concepts crucial to subsequent learning in chemistry are abstract and difficult for students to understand, such as the structure of matter, moles, and chemical bonding (Uzezi et al., 2017). In chemistry teaching, integrated pedagogical content knowledge is the teacher's ability to convert subject content into forms students can comprehend (Kind, 2009). Chemistry teachers must also master science process skills and create test and lab exercises based on them (Hikmah et al., 2018). It can be inferred from the Nigerian evidence that these skills are not shared equally amongst all chemistry teachers, as the level of implementation of this competencies was generally low with over 30% of the teachers leaving out some of the difficult concepts and there was a significant difference between teachers perception on the problems of implementation and the availability of the chemistry material resources ($t = 3.01$, $p = 0.03$) (Olubunmi & Aarinola, 2022). Student weaknesses in Chemistry practical examinations have been observed by the WAEC chief examiners, with some pointing out that students are only expected to "make do with observation rather than doing" (Nigeria, 2013). They suggest that both teacher capacity and professional development systems that underpin it are implicated, with the Nigerian teachers and HoDs viewing regular and consistent professional development as essential for classroom improvements (Ajani, 2022), while ongoing training workshops, mentorship programmes, and protected learning time for teachers to learn new techniques and skills are identified as strategies that have shown to have significant impacts on the quality of secondary education in Nigeria (Onyekwelu, 2024).

d. Pedagogical Effectiveness

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Pedagogical effectiveness is teachers' ability to create learning, measured by their pedagogical skills in teaching and learning, including clarity in content delivery, selection of appropriate teaching methods, pedagogical assessment skills, pedagogical communication skills, and classroom management (Akram & Kamran, 2025). At its heart, PCK is the process of linking content knowledge and pedagogical knowledge, enabling teachers to anticipate potential learner difficulties, choose representations, and adjust their instruction (Kind, 2009). In the context of the Nigerian context, Ogun State, a study was conducted to show that teachers' pedagogical content knowledge and competence in practical skills had a significant positive effect on students' academic performance; the competence in practical skills had a positive effect on students' understanding of biological concepts and overall performance (Onipede et al., 2025). The logic of that study applies beyond biology, and in a chemistry laboratory, it is appropriate to assess practical skills competence through laboratory work.

Laboratory-oriented pedagogical effectiveness is trainable. Research on teacher education (Hidayah et al., 2023) found that PCK for laboratory activities can be strengthened by designing activities using small-scale approaches in chemistry practicum. Experienced chemical demonstrators also have a larger repertoire and greater adaptive capacity to teach basic chemistry concepts than novices (Clermont et al., 1994), and are more aware of how demonstration complexity can hinder learning.

Leadership is a key factor in pedagogical effectiveness, which is not a teacher attribute. Head teachers' instructional leadership is significantly related to teacher effectiveness ($r = .65$) (Malik et al., 2025), while instructional leadership practices positively predict teacher effectiveness and students' academic resilience (Ahmad & Rizvi, 2026). For the present study, this implies that promoting pedagogy in chemistry classes should be integrated into teachers' effectiveness before it affects the student learning process. This pathway is further supported by Bakari et al. (2025), who found that even moderate pedagogical skills significantly predict chemistry achievement, and that leadership and professional development (Onyekwelu, 2024) can facilitate improvements in chemistry learning outcomes.

e. Students' Academic Performance

Students' achievement in chemistry is typically measured by scores from school tests and public examinations, especially the West African Examination Council and National Examination Council exams. The Nigerian situation is alarming: the percentage of credit passes in WAEC May/June chemistry in the last seven years (2008-2014) was low for the majority of the years reviewed, and the comments made on the chemistry results of the last 10 years (2007-2018) indicated a continuous drop in performance. These factors include ineffective teaching process, poor laboratory facilities, inadequate numbers of learning facilities when student's population is on the increase (Ibe et al, 2021), teacher variables, student variables, environment related variables (Edomwonyi-Otu & Avaa, 2011), laboratory adequacy, instructional materials

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and chemistry practicals and their behavior which have demonstrated significant positive correlation with achievement (Sibomana et al, 2021).

Studies on interventions and methods show that performance is malleable. Students taught using a laboratory-based teaching strategy performed better than their peers taught in a traditional classroom in Ekiti State in problem-solving skills, rate of learning, and methods of scientific enquiry, while there was no difference between them in terms of gender performance (Famuwagun et al., 2024). The laboratory activity method had a significant positive effect on improving the interest and achievement of 314 SS I students in Cross River State compared with the conventional method (Ekpo & Mfam, 2025). At the local level, in Niger State, the laboratory-based teaching had positive effects on female students' performance and attitudes (Libata et al., 2025). Enriched lecture and guided discovery methods significantly improved performance over the conventional teaching method in Kogi State, while a gender difference in favour of male students emerged (Omale et al., 2025). At the system level, Zafeer et al. (2024) used structural equation modelling across 210 secondary schools in Punjab and found that laboratories, curriculum, and teacher quality significantly and positively affect students' achievement in science subjects. Taken together, these findings provide a basis for a proximal analysis of instructional and resource environments that enhance chemistry performance, including laboratory-based instructional methods, and for why leadership is an antecedent to examine.

f. Chemistry Education

Chemistry is a privileged area in Nigeria's science curriculum. Chemistry is considered a key science for scientific advancement and a necessary subject for medical, pharmaceutical, applied science, and engineering (ajasse) professions (Nja et al., 2022; ajasse, 2019). It is taught as a single subject in the final three years of secondary level of education (senior secondary school) (Uzezi et al., 2017), and the National Policy on Education emphasizes science education in general and chemistry in particular (Uzezi et al., 2017).

However, Nigeria's chemistry education has been reported to face structural and professional problems in delivery. These include inadequate and untrained chemistry teachers, poor power supply and infrastructure, a defective curriculum, examination malpractice, laboratory hazards, and non-professionalism (Ajasse, 2019). Qualitative evidence and survey responses point to a combination of teacher-, student-, and environment-related factors, which is responsible for the persistent poor performance and hence, the need for teachers, school administrators, and curriculum planners to re-engage students' interest in learning chemistry and create an enabling environment for effective chemistry instruction (Edomwonyi-Otu and Avaa, 2011).

The above challenges are further complicated by the abstraction of the concept in the Chemistry curriculum, as students are unable to apply the concepts that they have learnt (Uzezi et al., 2017), and the implementation of the curriculum is further undermined when material resources

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are less than adequate, and teachers are not knowledgeable of the content matter (Olubunmi & Aarinola, 2022). Science process skills are important dimensions of scientific enquiry (Nigeria, 2013), and chemistry teachers need to know and explicitly teach these skills (Hikmah et al., 2018); hence, the quality of practical-oriented chemistry education and the leadership that ensures the continuation of laboratory work in chemistry education is of primary importance to the health of chemistry education in Nigeria. Science labs are seen as having a direct impact on students' attitudes and performance in school across the globe, and the quality of the learning experience depends on the quality of the laboratory facilities and their effective use by the teacher (Pareek, 2019).

g. Laboratory Instruction

Laboratory instruction is a pedagogical channel that helps chemistry students connect concepts and theory with phenomena. The systematic review of the research literature presented in this report indicates that laboratory investigations are important opportunities for meaningful science learning, and that the evidence from meta-analyses overwhelmingly favours student-centred, inquiry-based laboratory education over teacher-centred laboratory education (Gericke et al., 2022). The review is based on the following meta-analyses of inquiry teaching: A moderate effect size for inquiry teaching was achieved across 37 studies (Hedges' g = 0.5); and improved learning outcomes for inquiry-based learning across 13 studies (Hedges' g = 0.7) and a very large impact of hands-on science activities on science achievement (Hedges' g = 1.55) across 15 Turkish studies (Gericke et al., 2022). This evidence emphasises the pedagogical effectiveness of good laboratory work in chemistry.

Experimental studies in Nigeria support the international findings. The laboratory activity method achieved improvement in interest and achievement in Cross River State (Ekpo & Mfam, 2025); the laboratory-based teaching showed improvement in problem solving, rate of learning and scientific enquiry among learners in Ekiti State, with no gender difference in achievement (Famuwagun et al., 2024); while laboratory-based instruction showed significant improvement in performance and attitudes of female chemistry students in Niger State (Libata et al., 2025). Under laboratory conditions, the laboratory approach outperformed the lecture approach, with gender held constant, among tertiary-level chemistry education students in Rivers State Universities (Ogiga & Alu, 2025).

However, laboratory facilities and their use in Nigerian schools are invariably inadequate. Junior secondary schools in Osun State were short of basic laboratory equipment, as 40.0% of them were without beakers, boiling tubes, conical flasks and cylinders, while teachers in the schools did not use the laboratory facilities in their teaching activities, and students rarely performed practical activities (Olajide et al., 2017). In most schools surveyed in the Southwest region of Nigeria, although the laboratories were functional, they did not meet the expected standard of at least two periods of practical work per week; also, most teachers did not use the educational materials provided (ADEUYA & AMIRE, 2020). Similar findings were

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documented for low utilisation of biology laboratory materials despite their partial availability in Ilorin (Alabi et al., 2025), and physics teaching materials in Senior Secondary Schools in Nigeria (Akinbobola et al., 2019). These utilization deficiencies have profound implications for leadership. Classrooms are poorly equipped, as in South Africa, where HoDs borrow burettes (Malinga et al., 2021). Teachers are not trained to compensate for poor facilities; instructional leadership is crucial to the quality of chemistry instruction (Oliveira & Freitas, 2025).

h. Secondary Schools

Despite continuous policy change and instability in secondary education, Nigeria's secondary education pattern has shifted from the pre-independence 7-5-2-3 pattern to 6-3-3-4 and now to 1-6-3-3-4.The secondary education sector has undergone successive, systematic changes, from pre-independence Nigeria's 7-5-2-3 system to 6-3-3-4 to date, and now to the 1-6-3-3-4 pattern, all of which show that the sector has been characterized by continuous policy change and instability. It is a structure that consists of nine years of basic education (six years of primary and three years of junior secondary), which is controlled by concurrent federal and State authorities, and the Universal Basic Education Commission and State Universal Basic Education Boards are responsible for compulsory basic education (Dele-Ajayi & Taddese, 2020). These are the declared aims of secondary education in the Federal Republic of Nigeria: to give a diversified curriculum which takes into consideration differences in talents and future roles; to supply trained human resources in the applied sciences and technology; and to ensure self-improvement and rational and independent thinking (Akporehe et al., 2023).

Instructional leadership is enacted in secondary schools, where principals, vice principals, head teachers, assistant head teachers, and heads of department oversee school administration (Bush et al., 2021). Nigerian secondary education, however, faces systemic constraints: poor funding, dysfunctional school culture, weak commitment of leaders to professional development, and the absence of a shared vision of high-quality teaching and learning, which hinder teacher professional development and, consequently, the quality of education (Onyekwelu, 2024). The senior secondary level covers the final three years of senior secondary education and is the crucible where instructional leadership (in the laboratory), chemistry teachers' pedagogical effectiveness, and students' chemistry performance intersect. However, the conditions that might support the implementation of laboratory activities, which include the presence of well-equipped facilities, laboratory sessions, trained teachers, and supportive leaders, vary from school to school within the federation (ADEUYA & AMIRE, 2020; Olajide et al., 2017), as this study aims to uncover.

3.0 SYNTHESIS

The consulted material provides a consistent (though incomplete) picture. Teachers' pedagogical effectiveness, which is grounded in PCK and practical-skills competence,

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significantly influences student performance; laboratory instruction is a powerful pedagogical mode for chemistry learning; chemistry teachers' use of laboratories is underutilised; and Nigeria's secondary schools, where this interplay occurs, have systemic leadership and funding constraints, compounded by resource scarcity. What is largely lacking is a study that investigates the relationship between these strands as an empirical link, with the relationship between the two being at the level of instructional leadership exhibited by chemistry teachers and their pedagogical effectiveness and the relationship between the latter and the downstream effect of the teacher's pedagogical effectiveness on students' chemistry performance in Nigerian secondary schools. The current study aims to fill this gap.

4.0 CONCLUSION

Based on the literature reviewed, successful chemistry education relies on a combination of laboratory-based instruction, teachers' pedagogical competence, appropriate laboratory facilities, and purposeful instructional leadership. The deficiencies of the chemistry instructional support system and the poor utilization of the available instructional support materials and equipment in secondary schools continue to hinder the teaching and learning of chemistry in Nigeria, while the inconsistent teaching of the subject in the practical laboratory is reported to positively affect students' conceptual understanding, scientific process skills, attitudes, and academic performance.

Most importantly, the review uncovers a significant gap in current scholarship. Research to date has tended to focus on instructional leadership and lab provision and use, teacher effectiveness, and student achievement separately, without focusing on how leadership specifically affects laboratory instruction. Therefore, instructional leadership in the lab is an appropriate model for analyzing how principals' goal setting, supervision of practical instruction, resource management, professional development support, and monitoring of lab activities can enhance chemistry teachers' pedagogical competence and, in turn, improve students' performance. The present study therefore fills an important conceptual and empirical gap by exploring these relationships in the context of secondary schools in Nigeria and generating evidence to strengthen school leadership, chemistry pedagogy, and chemistry practical education.

4.1 Recommendations

The following suggestions are made based on the findings and conclusions of this study:

1. The secondary school principals need to institutionalize laboratory-based instructional leadership by establishing explicit objectives for practical chemistry teaching, regular supervision of laboratory activities, monitoring the practical competence of the students, and giving constructive feedback to the chemistry teachers on the instruction

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of practical chemistry. This will enhance teachers' pedagogical skills and the quality of laboratory-based learning.

2. Government and relevant education authorities should provide sufficient maintenance and effective utilization of chemistry laboratory resources and continuous professional development for principals and chemistry teachers in laboratory management and practical teaching skills. Coordinated support would improve the implementation of practical chemistry and, in turn, students' academic performance.

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