

Research Article

Innovative chemistry teaching and learning for sustainable national development: Addressing contemporary national challenges.

E. M. Ezra*

Department of Chemistry, Faculty of Science, Federal University of Education, Kontagora, Nigeria.

Abstract

The Nigerian chemical education has been faced with many challenges. One of these challenges is the methodology of teaching used by chemistry teachers. The old methods of teaching like lecture and demonstration methods did not favor the 21st century learners in chemical science which as a result contributed significantly to the poor performance of chemical students. It is against this background that this paper critically discussed the concept of innovation in chemistry education, the role of technology-based teaching and the weakness of lecture and demonstration methods to chemistry students. However, innovative teaching pedagogy such as Peer Instruction (PI), the use of Audio-Visual (AV) supplement, student-centered learning, improvisation and cooperative learning were briefly discussed as an alternative. This paper recommended among others, the research studies is aimed at devising a better method of teaching chemistry using Peer Instruction (PI) and Cooperative Learning (CL) in Nigerian schools at all levels should be carried out in chemistry education to ascertain their effectiveness.

Keyword: Audio-visual (AV) Cooperative learning (CL), innovation in education (IE), peer instruction (PI).

1. Introduction

Education has consistently attracted the attention of researchers and educators, particularly in relation to improving the teaching–learning process for both teachers and students (Okoro et al., 2012). The classroom remains the central environment where meaningful learning takes place, serving as a space in which knowledge, creativity, and learners' talents are developed (Reachlvy, 2017). The effectiveness of classroom instruction depends largely on the quality of interaction between teachers and students. According to Okoro et al. (2012) and Reachlvy (2017), effective teachers are able to create engaging learning environments that encourage curiosity, active participation, and meaningful interaction, thereby extending learning beyond the physical classroom.

The primary responsibility of the classroom teacher is to facilitate learning and support students in achieving maximum academic success (Aluko, 2008). To accomplish this, teachers are expected to possess a range of professional competencies, including the ability to apply appropriate instructional strategies and adopt innovative teaching approaches. As the educational landscape continues to evolve, the integration of innovation into classroom practice has become increasingly important. Etiubon (2016) noted that changes in the global educational system have made it

necessary to review and adapt the chemistry curriculum to meet contemporary scientific and technological demands. Similarly, Adikwu (2008) argued that the chemistry curriculum should equip learners with relevant knowledge, practical skills, and positive attitudes while promoting innovative methods of instruction.

The importance of innovation in science education has been emphasized by the (APA, 1989), which advocated reforms in science teaching across all educational levels. Findings from educational psychology, cognitive psychology, and the learning sciences consistently support learner-centered and active learning approaches that promote deeper understanding and greater student participation (Etiubon, 2016). Consequently, many educational institutions have increasingly adopted modern instructional technologies to improve the teaching and learning of chemistry.

The twenty-first century has witnessed significant changes in chemistry education, driven by rapid technological advancement and increasing demands for more effective teaching practices (Zeile & Jones, 2001). These developments have intensified global efforts to reform chemistry education and science education generally (Eilks, 2013, cited in Eilks & Hofstein, 2013). Innovative instructional technologies have created opportunities to

*Corresponding author: E. M. Ezra

Email address: elijahmatthew2@gmail.com (E. M. Ezra)

ORCID: <https://orcid.org/0009000708146441>

Received: 23/04/2026; Accepted: 29/07/2026; Published: 31/07/2026



Copyright: © The Author(s), 2026. This is **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>).

improve students' learning experiences by enhancing their understanding of abstract concepts such as molecular structures and the relationship between chemical structure and properties (Eilks & Byers, 2009). These innovations, which are discussed in detail in pages 8 and 9, also strengthen the connection between classroom instruction and independent learning (Mahaffy, 2014; Chemistryviews, 2014). When effectively integrated into instruction, they promote meaningful engagement with chemistry concepts and improve learning outcomes.

As teaching practices continue to evolve, chemistry teachers are expected to continuously evaluate and improve their instructional methods to meet students' diverse learning needs (Kristen et al., 2017). Since providing individualized support for every learner is often constrained by time and classroom realities, technology-enhanced instructional strategies offer practical alternatives for addressing students' learning difficulties, improving confidence, and making chemistry more engaging (Redish, 1997).

Despite its importance in everyday life and its contribution to scientific and technological development, chemistry is widely perceived as a difficult subject by many students. The abstract nature of many chemical concepts, coupled with inadequate instructional resources, often contributes to poor understanding and low achievement (Anne, 2025). Therefore, students experiencing learning difficulties should be provided with appropriate instructional support to help them achieve their full potential. The careful selection and implementation of effective and innovative instructional strategies can significantly improve the quality of chemistry teaching and learning, thereby enhancing students' understanding, interest, and academic performance.

1.1. Concept of Innovations in Educational Context

The capacity to generate new ideas and innovations has become a major priority for many organizations. Intense global competition and rapid technological advancement have made innovation an important source of competitive advantage (Popa, 2009). Innovation can be described as a new idea, creative thought, or imaginative concept expressed in the form of a product, device, or method (Merriam-Webster, 2010). Consequently, the concept of innovation has attracted considerable interest among researchers and professionals across various industries (Popa, 2009). It has been observed that the way innovation is defined within an organization determines the types of activities that are undertaken internally and those that are outsourced. Researchers and industry experts approach innovation from different perspectives, including radical and incremental changes in products and processes (Popa, 2009). Martins (2004) described innovation as a process aimed at improving the quality of human life.

The main objective of innovation teaching is to transfer knowledge and information to learners (Udu, 2018). Any instructional method that involves the use of computers or modifies the traditional chalk-and-talk approach can be regarded as innovative, provided it helps achieve the core goal of teaching (Okoye, 2012). In conventional innovation teaching methods, the teacher dominates the instructional process, delivers content to the entire class, and emphasizes

factual knowledge. In this approach, learning is largely passive, and students play a limited role in their own learning (Aniodoh, 2001). In science education, teachers are expected to demonstrate a high level of competence and mastery of subject matter before introducing it in the classroom in order to ensure effective instruction (Udu, 2018). Teachers are also expected to stimulate students' interest and attitudes toward science through appropriate teaching strategies. They should possess adequate exposure and experience in science and adopt innovative teaching methods that support students' cognitive and social development, align curriculum with learners' mental abilities, make learning relevant, and motivate students to learn (Nwachukwu, 2009).

Innovation in education, as emphasized by many scholars, refers to a deliberate, systematic, and sustained change introduced into an educational system with the aim of improving its effectiveness and efficiency in meeting the needs of society (Nwafor, 2007). Martins (2004) further stated that innovation, when incorporated into education—especially chemistry education—can make teaching and learning more interesting and effective. In an effort to clarify the concept, Kirsi and Seppo (1996) described educational innovation as a creative policy, a novel approach to renewing education, a new educational culture, and a means of addressing educational challenges. They further explained that innovation serves as a driving force that initiates change and progress.

In today's rapidly changing world, it has become necessary to modify traditional methods of teaching chemistry and introduce innovative practices that improve the quality of instruction at all levels of education (Udu, 2018). Okoye (2012) also maintained that a healthy educational system should strive to develop new teaching procedures, pursue new scientific goals, produce new educational outcomes, and continuously evolve rather than remain stagnant.

The concept of innovation in science teaching is essential because societal needs and challenges are constantly changing (Nwafor, 2007). As a result, the educational system must adapt in order to respond to these changes. The adoption of innovations in education enables institutions to improve teaching methods and achieve meaningful educational reforms. Therefore, any effort aimed at incorporating new knowledge, eliminating outdated content, and adopting a multidisciplinary approach can be regarded as an innovation in education (Udu, 2018).

1.2. Incorporation of Innovative Pedagogies in the Teaching and Learning of Chemistry

There is no doubt that students are expected to be technologically competent, and educators are responsible for preparing learners in colleges and future careers for the demands of the 21st century. With the wide variety of digital applications now readily available, teachers must identify the tools that best align with their subject content in order to enhance instructional delivery (O'Brien, 2018). In addition, students have adapted culturally to the widespread use of smartphones, which allow them to download applications for practicing chemistry skills, drawing and rotating molecular structures, and constructing reaction mechanisms. Although

these digital tools offer numerous advantages, traditional paper-and-pencil methods should not be completely discarded (Williams & Pence, 2011).

Clifford, 2013 cited in McDonnell (2013), wisely stated that technology will not replace teachers, but teachers who use technology will replace those who do not. Research has also shown that the use of technology increases students' academic achievement and motivation, while computer-based instruction enhances meaningful learning and creates supportive learning environments in chemistry (Dori & Barak, 2000). Furthermore, integrating technology into secondary and higher education classrooms enables students to develop essential 21st-century technological skills that they can apply throughout their professional lives (Brown et al., 2018).

According to the U.S. Department of Education (2010), numerous research studies and literature reviews have been conducted by educators and technologists to determine the most effective ways students learn chemistry. However, there is still limited research on student learning outcomes based on formative, summative, and state assessments resulting from the use of technology in instruction. Bretz (2018) noted that chemistry education research has expanded considerably, with numerous studies examining how students learn chemistry and identifying evidence-based instructional practices that improve teaching.

Ahmad et al. (2023) conducted a systematic review and meta-analysis of 35 instructional approaches in chemistry education to identify evidence-based teaching practices that most effectively improve students' learning outcomes.

The National Center for Education Statistics (NCES, 2002) published a report based on findings from the National Assessment of Educational Progress (NAEP, 2000), which examined science assessment scores of eighth-grade students. The results showed that students whose teachers used computers for simulations and data analysis achieved significantly higher scores than those whose teachers did not use computers for such purposes.

Onyia (2010) emphasized that technology-based innovation for hands-on chemistry instruction help engage students and improve their chemistry literacy. He further explained that electronic learning systems such as Owl, Mastering Chemistry, Smart Work, and Wiley Plus are innovative, research-based online environments designed to support both teaching and learning. These platforms provide concept simulations, tutorials, visual exercises, and problem-based homework that:

- (i) Improves student learning and academic performance,
- (ii) Helps students visualize chemistry and improve problem-solving skills,
- (iii) Allows learners to progress at their own pace until they master key ideas and
- (iv) Support the assessment of student progress.

The Federal Government of Nigeria has emphasized the need for socioeconomic development, including the integration of information and communication technology (ICT) at all levels of education (Chinwe & Nnamdi, 2015). In response, several curriculum reforms have been implemented. Consequently, the use of ICT in teaching

chemistry content is essential, as it enhances students' understanding, retention, and transfer of knowledge.

To effectively integrate technology into lessons, teachers must consider the subject content, the most appropriate teaching method, and the technology that best supports instruction for a particular group of learners (O'Brien, 2018). One of the simplest and most effective ways to incorporate technology into teaching is through podcasts and screencasts. Podcasts (audio-based) and screencasts (audio with video or screen capture) enable students to review learning materials at their own pace and at a convenient time (Seery, 2013). These digital resources can either reinforce classroom content or provide additional explanations beyond what is covered in class.

Dalgarno (2009) observed that a simple online search for chemistry video games can introduce students to a virtual environment of molecules, molar masses, and complex equations. Virtual laboratories have proven to be one of the most effective ways for chemistry teachers to engage students in active learning. In addition, PowerPoint presentations have replaced the traditional chalk-and-talk method in many classrooms, making lessons more engaging. Teachers now use projectors to display slides containing diagrams and flow charts, thereby making instruction more interactive.

2. Common Methods of Teaching Chemistry

The instructional approaches most commonly employed in science education, particularly by chemistry teachers, are the lecture method and the demonstration method. These two methods are briefly discussed below.

2.1. Lecture method (Old method)

The use of lectures as a method of transmitting information, facts, and knowledge to learners dates back to the 14th century, long before it was formally introduced into science subjects such as chemistry, physics, and biology. The term "lecture" originates from the Latin word *lectus*, meaning "that which is read" or "the act of reading," and refers to an oral presentation designed to convey information or teach a specific subject, usually by a university or college instructor (Murphy, 2012).

The lecture method is a teaching approach in which the teacher verbally presents a pre-planned body of knowledge to students (Okoro, 2012). In this method, the teacher speaks while the students listen and take notes. It is often used to deliver a large volume of information to learners within a short period of time (Berry, 2008). According to Bauum and Weinberger (2014), lectures are primarily designed to communicate new information to large groups of students, although they can also be used for smaller classes. Research indicates that this method dominates teaching practices in many tertiary institutions (Deslauriers et al., 2011).

As the foundation of university instruction, lectures can be an effective means of presenting theories, concepts, and factual knowledge to students. However, to be effective, lectures must follow well-structured procedures that support student learning (Murphy, 2012). Despite their widespread use, there has been considerable debate regarding the effectiveness of lectures in promoting student learning.

Commonly identified limitations of the lecture method include placing students in a passive role, encouraging one-way communication, requiring extensive independent study outside the classroom, and depending heavily on the lecturer's communication skills.

Research has shown that students' retention of information in lecture-based science courses is generally low. Bok (2006) reported that an average student retains only about 42% of the material immediately after a lecture and approximately 20% one week later. Other studies have revealed that the lecture method does not adequately support the development of functional understanding among students (Bernhard cited in Kola & Langenhoven, 2015). Consequently, Berry (2008) argued that the lecture method lacks the effectiveness of active-learning strategies. Fagen and Mazur (2003) also observed that the lecture method can contribute to poor reading habits among students.

2.2. Demonstration method (Innovative Method)

The demonstration method refers to an instructional approach in which the teacher shows students how to manipulate equipment and apparatus and how to solve numerical problems (Okoro, 2012). Through this method, scientific procedures, processes, and phenomena are presented to students in a visual and practical manner. This method helps address some of the limitations of the lecture method, which places excessive emphasis on the teacher (Mallick, 2018; McKee, 2007).

The demonstration method is particularly important in science teaching because science is not purely theoretical but also involves a significant amount of practical work. By conducting demonstrations during lessons, teachers can provide students with concrete learning experiences. This method is especially useful when class sizes are large and laboratory equipment is insufficient for individual student use (Okoro, 2012; Mallick, 2018).

Demonstration is an effective teaching method because it improves students' understanding and retention of scientific concepts (McKee, 2007). Al-Rawi (2013) also reported that the demonstration method is effective for teaching practical skills such as the use of laboratory tools and conducting experiments in chemistry. However, the time available for demonstrations in classroom settings is often limited. As a result, demonstrations are usually designed to allow students to observe experiments rather than actively participate in hands-on laboratory activities (McKee, 2007).

2.3. Peer Instruction (Innovative method)

Peer Instruction (PI) is a research-based instructional approach developed for teaching large introductory science courses such as chemistry (Fagen & Mazur, 2003). It was designed to make lectures more interactive and to actively engage students intellectually during class sessions. This method has been tested in various science disciplines and has been found to improve students' academic performance and help identify areas where learners experience difficulty. Peer Instruction has also been applied across different subjects in many countries (Kola & Langenhoven, 2015). However, in several countries, PI is still relatively new to many teachers due to its distinctive feature of using conceptual questions known as Concept Tests.

Peer Instruction is defined by Kola and Langenhoven (2015) as an instructional strategy that actively involves students in class through a structured questioning process that engages every learner. The method creates a supportive environment in which students express their ideas and resolve misconceptions by discussing concepts with their peers (Gok, 2012). Peer Instruction promotes student participation through activities that require learners to apply core concepts and explain them to their classmates. Unlike the traditional practice of asking informal questions during lectures—which typically engages only a few highly motivated students—PI uses a structured questioning process that involves all students in the classroom.

The main objective of Peer Instruction is to transform the lecture environment into an active learning space where students are fully engaged and focused on understanding fundamental concepts (Kola & Langenhoven, 2015). Instead of relying solely on textbooks or lecture notes, instructors present short explanations of key ideas, followed by conceptual multiple-choice questions known as Concept Tests. These questions assess students' understanding of the topic being discussed.

According to Turpen and Finkelstein (2010), the Peer Instruction process involves the following steps:

- (i) The instructor presents a conceptual question.
- (ii) Students are given time to think individually.
- (iii) Students record or report individual answers.
- (iv) Students discuss their answers with nearby peers.
- (v) Students submit revised responses.
- (vi) Feedback to teacher: Tally of answers.
- (vii) Explanation of the correct answers by the instructor.

2.4. Audio-visual (AV) Supplements

The application of audio-visual resources in industrial settings has been widespread due to their effectiveness in increasing productivity and improving retention rates. Research has shown that individuals remember approximately 20% of what they see, 40% of what they both see and hear, and about 75% of what they see, hear, and actively do at the same time. Audio-visual tools have now become increasingly integrated into the educational system as effective instruments for teaching and learning.

In many countries, such as India, several educational institutions have equipped their classrooms with audio-visual facilities to enhance students' understanding and learning experiences. Teachers use graphical representations of complex equations with the help of smart boards to explain difficult subjects such as physics, mathematics, and chemistry (Reachlvy, 2017). Subject teachers also use audio-visual tools creatively to stimulate students' curiosity through images, animations, and puzzles, encouraging them to think creatively and critically. This method is particularly suitable for teaching science and chemistry at the secondary school level, as it satisfies students' need to see and hear concepts in order to fully understand them.

Audio-visual resources can be described as a combination of various media tools such as videos, CD-ROMs, floppy disks, internet-based resources, and software that allow for interactive learning. Reachlvy (2017) further

defined audio-visual tools as instructional materials that incorporate one or more media formats, including graphics, video, animation, images, and sound, alongside textual content.

2.5. Learner's Centered Method

Since teaching and learning revolve around the learner, it would be inappropriate for any instructional method to ignore the central role of the student. Therefore, adequate attention must be given to learners in the teaching process (Udu, 2018). In the context of chemistry education as a science subject, the learner is regarded as the most important participant, and their interests must be fully considered. This approach recognizes the needs, values, and significance of the learner as the focal point of instruction.

This perspective represents a modern approach to science teaching and differs from traditional methods in which the teacher was considered the most important figure in the teaching and learning process. Learner-centered instruction emphasizes active participation and engagement, allowing students to take responsibility for their learning.

Learner-centered innovative methods include planned discussions, advisory approaches, panel discussions, small-group discussions, seminars, debates, committee and group work, problem-solving activities, research, and case studies (Ezeano, 2013). Several innovative teaching strategies based on learner-centered principles have been developed to improve the teaching and learning of science subjects in Nigerian schools (Aliyu, 2024).

These learner-centered strategies include, among others, the use of analogies, constructivist approaches, learning activity packages, concept mapping, cooperative learning, individualized instruction, computer-assisted instruction, programmed instruction, multimedia-based teaching, information and communication technology (ICT) approaches such as internet use, and the science–technology–society (STS) approach (Udu, 2018).

2.6. Improvisation

Improvisation has been described as intuition guiding action in a spontaneous manner (Crossan & Sorrenti, 1997). Keefe (2002) defined improvisation as making the best use of available resources and maximizing the value of what is created. It is a communicative skill which, like other social and interactive abilities, can be taught and developed (Udu, 2018). According to Mills, cited in Uniproject (2016), improvisation involves producing instructional materials that resemble original designs by using locally available resources.

When improvisation is applied in chemistry teaching, students generate a variety of responses during discussions, and the teacher does not immediately judge these responses but instead guides the improvisation process. The aim is to help students discover knowledge through their own reasoning and exploration (Okoro, 2012; Udu, 2018).

Chemistry is an exact science that often demands creativity and improvisation in its teaching. Teachers who are skilled in improvisation are more likely to succeed in effectively communicating chemistry concepts to beginner learners (Uniproject, 2016). Improvisation allows students to express themselves creatively, collaborate with peers, and have their

ideas respected while learning from their mistakes in a supportive environment.

Innovative improvisation techniques sometimes referred to as activities, exercises, or games, can be incorporated into existing science teaching strategies (Udu, 2018). These techniques help increase students' awareness of key ideas and problems that are fundamental to their intellectual growth. Structured and purposeful improvisation provides educators with a framework for developing creative science instruction within established curriculum structures (Okoye, 2012).

2.7. Cooperative Learning

Cooperative learning refers to the division of tasks among group members in order to solve a given problem. In this approach, students share responsibilities and later come together to present their findings (Johnson & Johnson, 1992). Each learner contributes individually to the group's overall performance. Ziele and Jones (2007) explained that cooperative learning is based on the belief that learning is most effective when students actively exchange ideas and work together to accomplish academic goals.

Cooperative learning is a teaching strategy in which small groups, consisting of students with different ability levels, engage in various learning activities to improve their understanding of a subject (Mehta & Kulshrestha, 2014). It differs from collaborative learning, which is more of a philosophy of interaction and personal responsibility for learning. In contrast, cooperative learning is a structured approach designed to achieve a specific academic objective through group effort (Panitz, 1997).

In cooperative learning, each group member is responsible not only for their own learning but also for supporting their peers' learning, thereby fostering a sense of shared achievement. The cooperative learning model has gained increasing attention among science educators, as it supports curriculum design that promotes learning through teamwork, problem-solving, and decision-making (Mehta & Kulshrestha, 2014).

In a cooperative classroom environment, the teacher assumes the role of a facilitator and guide rather than a controller. Students take responsibility for their learning by asking questions, identifying problems, designing activities, and discussing results with their peers. Research has shown that students develop more positive relationships with one another when they learn cooperatively compared to when they learn individually or competitively, regardless of differences in ability, background, or physical condition (Mehta & Kulshrestha, 2014; Hermann, 2013).

Innovative methods of teaching chemistry play a significant role in addressing national challenges by equipping learners with the scientific knowledge, practical skills, and problem-solving abilities required for sustainable development. Through learner-centered instructional approaches, students are encouraged to apply chemical concepts to real-life situations, thereby enhancing their capacity to contribute to industrial development, environmental protection, healthcare improvement, food security, and technological innovation. Furthermore, innovative teaching strategies promote critical thinking,

creativity, collaboration, and entrepreneurship, enabling graduates to develop practical solutions to societal problems and contribute meaningfully to national economic growth and development.

3. Conclusion

The applications of innovations in the teaching of chemistry as tools that when implemented right will enhance the students' performance and improve the learner's active participation in chemistry. However, It is obvious that there are already known teaching pedagogies in chemistry education that actively engages students in the class such as the concept of cooperative learning, integrated innovative technology in chemistry teaching (e.g. using power point and CHEMSKETCH). Thus, PI and other innovative methods discussed in this review could be a better one. These pedagogies of teaching are innovative strategies or tools that empower both students and teachers. Inco-operating innovation in chemistry teaching will also assist the learners to meet their basic needs, because they support students' preference for learning by doing. Meanwhile, the use of innovative technologies is promising tools for instructors because they support teachers to engage students with hands-on inquiry learning.

Recommendations

The author suggested the following:

1. Many literatures reviewed by different authors confirmed the effectiveness of Peer Instruction and cooperative learning for improving conceptual and problem-solving skills of the students at different level of education. Therefore, this paper recommended that innovative teaching using Peer Instruction (PI) and Cooperative Learning (CL) in Nigerian schools at all levels should be carried out in chemistry education to ascertain their effectiveness.
2. Chemistry or science teachers should be allowed to visit schools that are using innovative methods to observe new strategies and materials enhancing chemistry teaching.
3. Chemistry teachers should change and utilize the innovative methods in their lesson delivery to enhance students' active participation in the lesson for enhanced academic performance in chemistry.
4. Attendance of workshops, conferences and seminars will also be of great advantage to teachers.

Abbreviations

CL	Cooperative learning
AV	Audio-Visual
IE	Innovation in Education
PI	Peer Instruction
ICT	Information and Communication Technology
STC	Science Society Technology
NCES	National Center for Education Statistics
NAEP	National Assessment of Educational Progress

Author Contributions

Elijah Matthew Ezra: Conceptualization, Investigation,

Validation, Writing –Review & Editing, Project Administration, Methodology.

Conflicts of Interest

The author(s) declare that they have no known competing financial interests, professional affiliations or personal relationships that could have appeared to influence the work reported in this paper.

Funding

None

References

- Adikwu, M. U. (2008). *Curriculum Development in Science, Technology and Mathematics (STM) Education*. A Keynote Address Presented at the 49th Annual Conference of Science Teacher Association of Nigeria (STAN) Yenegoa.
- Ahmad, Z., Ammar, M., Sellami, A., & Al-Thani, N. J. (2023). Effective pedagogical approaches used in high school chemistry education: A systematic review and meta-analysis. *Journal of Chemical Education*, 100(5), 1796–1810. <https://doi.org/10.1021/acs.jchemed.2c00739>
- Aliyu, I. K. (2024). Effect of Individualized Instruction on Academic Performance and Interest in Chemistry Among Secondary School Students in Katsina State, Nigeria. *A Journal of African Advancement and Sustainability Studies*, 5(2). <http://ssaapublications.com/index.php/sjaass/article/view/251>
- Al-Rawi, I. (2013). Teaching Methodolgy and its Effects on Quality Learning. *Journal of Education and Practice*, 4 (6): 100-105.
- Aluko, K. O. (2008). Teaching Chemistry in Secondary Schools: A case for Cooperative Instructions Strategy. *Ethiopian Journal of Education and Science*, 3 (2).
- American Psychological Association (APA) (1989). APA for the Advancement of Science, for all Americans: project 2061, *Oxford University Press*. 1989.
- Aniodoh, H. C. O. (2001). Modern Aspect of Integrated Science Education, Enough. *Nigeria: Hacoform Educational Books*.
- Anne, S. (2025). *How to Teach Chemistry*; Wikihow. Accessed from <https://www.teachchemistry.org/content/aact/en/professional-development.html>
- Baum, G. V. & Weinberger, A. (2014). Teaching, learning and media use in today's lectures. *Computer-Human Behavior*, 37 (2014): 171-182.
- Berry, W. (2008). *Surviving Lecture: A Pedagogical Alternative*. *College Teaching*, 56 (3): 149-153.

- Bok, D. (2006). Our Underachieving Colleges: A Candid Look at How Much Students Learn and Why They Should Be Learning More. *Princeton University Press*: Princeton, NJ.
- Bretz, S. L. (2018). *Chemistry education research—From personal empiricism to evidence, theory, and informed practice*. *Chemical Reviews*, 119(6), 3899–3981. <https://doi.org/10.1021/acs.chemrev.8b00020>
- Brown, K. K.; Gilmore, M. W.; Dillihunt, M. and Minor, K. (2018). Utilizing Online Technology to Effectively Teach Chemistry in Secondary Education. *Mod. Chem App.*, 6: 244 doi: 10.4172/2329-6798.1000244.
- Chemistryviews, (2014). *Innovative Learning and Teaching Practices*. Retrieved on January, 2019 from <https://www.chemistryviews.org/details/education/513199/innovative-learning-and-teaching-practices.html>
- Chinwe, N. B. & Nnamdi, E. (2015). Availability and Usage of ICT Resources for Chemistry Curriculum Delivery in Schools. *International Journal of Engineering and Science (IJES)*, 4 (6): 26 – 30, ISSN 2319-1813.
- Crossan, M. & Sorrenti, M. (1997). Making Sense of Improvisation. *Advances in Strategic Management*, 14 (1): 155-180.
- Dalgarno, B.; Bishop, A.; Adlong, W. and Bedgood, D. (2009). Effectiveness of a Virtual Laboratory as a preparatory resource for Distance Education chemistry students. *Computers & Education*, 53: 853-865.
- Deslauriers, L.; Schelew, E. & Wieman. (2011). Improved learning in a large-enrollment physics class. *Science*, 332: 862–864. <http://doi.org/10.1126/science.1201783>.
- Dori, Y. & Barak, M. (2000). Computerized Molecular Modeling: Enhancing Meaningful Chemistry Learning - 4th International Conference of Learning Science, pp 185-192.
- Eilks, I. and Hofstein, A. (2013). Teaching Chemistry -A Study Book (Practical Guide and Textbook for Students Teachers, Teacher Trainees and Teachers (Ed's). *Sense Publisher*. Retrieved on February, 2019 from <https://www.sensepublishers.com/>
- Eilks, I. & Byers, B. (2009). Innovative Methods of Teaching and Learning Chemistry in High Education. *RSC Publishing*, 978-1-84 755-958-6.
- Etiubon, R. U. (2016). *The Effect of Problem-Based Learning on Students' Cognitive Achievements*. <https://www.afrischolar.net>
- Ezeano, C. A. (2013). Science Teaching for Effective Development in Nigerian Schools. Partharcout, Nigeria. *Ecnet Printing press*. <https://worldresearchacademy.com>
- Fagen, A. P. & Mazur, E. (2003). *Assessing and Enhancing the Introductory Science Courses in Physics and Biology: Peer Instruction, Classroom Demonstration, and Genetic Vocabulary*. (Doctoral thesis, Harvard University) Cambridge, Massachusetts.
- Gok, T. (2012). The Impact of Peer Instruction on College Students' Beliefs About Physics and Conceptual Understanding of Electricity and Magnetism. *International Journal of Science and Mathematics Education*, 10: 417–437.
- Hermann, K. J. (2013). The Impact of Cooperative Learning on Student Engagements: Results from an Interaction, *Active Learning in Higher Education*, 14 (3): 175-187.
- Johnson, D. W. & Johnson, R. (1992). Positive Interdependence: Key to Effective Cooperation. *Interaction in Cooperative Group Learning*. Cambridge University Press, New York, N.Y. USA.
- Keefe, J. A. (2002). Improving Yourself: Business Spontaneity at the Speed of Thought. *Hoboken, N.J: Wiley*.
- Kirsi, T. and Seppo, T. (1996). *Educational Innovation as Identified by some Finesse Decision Makers*. A paper presented at the Symposium on European Identity in Charge in Vasa in May 1996.
- Kola, A. J. and Langenhoven, K. (2015). Teaching Methods in Science Education: The Need for a Paradigm Shift to Peer Instruction (PI) in Nigerian Schools. *International Journal of Academic Research and Reflection*, 3 (6): ISSN 2309-0405.
- Kristen, K. B.; Malinda, W. G.; Monica, D. and Kendra, M. (2017). *Pedagogical Methods and Technology Used in Chemistry Secondary Education*. *Mod Chem App* 5:223. doi: 10.4172/2329.6798.1000223.
- Mahaffy, P. G. (2014). *Telling Time: Chemistry Education in the Anthropocene*. *J.Chem.Educ.*(2014)91(4):463-465. <https://doi.org/10.1021/ed5001922>.
- Mallick, H. (2018). *What is the Demonstration Method of Teaching Science*. Accessed from www.preservearticles.com/education/what-is-the-demonstration-method-of-teaching-science/27824 on

September, 2019

Martins, S. D. (2004). In: *Finding Balance: Impact of Classroom Management Conception on Developing Teacher Practice. Teacing and Teacher Education*, 20, 405-422. <https://doi.org/10.1016/j.tate.2004.04.002>

McDonnell, C. (2013). *Applying Technology to Enhance Chemistry Education. Chemistry is All Around Us. Network Conference Initiatives in Chemistry Teaching Training* 29th November, 2013.

McKee, E.; Williamson, V. M. & Ruebush, L. E. (2007). Effects of a demonstration laboratory on student learning. *Journal of Science Education and Technology*, 16: 395–400. <http://doi.org/10.1007/s10956-007-9064-4>

Mehta, S. & Kulshrestha, A. K. (2014). Implementation of Cooperative learning in Science :A Developmental-cum-Experimental Study. *Educational Research International. Article* 10. 431542 page7.

Merriam-Webster.com" Innovation" (2010).

Murphy, P. A. (2012). Are College Lectures Unfair? *Sunday Review. New York Times*. National Center for Education Statistics (NCES) (2002). Science Highlights: The National. <https://www.nytimes.com>

Report. Card 2000://US Department of Education. *Ed Pubs, Jessup MD: US*.

Neboh, O. I. (2012). Effect of Learning Activity Package (LAP) on Male and Female Students' Achievements in Secondary School Biology. *Journal of Science and Computer Education*, 2 (1): 1-13.

Nwachukwu, P. O. (2009). Understanding Teachers Professional Competencies for Education Effectiveness. Owerri, Nigeria: *Springfield Publishers Limited*.

Nwafor, O. M. (2007). *Educational Innovation Process and Products*. Onitsha, Nigeria: Perfect Image.

O'Brein, S. (2018). *Technology Considerations for the Chemistry Classroom*. Retrieved from <https://www.chemedx.org>.

Okoro, R. U.; Haruna, M. J, and Abubakar, B. (2012). Introduction To Principle & Practice of Education for NCE and Undergraduate Students. *Mathy Productions, Sokoto ISBN 978-071-356-5*.

Okoye, F. N. (2012). *Influence of school climate on educational innovations in Nsukka education zone of Enugu State Nigeria*. Unpublished M.Ed Dissertation, Department of Educational Foundation, Faculty of Education, University of Nigeria, Nsukka. Retrieved on

February, 2019 from <http://www.unn.edu.ng/publications/files/images/Okoye%20F.N.O.pdf>.

Onyia, N. (2010). *Application of Innovative Methods to Enhance the Teaching and Learning of Chemistry*. <https://doi.org/10.35386/SER.V1911.208>.

Panitz, T. (1997). Collaborative Versus Cooperative Learning: A Comparison of the Two Concept. *Cooperative learning and College Teaching*, 8 (2): 5-7.

Popa, I. L.; Preda, G. and Boldea, M. (2009). *A Theoretical Approach of the Concept of Innovation*. <https://openurl.ebsco.com>

Reachlvy, (2017). *TBI Blogs: 7 Brilliant Innovations that Teachers Can Use to Make Their Classrooms More Engaging*. Retrieved on December, 2018 from <https://www.thebetterindia.com/101112/innovations-introduced-enhance-education-system/>

Redish, E.; Saul, J. and Steinberg, R. (1997). On the effectiveness of active-engagement microcomputer-based laboratories. *Am J Phys*, 65: 45.

Seery, M. (2013). Podcasting: Support and Enrich Chemistry Education. *Education in Chemistry*, 49 (2): 19-22.

Tarhan, L.; Ayar, K. H.; Urek, R. and Acar, B. (2008). Problem-Based Learning in 9th Grade Chemistry Class: 'Intermolecular Forces. *Research in Science Education*, 38: 285-300.

Turpen, B., and Finkelstein, N.D. (2010). The Construction of Different Classroom Norms During Peer Instruction: Students Perceive Differences. *Physics Education Research*, 6 (020123): 1-22.

Udu, D. A. (2018). Innovative Practices in Science Education: A Panacea for Improving Secondary School Students' Academic Achievements in Science Subjects in Nigeria. *Global Journal of Educational Research*, 17: ISSN 1596-6224.

Uniproject (2016). *Assessment of the Use of Improvisation in Teaching Chemistry*. <https://publications.oasisinternationaljournal.org>.

Williams, A. J. & Pence, H. E. (2011). Smart Phones, A powerful tool in the Chemistry Classrooms. *Journal of Chemical Education*, 88 (6): 683-686.

Zeile, J. V. & Jones, L. L. (2001). General Chemistry Symposium Report: Teaching Chemistry in Chemistry in the New Century. <https://doi.org/10.35386/SER.V1911.208>