BRIDGING RESEARCH AND PRACTICE THROUGH ICT-BASED INNOVATIONS: IMPLICATIONS FOR CHEMISTRY EDUCATION STUDENTS' LEARNING OUTCOMES IN NIGERIAN UNIVERSITIES.

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Abstract

This study discussed the learning outcomes of chemistry students in bridging research and practice through the potential of ICT based innovations. The learning outcomes in question are students' motivation and academic performance of chemistry students in Nigerian universities. Basically, the growing complexities of university governance and the challenges posed to university management makes the application of information, communication and technologies indispensible for quality teaching, research, practice and goal attainment. The crucial role that information, communication and technologies play in effective learning, research and practice in universities is the focus of this paper. The paper analyzed the variables; meaning of information and communication technology, teaching and research, research and practice, learning of science, chemistry education, integration of information, communication and technologies-based innovation in students' research and practice, implications on students' motivation and performance, ICTs facilities necessary in chemistry, challenges of application of information, communication and technologies in research in universities. On the bases of the foregoing analysts, university lecturers and students were challenged to bridge research and practice by embracing ICTs based innovations, develop generalizable knowledge and apply the knowledge, skills, and techniques into professional or creative contexts; and in all areas of chemistry education to improve quality of teaching and learning, also, for promotion of students' motivation and academic performance in chemistry in Nigeria universities. The need for this decision in enhancing professional development is both urgent and demanding. It was then recommended that adequate ICT equipment for research and practice should be provided by the ministry of education and school management.

Keywords: Bridging Research and Practice, ICT Based Innovations, Chemistry Education Students' Learning Outcomes, and Nigerian Universities.

Introduction

Being an essential part of the present time, Information and communication technology (ICT) significantly influences all domains of human life (Voithofer & Nelson, 2020). Similarly, ICT has also transformed the education sector and turned instructional practices into more interactive and productive (Nowfeek, Farwis & Nowzath, 2021), as it offers various tools which are used in traditional as well as online teaching spaces and assist in building a proactive classroom environment. Technology-incorporated instructional practices not only enhance the quality of teaching and learning but also enable students to develop their skills through research and practice, boost their motivation, and enhance their knowledge and information efficiently (Oluwatosin, & Ajani, 2022).

Meaning of ICT

Information Communication Technology is a network which offers a steadily expanding range of new services that have major economic consequences for the standardization of information in universities (Haleem *et al* 2022). It is computer-based tools used by organization personnel in the processing of their information and communication needs. It encompasses the computer hardwareand software, the network and several other devices, like audio, video, photography, camera, etc., that convert information into common digital form. Technological advancement is a continuous process of innovation, improvement, and integration of new tools, techniques, and systems to enhance efficiency, productivity, and convenience in various field (Oguezue, 2025). Therefore, technological advancement may not be achieved without a solid foundation in a basic science like chemistry (Nnoli, 2023).

ICT in Teaching and Research

Available literature indicates that integrating ICT in teaching and research is generally positive, leading to radical shift from the traditional teacher-directed/didactic approach to a more student-centred/constructivist approach (Nnoli, 2023). ICT in teaching is less expensive, enables lessons to be introduced speedily, provides consistentmessages; make possible working from any location anytime, updating contents easily and quickly, increase learners' retention and management of large group of students. It is argued that ICT increase the productivity of lecturers and teachers; help teachers to be more effective and productive; increase teachers' interest in teaching. According to Marín and Castaneda (2023) digital technology assist teachers in reorganizing and restructuring their courses; increase teachers' emphasis on individualized instruction; provide teachers with the opportunity to experiment with emerging technologies thus providing multi-media presence in the classroom; and also

provide teachers with increased opportunities to collaborate and network with colleagues.

Teachers should become competent to make personal use of ICTs; competent masters of a range of educational paradigms that make use of ICT; sufficiently competent to make use of ICTs as a tool for teaching; competent in mastering a range of assessment paradigms which make use of ICTs; competency in understanding policy dimension of the use of ICTs for teaching and learning. Hazrat*et al* (2023) argues that in using ICTs, lecturers should be competent in the use of variety of softwares, particularly, softwares that has specific application in various disciplines. Example, lecturers in education should be able to use statistical packages to enhance their output.

The value of ICTs is very important in designing research, implementing experimental and descriptive studies, statistical analysis, data production, storage, and dissemination of research information. Science used to be composed of two endeavors-theory and experiment, but today it has a third component (computer simulation) which links to the two (Hernandez-de-Menendez and Morales-Menendez (2019). ICTs facilitates research in the universities in the following ways;

- Lecturers are enabled to be guided into new frontiers in basic and fundamental researches.
- Lecturers are provided with greater opportunities for research collaboration and networking among scholars
- Research in any discipline is facilitated as they provide quicker and easier access to mor extensive and current information through digital libraries, electronic list, gopher, CD-ROM, etc
- Complex mathematical and statistical calculations which are important in research can be solved within two seconds, example, data manipulations and analysis.
- Ready avenue for disseminating research reports and findings is provided, example, e-book, e-journals, etc.

Research and Practice

Research is a systematic investigation designed to develop generalizable knowledge, while practice refers to the application of knowledge, skills, and techniques in professional or creative contexts (Tuhaise,Tah, & Abanda, 2023) For example, skills in the field of education, medicine and law. The purpose of research is to produce new knowledge, test theories, or solve problems. The processes in research are; designing, implementing experimental and descriptive studies,

statistical analysis, data production, storage, and dissemination of research information. Research presents a new systematic framework developed based on an in-depth review for utilizing technology in education, training and learning processes. The framework provides a novel and structured learning process to integrate theoretical knowledge with practical skills to support workforce development. This framework offers a structured roadmap for future research and practical applications (Hazrat, *et al* 2023). Citing an example, Nnoli (2021) examined the impact of improvised organic reagents on senior secondary school students' level of motivation in Chemistry, the researcher, after the findings, utilizes the knowledge and skill acquired from the improvised organic reagent applied in students' learning. This is the final step in research and practice.

Learning of Science

Science is the knowledge obtained from the systematic study of the structure and behaviour of the physical world, especially by observing, measuring and experimenting and the development of theories to describe the results of these activities (Ajayi & Ogbeba, 2017). Also, science is viewed as a systematic and practical investigation of natural phenomena aimed at discovering more knowledge. It also involves the use of many practical processes of investigation and discovery. Science has been and will continue to be of tremendous importance because of its ability to explain many natural occurrences and the central role it plays in the world's current technological development (Osborne, 2020). Science is an economic and technological development tool for improving the quality of life of individuals and society at large.

In appreciation of these views of scientific literacy, the Nigerian government emphasized the introduction of science subjects to enable its citizens to acquire knowledge of their environment, develop problem-solving skills and desirable scientific attitudes as well as increase the understanding of the role and functions of science and its application in everyday life (NPE, 2019). Akpan, (2018) pointed out that science has a great impact on the standard of life in different and diverse areas like agriculture, transportation, energy production, health, shelter, food etc. Apart from that he also stated that science ensures the safety of the environment that we interact with in our daily lives. So if science possesses this importance, improving science achievement in Nigerian schools should be a priority among other sectors.

Science is regarded as a means of providing explanations to various natural phenomena and events making it essential for human development (Iwu, 2021). Therefore, there is a need for effective science and technology education of the learner. For this reason, Science Teachers Association of Nigeria (STAN) often hold

workshops, seminars and conferences for science teachers, geared towards improving the methods of teaching science subject and making them interesting to students, particularly in universities in order that the teaching will not be affected by rote human learning.

Learning of Chemistry

Chemistry is the study of matter and the changes it undergoes. It is the process of acquiring the fundamental knowledge about the universe. It is sometimes called the "central science" because it connects physical science with the life sciences and applied sciences such as medicine and Engineering (Ngawang & Norbu 2021). Chemistry is a science that systematically studies composition, properties and activities of organic and inorganic substances and various elementary forms of matter (Nnoli & Muogbo, 2025). It is a vehicle through which chemical knowledge and skills reach the people who need capacity and potential for development (Okeke & Okey, 2018). The teaching and learning of chemistry as in the case of other science subjects has tremendous role towards industrialization in this age of artificial intelligence, technological developments in a developing country. It shows how facts are established by experiment and observation, how generalizations are built upon, how knowledge and concepts developed (Omeodu, 2023).

The 20th century saw dramatic advances in the comprehension of the marvelous and complex chemistry of living organisms, and a molecular interpretation of chemistry and disease holds great promise (Okon, 2017). To teach chemistry effectively requires the help of skilled and knowledgeable experts with innovative teaching methods who can help students become active participants in discovering knowledge in their teaching and learning environment.Teaching and learning of chemistry can benefit students by using and integrating information and communication technology (ICT). However, to what level and quality ICT is implemented in teaching and learning of chemistry heavily depends on the decisions teachers make for the instructional design of their lessons.

ICT Based Innovations in Students' Research and Practice

ICT played a supporting role in sustaining teaching-learning activities on the one hand, while on the other hand, ICT-integrated teaching and learning provided a flexible approach and better access to learning opportunities as a substitute for face-to-face instruction (Akram, 2021). ICT-integrated instructional approaches are significant in meeting the educational needs of the learners by increasing their thoughtfulness and keeping students motivated, which is viewed as a significant predictor of students' educational growth (Xu,Yuam & Liu, 2021).

Voithofer & Nelson (2020) identified that technology-integrated learning increases the cognitive understanding and learning achievements of students. In addition, ICT-incorporated teaching-learning practices also enable learners to stay connected with their instructors and peers via various social media platforms (Martínez-Gutiérrez, Díez-González & Perez,2023), it also help students resolve their academic challenges and keep them participating actively in the learning activities (Akram & Yang, 2021).

In this 21st century, technology has become the knowledge transfer highway in most countries. Technology integration nowadays has gone through innovations and positively changed our societies that have totally reshaped the way people think, work and live. Because of this, schools and educational institutions alike need to consider ICT integration in their curriculum. Teachers prefer those technological applications that align with their pedagogical strategies and existing beliefs about teaching and learning practices. In other words, technology use is greatly associated with teachers' perspectives regarding the nature of teaching and learning in a classroom. Taking this into account, innovative educational strategies suggest that technology integration can only be comprehended well when teachers' perspectives regarding technology use are taken into consideration (Watson & Rockinson-Szapkiw, 2021). In this regard, this study is intended to investigate teachers' and students' perceptions regarding the experiences they encounter while integrating ICT into the teaching and learning of Chemistry.

ICT Facilities for Chemistry Teaching

Chemistry deals with the compositions, properties and uses of matter. The utilization of ICT in educational institutions globally has facilitated the streamlining of the instructional process thereby fostering National stability and economic sustainability. ICT can increase the learners' motivation and engagement in classroom learning (Okocha, 2021). It equips learners with digital-age literacy, inventive thinking, high-order thinking, sound reasoning, effective communication and a high productivity. ICT will facilitate the field of education by leveraging electronic media, the internet and other related technologies. According to Almed et al (2017), the ICT resources normally utilized in teaching chemistry are; internet/web-services, multimedia projectors, computers, smart phones, interactive radio, search engines, LAN/WLAN, chart-room, Computer Assisted Learning (CAL), e-learning applications, computer laboratories, electronic cameras, tablet and web Quest. It was observed that many of the available ICT resources were rarely utilized among chemistry teachers while most of them do not utilize at all, due to lack of knowledge of operations and applications of those resources.

With ICT, practical work and arranging apparatus becomes easier in chemistry. The innovation methods of utilization of ICT in the teaching and learning of chemistry are based on the advantages of the use of computer (Almed et al, 2017). This facilitates and advance the work of teachers and students in both theoretical and practical. The computer offers plenty of possibilities in the theoretical aspect of teaching. As a result of which students are shown various aspects of chemical processes, national phenomena on the computer and vividly presented with principal chemical laws, structures of molecules, atoms, and crystal systems. These were alwaysclearer in computer instead of a two-way dimensional diagram. Students can have access to these ICT resources by sensitizing their teachers on the need for effective utilization in teaching chemistry. The government should also be committed to monitor and enhance the necessary environment for ICT instructions remain daunting.

Implications on Students' Motivation

Students performing better than the expectations and norms set by the society are mostly expected to contribute to the growth, development and sustainability of the society (Oluwatosin and Ajani, 2022). Although students cannot perform better if there is lack of motivation. Hence, motivation is essential in promoting learning.

Motivation is the inner drive or external influence that compels an individual to take action towards achieving a goal or fulfilling a need. Nnoli (2021) opined that motivation is the process that initiates guides, and maintain goal-oriented behavior. She also sees motivation as a vital role in learning, energizing and directing behavior toward specific goals. It facilitates knowledge acquisition, social development and discipline. It represents the desire and willingness to take action towards a goal arising from internal or external forces that arouse enthusiasm and persistence. Motivation is intrinsic to individuals fueling the desire for change within oneself or the environment. Motivation according to Silva (2021) student's attention and behavior can be maintained as well as provides them with some energy needed to lead tasks to completion. Motivation is the process of embracing challenging circumstances to face them with intention, persistence, direction, quality and intensity of behavior.

Motivation is the driving force that propels individuals to take action, pursue goals, and overcome challenges (Caroll, 2021). It can be fueled by intrinsic factors like passion and curiosity, or extrinsic factors such as rewards and recognition. When students are motivated, they are more likely to engage actively in their learning, persist through difficulties, and strive for excellence. This sustained effort and dedication ultimately lead to higher levels of academic achievement, as

motivated learners are better equipped to absorb, retain, and apply knowledge effectively. By fostering a motivating learning environment, educators can significantly enhance students' academic success and personal growth.Achieving high academic standards is influenced by various factors, including motivation, access to resources, teaching quality, and family support.

Implications for Students' Performance

Academic performance refers to the capacity to learn, retain and apply knowledge; as well as communicate thoughts and ideas through verbal or written means, demonstrating understanding and mastery of subject content (Okeke, 2022). In any school system, academic performance is a priority to the student as well as the teacher. Academic performance refers to how well or poorly a student does in his or her academic pursuits as evaluated through various means such as quizzes, assessments, field work and examinations for the entire implementation of any curriculum. Teachers' motivational strategies, including positive reinforcement and teaching methods influence academic performance and significantly impact students' learning outcomes and encourage active participation and critical thinking of students (Ezurike & Ayo, 2020)

Challenges of Applications ICT Based Innovations

A strong information system support is vital for meaningful progress in the management of complex organizations, like the university of the 21st century. Mazurchenko & Zelenka (2022) argue that the ability of modern organization to attain its set goals and the decision-making efficacy of contemporary managers is no longer dependent on just the quality of the manager, but more importantly is a function of the quality of information channels feeding and transmitting their actions. As a complex organization, the universities are required to handle large volumes of data which they must process speedily in order to provide information requirements of the various students. It seems that the growing complexities of the universities in Nigeria and the challenges it poses to management make the application of ICT indispensible for quality education. There are many forces and factors that pose challenges and problems to inhibit effective diffusion of ICT for research and practice in universities.

According to Martínez-Gutiérrez, Díez-González & Perez, (2023) reported low level of internet utilization among university students due to; low level of connectivity (internet/computer outlet); lack of computer; irregular power supply; high cost of cyber café facilities; lack of substantial online learning resources; academic qualifications and faculty's unwillingness to use ICT for lack of skill on the part of staff and students. Okocha (2021) revealed academic qualifications as a significant prediction of the utilization of ICT in the context of

education. He however advised that chemistry teachers should be actively engage in initiatives aimed at enhancing effective utilization of ICT in teaching and learning by eliciting their perceptions in the factors affecting the effective utilization of ICT in teaching chemistry. This will reawaken them to be more committed in the use and help them serve as agents in the spreading of the effective use of ICT for teaching and learning of chemistry. With ICT, practical work and arranging apparatus becomes easier in chemistry.

Conclusion

This study on the learning outcomes of chemistry students in bridging research and practice through the ICT-based innovations was discussed. The use of innovative ICT in research and practice requires competencies on the part of the teacher and has indeed made the profession a more challenging experience and retained knowledge for a longer time. The integration of information and communication technologies into the curriculum is a crucial process in ensuring the quality of education. However, the presence of technology alone will not stimulate significant changes in a school. Teachers are an important ingredient in the implementation of innovative ICT in research motivates and enable students to practice and gain skills for professional development. Without the involvement of teachers, most students may not take advantage of all the available potential benefits of ICT on their own.

The review however, suggests that the availability and utilization of ICT have significant input in the improvement of teaching and learning of chemistry education in universities. This paper argues that ICT-based innovations have the potentials to bridge the research- practice gap but was observed that some resources available were not well utilized by the teachers due to lack of interest and technological application. Teachers need to be actively participating in using ICT-based innovations in teaching. Most teachers in universities have not been motivated in integrating it and thereby, leading to gap in research-practice. The tendency of using ICT in research and practice depends on factors such as the attitude of teachers, teachers' demography, teaching experience, qualifications and materials available. This determines the performance of students, and it has been a source of concern to researchers and science educators. Hence, if ICT based innovations are effectively utilized by chemistry teachers in the universities, definitely, there must be a great bridge in research and practice and students would surely be motivated to learn chemistry. This will help to minimize the abstract nature of chemistry and leading to a great improvement in the performance and professional development.

Recommendations

1. Government should create and sustain an enabling environment for effective ICT integration in teaching chemistry.
2. Government should be committed to monitor the necessary environment for ICT instructions remain daunting.
3. Adequate ICT equipment for teaching chemistry should be provided by the school management.
4. Chemistry lecturers should make constant use of ICT equipments in teaching as it improves the academic performance of students.
5. Government and educational institutions should provide funding to schools for adequate purchase of ICT resources.
6. Ministry of Education should integrate ICT into the school curriculum.
7. Teacher education programmes should mandate ICT training to ensure that teachers acquire the competencies required for effective technology integration for teaching and learning.

References

Ajayi, V.O. & Ogbeba, J. (2017). Effect of gender on senior secondary chemistry students' achievement in stoichiometry using hands-on activities. *American Journal of Educational Research*, 5(8), 839-842.

Akram, H., & Yang, Y. (2021). A critical analysis of the weak implementation causes on educational policies in Pakistan. *International Journal of Human Innovation*, 4, 25–28.

Almed, M.A; Metu, D.V & Luwoye, A. (2017). Availability and Utilization of Communication technology Instructional Materials in Teaching of Chemistry in Ilorin Metropolis. *UNIOSUN Journal of Law, Development and Humanities*, 2(2), 5-12.

Caroll, A. (2021). How to encourage self-motivation in students: 5 strategies for success. Exam study expert. Willey way media & Leo web service. Retrieved from https:// exam study expert.com>self...

Ezurike, F. & Ayo-Vaughan, L. (2020). The effect of teaching methods on students' academic performance in Biology. *Journal Scientific Research and Reports*, 7(4), 130-145.

Haleem, A., M. Javaid, M. A. Qadri & R. Suman (2022). "Understanding the role of digital technologies in education*: A review." Sustainable operations and computers* 3: 275-285.

Hazrat, M. A., N. M. S. Hassan, A. A. Chowdhury, M. G. Rasul & B. A. Taylor (2023). "Developing a skilled workforce for future research demand: The potential of digital twin-based teaching and learning practices in engineering education.*"* *Sustainability* 15(23): 16433.

Hernandez-de-Menendez, M. & R. Morales-Menendez (2019). "Technological innovations and practices in engineering education: a review." *International Journal on Interactive Design and Manufacturing* (IJIDM) 13: 713-728

Iwu, N. S. (2021). Experiential learning and academic achievement in STEM subjects. *Journal of Educational Research and Review*, 6(3), 24-33.

Marín, V. I. & L. Castaneda (2023). Developing digital literacy for teaching and learning. In Handbook of open, distance and digital education. *Springer Nature Singapore*. Singapore: 1089-1108.

Martínez-Gutiérrez, A., J. Díez-González & P. Verde, & Perez, H (2023). "Convergence of virtual reality and digital twin technologies to enhance digital operators' training in industry."*International Journal of Human-Computer Studies* 180: 103136.

Mazurchenko, A. & M. Zelenka (2022). " Employees' digital competency development in theconstruction and automotive industrial sectors." *Central European Business Review* 11(1): 41.

Ngawang N. & Norbu, K. (2021). The flipped classroom model: A comprehensive review. *Journal of Educational Technology Development and Exchan*ge, 12(1), 1-24.

Nnoli, J. N. (2021). Impact of improvised organic reagents on senior secondary school students' level of motivation in Chemistry. *Oko Journal of Communication and Information Science*, 3(3), 1-9.

Nnoli, J.N. (2023). The Effects of e-learning assisted Instruction on Students achievement in Chemistry. Forum for Education studies1(1),308-312.

Nnoli, J.N. & Muogbo, U. F (2025). Perception of Teachers and Students on the Integration of ICT in Chemistry Instruction in Senior Secondary Schools in Awka Education Zone. *International Journal of Social and Education* (INJOSEDU), 3(2) 351-362.

Nowfeek, M. R., Farwis, M. & Nowzath, M. B. (2021). The contribution of integrated ICT in teaching and learning practice: Teachers' perspective. *International Journal of Advanced Multidisciplinary Research*, 8(5), 78-89.

Oguezue, N. K. (2025). Unveiling Teacher Competence: A Mixed-Method Exploration of Technology Integration in Upper-Basic Education in Nigeria. *Journal of Science Learning*, 8(1), 60-67.

Okocha, S.N. (2021). Lecturers' job Effectiveness through the use of e-learning Facilities in University of Ibadan. *The African Journal of Behavioral and Scale Development Research,* (31)

Okeke, A. M. (2022). Understanding Academic Performance and its Measurement. *Journal of Education Psychology,* 8(1), 15-28.

Voithofer, R. & Nelson, M. J. (2020). Teacher Educator Technology Integration Preparation Practices around TPACK in the United States. *Journal of Teacher Education*, 72(3), 314–328.

Oluwatosin, O. R., & Ajani, O. A. (2022).Impact of cooperative learning's group tasks on students' academic performance during continuous assessments. *International Journal of Innovation, Creativity and Change, 16(1), 304-322.*

Omiko, T. (2019).The Impact of Continuous Assessment on Student Learning Outcomes.*International Journal of Educational Research, 5(2), 78-90.*

Onah, R. O., & Anamezie, H. A. (2022). Academic interest as a predictor of academic achievement among secondary school physics students in Enugu State. *International Journal of Science Education and Culture, 1(1), 1-10.*

Nwosu, C. C., &Okoro, A. C. (2023).The Impact of Continuous Assessment on Student Performance in Nigerian Secondary Schools. *Journal of Educational Measurement and Evaluation, 16(2), 85-98.*

Silva, V. (2021). 8 factors that affects students motivation in education in built by me-STEM learning. Retrieved from https://www.built by me.com> student

Tuhaise, V. V., Tah, M. J. &Abanda, F. H. (2023)."Technologies for digital twin applications inconstruction." Automation in Construction 152: 104931.

Watson, J. H., &Rockinson-Szapkiw, A. (2021). Predicting pre-service teachers' intention to use technology-enabled learning. *Computer Education*, 168.

Xu, Z., Yuan, H., & Liu, Q. (2021). Student performance prediction based on blended learning. *IEEE Transactions on Education*, 64, 66–73.