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Qualitative Study on the Role of AI-Driven Problem Based Learning in Transforming Biology Classroom for Dual Mandate System in Nigeria

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Abstract

Dual mandate - the federal College of Education act 2023 signed by President Bola Ahmed Tinubu legally and officially empowered these institutions to award education degrees while the NCE programmes continues. The Nigerian curriculum for biology at the senior secondary school level is designed to help students develop a range of skills which include understanding biological concepts and principles, application of the knowledge to solve real-life situations, problem solving skills and ability to communicate biological ideas and concepts effectively. Problem based learning is a pedagogical approach that involves students learning through the experience of solving real world problems. It is a student centered approach that encourages critical and creative thinking, collaboration, active learning and application of skills to solve real world problems. Problem based learning can be effectively integrated with STEM subjects; science, technology, education and mathematics. Problem based learning is grounded in several theories like constructivist, social constructivism posits by Vygotsky 1978. Artificial Intelligence has the potential to make up for the shortcomings of traditional problem based learning by giving full account of students reports in the project, timely feedback and helps teachers to monitor students learning outcome. AI tools used in education/science include machine learning algorithms; natural language processing techniques which are used to create personalized learning; AI powered VR or AR are also used. AI driven PBL used include Khammigo or custom GPT, Google Docs, Padlet AI, Gradescope, Google sheets etc. The global AI in education market size was estimated at USD 5.88 billion in 2024 is projected to grow at Compound Annual Growth Rate (CAGR) of 31.2% from 2025 to 2030. However, with PBL, the teachers have to provide students with necessary resources e.g. learning materials, tools and technological support as well as guidance. One of the opportunities of integrating AI in education include personalized learning, creating more interactive and immersive learning experiences, games and simulations that boost students confidence, motivation and persistence leading to improved academic achievement.

Keywords: Problem-based learning, Artificial intelligence, Dual Mandate, Personalized learning

Introduction

Dual Mandate – Means "Colleges of Education in Nigeria can train students from NCE level up to Bachelor's Degree level under one institution". College of Education are not legally converted into universities but legally and officially empowered to award degrees in education related fields. The regulatory body involved are NUC, NCCE, JAMB, TETFund, Federal Ministry of Education. These institutions are to ensure curriculum standards, accreditation, staffing, infrastructure and quality assurance. Dual Mandate – Federal Colleges of Education can new run BOTH NCE program and Bachelor's Degree in same institution. The Federal Colleges of Education Act 2023 signed by President Bola Ahmed Tinubu officially empowered these schools to independently award education degrees while continuing with the NCE programme. It is a continuous 5 year NCE to Degree structure i.e 3 years NCE and 2 years Degree programme. After NCE and having met the requirements the students proceed to the additional 2 years and earn both certificate. The main purpose of the dual mandate include:

1. Improve teacher quality and standard – Science, Technical Vocational and ICT Education
2. Increase Access to Degree Education – promote difference pathways to earn degree
3. Revive College of Education – Public interest also boost
4. Remove/reduce university affiliation dependency
5. Address specialized teacher shortages
6. Boost research - strengthen research culture and innovations

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The Dual Mandate covers NCE, B.Ed, B.A. Ed, B.Sc. Ed (NCCE, 2026). Education constantly evolves and adapts to meet the changing demands of a globalized world (Djumanova & Makhmudov, 2020). One of the most critical aspects of 21st-century education is developing students' creative thinking, problem-solving skills for complex tasks, and ability to collaborate effectively (Suherman et al., 2021; Rehman et al., 2021a). Problem-Based Learning has increasingly been adopted as a pedagogical strategy that responds to these demands through student engagement in real-world, authentic tasks, requiring cross-disciplinary application of knowledge and skills (Boss & Krauss, 2017). Grounded in constructivist and experiential learning theories, PBL shifts education away from traditional teacher-centered, content-based instruction toward a more learner-centered, inquiry-driven approach (Rehman et al., 2021b). With the remarkable development of AI technology and the rapid expansion of application fields, AI has become the world's cutting-edge technology and hotspot issue, which is widely used in various fields of social development. Therefore, in this context, problem-based learning has become an inevitable trend to embrace the era of artificial intelligence as an important learning mode to cultivate students' core literacy: information literacy, reading and writing literacy digital literacy, communication and communicative literacy as well as critical and creative literacy. AI has the potential to make up for the shortcomings of traditional problem-based learning, by giving full accounts of students' progress in the project, timely feedback, assessment and thus to helps teachers and students monitor their learning outcomes.

Biology is one of the recognized science subjects taught in Nigerian educational system at both senior secondary schools and tertiary institutions. According to the Nigerian Educational Research and Development Council (NERDC, 2015), Biology is one of the core science subjects that students are expected to study at the senior secondary school level (NERDC, 2015). Biology is a vital subject that helps students understand the living world and the interactions between living organisms and their environment. This subject connects directly to the everyday experiences of Nigerians by emphasizing conservation, health, and the relationship with the natural world (Okebukola, 2015). Problem-Based Learning (PBL) is a pedagogical approach that involves students learning through the experience of solving real-world problems. It is a student directed centered approach that encourages active learning, critical thinking, and problem-solving skills. According to Hmelo-Silver (2017), Problem-Based Learning (PBL) is an instructional approach that centers on presenting students with authentic problems or scenarios requiring the application of knowledge, skills, and critical thinking. PBL has gained considerable attention as an innovative approach to education, emphasizing active learning and real-world application of knowledge. PBL engages students in authentic, complex projects—like those in 3D virtual laboratories that require critical thinking, problem-solving, collaboration, and communication skills (Malik & Zhu, 2023). This pedagogical approach has been adopted extensively across educational levels, from primary schools to tertiary institutions, to improve academic performance and equip students for 21st-century demands (Randazzo et al., 2021; Rehman et al., 2021c). Evidence from these studies is predominantly positive, suggesting that PBL promotes student achievement, retention, and motivation, as well as the development of higher-order thinking skills (Sari & Prasetyo, 2021).

The key characteristics of PBL include: real-world problems, learner-centered approach, hands-on-learning, critical thinking, collaboration, self-directed learning and feedback and reflection. The benefits of PBL in the teaching and learning of science include:

1. Improved critical thinking and problem-solving skills (Hmelo-Silver, 2017)
2. Increased student engagement and motivation (Dochy et al., 2020)
3. Development of collaboration and communication skills (Savery, 2015)
4. Improved retention and application of knowledge (Hmelo-Silver, 2017)
5. Preparation for real-world challenges and careers (Dochy et al., 2020)

Problem-based learning can be effectively integrated with STEM subjects to provide a holistic learning experience; the use of real-world problems to contextualize learning which increases student engagement and motivation. It also encourages collaborative learning which helps develop essential skills, such as communication, teamwork, and problem-solving skills. Problem based learning is more effective when students are motivated and engaged in the learning process. When they are interested in the problem or scenario, they are more likely to be interested in finding a solution. When the problem is relevant and authentic, meaning it is connected to real-world scenarios or issues. This helps students to see the value and

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purpose of the learning when the learning environment is supportive and collaborative, it encourages students to share ideas, ask questions, and learn from each other (team work). PBL is effective when technology is used to support learning, such as online resources, simulations, and collaboration tools. Student reflection and self-assessment enhance PBL effectiveness by helping learners identify gaps in their understanding and build a growth mindset (Hmelo, 2017).

The study would enhance student's participation in science activities that will increase their acquisition of knowledge, interest, retention and achievement in biology, it will develop problem solving skills, enable student to learn effectively in the learning process, and help them to take control of their learning. The study will give biology teacher's alternative teaching techniques when teaching a complex concept or topics. Apart from adding to the number of instructional strategies at the teacher's effectiveness, it will equally make biology teacher more flexible in changing their teaching strategies to suit the need of the student at a particular period, thus making teaching and learning to be student – centered instead of teacher centered. Biology teacher can also provide student with information about how the brain processes information, how it forms knowledge and memories, as well as the impact it has on these abilities.

The Mission of the Dual Mandate Policy in Nigeria

Colleges of Education is to autonomously and concurrently award both the NCE and Bachelor's Degrees in Education, thereby improving teacher quality and expanding degree access without depending on university affiliations (UNESCO, 2023). In a rapid evolving world, education must go beyond traditional knowledge transfer, this is in agreement with the four pillars of education that include:

1. Learning to know – mastering critical thinking, acquire the tools of understanding
2. Learning to do – gain practical skills ability to apply knowledge in zeal-world situation and the workplace
3. Learning to lives together – building peaceful cooperative and harmonious relationship with others (team work)
4. Learning to be – for personal growth, self-awareness, creativity

There is a strong congruence between the four pillars of education and Problem Based Learning principles, thus PBL is in harmony with the four pillars of education.

Problem Statement

The persistent issue of low achievement in biology continues to affect secondary school students across Nigeria (Adebayo, 2017 and Okebukola, 2015). Although various measures have been introduced by biology educators and policymakers, students' difficulties in understanding and applying biology concepts persist (Kolawale, 2017). Consequently, poor results in biology exams have restricted students' access to future academic and career prospects (Akpochafo, 2018). As Katcha (2017) observes, the reliance on traditional, teacher-centered methods that prioritize rote learning over practical application contributes significantly to poor biology performance in Nigerian schools. In addition, low student interest and motivation in biology have further worsened academic performance (Esiobo, 2018). Okebukola (2015) identifies multiple challenges facing biology teaching in Nigerian senior secondary schools: insufficient qualified teachers, inadequate laboratories, and restricted access to textbooks and other instructional resources. Despite these challenges, Biology remains a vital subject in the Nigerian educational system, and efforts are being made to improve the teaching and learning of the subject at the senior secondary school level (NERDC, 2015). The Nigerian curriculum for Biology at the senior secondary school level is designed to help students develop a range of skills which include

1. Understanding of biological concepts and principles (NERDC, 2015)
2. Ability to apply biological knowledge to real-life situations (Okebukola, 2015)
3. Development of critical thinking and problem-solving skills (NERDC, 2015)
4. Ability to communicate biological ideas and concepts effectively (Okebukola, 2015)

Some factors responsible for the failure to achieve the objectives of biology education over the years in Nigerian secondary schools include Inadequate qualified teachers, Inadequate laboratory facilities and equipment, Insufficient textbooks and learning resources, Poor teaching method, Large class size, Lack of motivation and interest among student, Inadequate assessment and evaluation method. (NERDC, 2015) According to various studies and reports, some poor teaching methods used by biology teachers in Nigerian secondary schools include: Lecture method, Rote memorization, Textbook-based teaching, Didactic teaching, Limited use of visual aids, insufficient practical work, teacher-centered approach etc.

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Theoretical Framework

Constructivist Theory

Social constructivism – foundation for AI-Driven PBL

The theoretical foundation for this study is Vygotsky's Social Constructivism (1978). Vygotsky posited that learning occurs through social interaction within the Zone of Proximal Development (ZPD). He argued that learning doesn't happen in isolation. It happens through interaction with people, tools and culture.

Social Interaction: Every function appears twice: First on the social level, then on the individual level (Vgotsky, 1978). It means, first we learn with others, then we internalize it.

Link to PBL – group work, discussion and collaboration are not extras, they are how learning happens.

Zone of Proximal Development (ZPD): Is the gap between what a learner can do independently and what a learner can do with guidance (sweet spot for learning with just enough help).

Link to AI Driven PBL – AI can act as a "digital tutor" to provide scaffolding inside each students ZPD.

Scaffolding by MKO (More Knowledgeable Other): An MKO can be a teacher, peer, textbook or tool.

Link to AI-Driven PBL – AI Chatbots, adaptive platforms, AI analytics.

Vygotsky emphasized that cognitive development occurs through social interaction within the Zone of Proximal Development (ZPD). Learning is maximized when students receive appropriate scaffolding from a More Knowledgeable Other (MKO). In AI-driven PBL technology serves as an MKO by providing adaptive guidance, feedback and resources as students collaboratively solve authentic problems. This framework aligns with Boss and Kraus (2017) who argues that effective PBL requires structured collaboration and technology integration to support diverse learners.

Why Vygotsky matters for AI-driven PBL

Traditional PBL = Teacher is the only MKO. 1:50 or more ⇒ bottleneck (learning slows down or stops because resources are limited).

AI-Driven PBL = every student gets an MKO through AI tutoring, plus peers, plus teacher.

Empirical Studies on AI Driven PBL

Recent empirical evidence shows that AI driven PBL increases student engagement in biology. Yin (2022) found that integrating AI with virtual reality in biology PBL led to a 32% increase in student engagement and higher time on task compared to traditional PBL. Similarly, AI scaffolding sustains student interest Chen and Wang (2023) found that an AI Chatbot used as a tutor in genetics PBL increased students situational interest and persistence as learners received immediate guidance.

Chen & Wang (2023) AI tutor in biology PBL

Focus: Undergraduate Genetics PBL

Intervention: Custom ChatGPT trained on biology curriculum acted as result tutor during PBL

Finding: AI asked Socratic questions instead of giving answers. Students in ZPD made fewer conceptual errors in mitosis/meiosis

Result: Students reported higher situational interest and task value. AI prevented them from getting stuck, so they didn't disengaged.

Conclusion: In biology specifically Chen & Wang (2023) found that an AI Chatbot used during PBL improved students conceptual understanding of difficult topics like genetics by guiding them through the Zone of Proximal Development (Vygotsky, 1978).

Yin (2022) AI + VR in PBL biology

Focus: Distance learning biology during Covid Intervention: students solved biology problems in a virtual lab using AI guided VR. AI gave hints and adapted difficulty.

Finding: Students in AI-VR PBL group scored 22% higher on problem-solving and had higher motivation.

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Result: Yin (2022) AI – VR group had significantly higher behavioral engagement. More questions asked, more time on task. Motivation scores on IMMS scale (Instructional Materials Motivation Survey) were 18% higher.

Conclusion – AI with virtual reality in a biology PBL setting had significant gains in student engagement and problem-solving skills.

The Use of AI-Based Tools for Teaching Biology

The application of AI tools to biology education has the potential to enhance the learning experience for students and improve their understanding of complex biological concepts: According to a report from the National Science Board (2016), the use of technology in education can increase student engagement, improve learning outcomes, and reduce the achievement gap between students (National Science Board, 2016) AI tools, such as machine learning algorithms and natural language processing techniques, can help educators create personalized learning experiences that cater to the needs of individual students. For instance, Al systems can analyse students' learning patterns and performance, then tailor educational content to fit their unique needs. Furthermore, AI-powered Virtual Reality (VR) or Augmented Reality (AR) tools are being used to create interactive simulations or visualizations of complex biological systems, offering a more immersive and intuitive understanding of the subject matter. Biology is a complex subject that requires students to understand a great deal of information about the interactions between living organisms and their environment. Multimedia resources such as AI-driven visualizations and simulations address learning barriers. Specifically, VR simulations, immerse students in three-dimensional biological systems, allowing clearer understanding of spatial relationships between different structures and organisms (Chang et al., 2018). Similarly, interactive visualizations can help students grasp difficult concepts such as protein folding and molecular interactions (Marx, 2013).

AI Tools Used in Biology Education

1. Consensus – AI academic search engine – provide student with evidence-based answers to complex biological questions.
2. Khan Academy – (interactive and adaptive) – AI powered foundation for Nigerian students, braking down complex biological concept – genetics.
3. Biology specific chatbots – like ChatGPT or Gemini.
4. Virtual laboratories and simulations – PhET interactive simulation – allows students conduct virtual experiment.
5. Research and data analysis – Google, NotebookLM – allows users to upload local biology textbooks, syllabus or research papers.
6. Ecology and biodiversity – AI driven application like iNaturalist are used.
7. Biochemistry and structure biology – tools like Alphafold and Uniprot – allow students to predict protein folding and study disease mechanism.
8. Platforms like scispace copilot - literature and data review.

AI in Education Market Size and Trends

Schools and institution are using AI-powered tools such as intelligent tutoring system, chatbots, google, notebookLM etc to enhance student engagement and optimize teaching methods. The integration of AI in the education industry is further propelled by the shift towards e-learning platforms accelerated by the COVID-19 pandemic, and strong investments in EDTECH startups. In addition advancement in Natural language processing and comparison are expanding AI applications for automated assessments, content delivery and adaptive learning solutions. This indicates the increasing adoption of AI in education sector including science education (Grand View Research, 2024). Virtual facilitators such as AI-powered tutors and teaching assistant, enable real-time student interacts and support, improving engagement and learning outcomes e.g. online training sessions virtual meetings, online courses, virtual events etc. VR has emerged as a transformative technology in education providing new avenue for immersive and interactive learning experience. AR in education involves adding digital information into the zeal held to create interactive and immersive learning experiences. It can be used to visualized abstract concepts, enhance practical skills, personalized learning etc e.g virtual field trips, virtual labs and experiment. According to a report by Grand View Research (2021), the global AI in education market size was valued at USD 1.47 billion in 2020 and is expected to grow at a compound annual growth rate (CAGR) of 36.4% from 2021 to 2028.

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This indicates the increasing adoption of AI in the education sector, including biology education (Grand View Research, 2021). The global AI in education market size was estimated at USD 5.88 billion in 2024 and is projected to grow at a CAGR of 31.2% from 2025 to 2030, driven by the increasing demand for personalized learning experiences.

Problems with Problem-Based Learning

From the perspective of students, problem-based learning has the following main problems:
Firstly, problem-based learning requires student to have strong self-management and time management skills. They need to take the initiative to find problems, gather information, and analyse and solve them, so their time management ability is one of the abilities needed for problem-based learning. Secondly, teamwork is the key to whether problem-based learning can achieve goods results, but many teams may encounter a series of problems due to inappropriate division of labour, thus reducing the learning effect. Third, while PBL is open-ended, this flexibility can be challenging for some students. New PBL learners often mimic teacher examples, also the depth of topic selection remains limited (Sylva et al., 2023).

From the teacher's perspective, problem-based learning has the following main problem: First, in problem-based learning, teachers play the role of leaders and facilitators, not just knowledge transmitters, and are required to provide students with the necessary resources (e.g., learning materials, tools, and technological support) and provide guidance throughout the project process. This means that teachers usually need to spend more time than traditional teaching methods to prepare materials, design projects, and provide continuous guidance, which invariably increases the burden on teachers and leads to increased pressure and excessive workload. Second, problem-based learning requires teachers to have strong curriculum design skills and problem-oriented teaching methods. This may be a challenge for teachers who are used to traditional teaching. In problem-based learning, there is often an emphasis on student autonomy and inquiry. However, this can sometimes lead to a situation where teachers provide too much freedom, resulting in students feeling lost or unsure of how to proceed. Problem-based learning emphasizes students' overall development and practical skills, not just knowledge memorization and understanding. Student performance includes aspects of teamwork, creative problem-solving skills, critical thinking, project management, and communication skills. These skills and competencies are difficult to quantify using traditional grading scales.

Personalizing Biology Learning Experiences with AI

With the use of AI-based approaches that addresses learners' individual differences, varying learning rates, and feedback requirements, AI can integrate these components into the learning process and ensure inclusive engagement of all students (Eden et al., 2024). In the case of education, there are intelligent tutoring systems and other personalized learning platforms. By applying machine learning, AI identifies learning approaches best suited to each student's background, ability, and preferences, which enhances the likelihood of successful outcomes at the end of the course (Tiwari, 2023). Thus, AI tools based on large language models generating lessons and materials in different approaches can help teach separate biology topics. AI tools offer multiple-choice assessments to check understanding and encourage more study time on difficult subjects (Akintade, 2024). Furthermore, AI-based education tools enable blended learning in science through educational data mining. By analysing student data clusters, teachers can better tailor instruction to address varied student needs (Setiadi et al., 2022).

Opportunities of Integrating AI in Education

A key advantage of integrating AI into education is its capacity to deliver personalized learning experiences tailored to individual students (Qushem et al., 2021; Chen et al., 2022; Ahmad et al., 2020). Conventional education models that apply a uniform approach tend to overlook differences in students' learning styles and rates, limiting their effectiveness (Lopez & Schroeder, 2008; Mustapha, 2015). In contrast, AI-powered adaptive learning systems analyse extensive data on student performance and preferences, enabling instruction that is tailored to each learner's unique needs (Gligorea et al., 2023). Personalized learning enhances engagement, motivation, and achievement among students, as it fosters a sense of empowerment and support in their learning process (Song et al., 2012; Zakaria et al., 2024). Personalized learning also promotes equity and reduces achievement gaps by giving every student access to high-quality, customized instruction (Patrick et al., 2016; Pape & Vander Ark, 2021). AI technologies have the potential to significantly enhance student engagement and academic outcomes by creating more interactive and immersive learning experiences. For example, AI-

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powered chatbots and virtual tutors mimic human instructors by engaging students in conversation, addressing queries, and offering real-time feedback (Chen et al., 2023; Labadze et al., 2023). This personalized support can boost student confidence, motivation, and persistence, leading to improved academic performance. Furthermore, AI-driven educational games and simulations offer engaging and interactive ways for students to apply their knowledge and skills in authentic contexts. Gamification combined with adaptive learning enables educators to build learning environments that are fun, engaging, and effective at helping students master complex concepts and skills (Du & Wang, 2023; Westera et al., 2020). AI-powered systems can automate routine administrative tasks such as grading, lesson planning, and scheduling, freeing up educators to devote more attention to designing engaging learning experiences, providing individualized support to students, and collaborating with colleagues. AI can also assist educators in analysing student data to identify patterns, trends and areas for improvement. AI in education aims in creation of immersive learning environments through virtual reality (VR) and augmented reality (AR) technologies. These immersive technologies have the potential to transport students to virtual worlds, historical settings, or scientific simulations, allowing them to explore and interact with concepts in ways that would be impossible in a traditional classroom setting. For example, students studying biology could use AR to overlay digital images of anatomical structures onto physical models, enabling them to visualize and understand complex biological processes in three dimensions. VR also enables students to experience immersive recreations of events and locations, fostering deeper insight into the context and importance of key moments (Yin, 2022; AlGerafi et al., 2023; Gandedkar et al., 2021).

The Role of Analytic AI in Enhancing Students Engagement and Motivation

Problem-based learning presents content through task-driven projects centered on real-life problems. Students use resources for cooperative inquiry and innovation to better understand subject matter and strengthen their comprehensive abilities (Wenlan et al., 2016). Analytic AI supports the four ARCS dimension of motivation measured by IMMS which was developed by Keller (2010). The instructional materials motivation survey is a 36 items 5 point Likert Scale instrument which is the most widely validated instrument used in measuring motivation in technology based learning and therefore directly aligns with the four (4) things AI driven PBL is design to improve. The ARCS – Attention, Relevance, Confidence and Satisfaction.

1. Tracks engagement in real-time – Analytic AI monitors time-on-task, number of hints used, questions asked. AI gives a scaffold support – Intelligent Tutoring System e.g cognitive tutor that boots confidence – IMMS.
2. Personalizes the PBL problem – Analytic AI analyses student interests/career e.g medicine, agriculture etc. It provide biology cases that relate to students interests and future careers.
3. Gives Teacher Data – Analytic AI summarizes class: It gives the teacher areas where he needs to re-teach (measures motivation).
4. Analytic AI can link IMMS survey schools to behaviour: Students having low satisfaction clicked way fast

Summary

The innovation of Artificial Intelligence-enabled Problem-Based Learning (PBL) is the integration of advanced AI technologies into the traditional PBL model, which greatly improves the personalization, efficiency, and interactivity of learning. Specifically, this approach improves student engagement and learning outcomes by predicting required project resources through project management tools (e.g., Trello and Cornofy) integrated with AI plug-ins, providing students with personalized learning content using adaptive learning platforms (e.g., Knewton Alta), and creating realistic learning environments using VR and AR technologies. In addition, AI-assisted design tools (e.g., Autodesk Dreamcatcher, Canva) and intelligent project management software (e.g., Asana, Monday.com) are used to help students become more efficient in the production of their work and project management. This approach provides a more efficient, personalized, and technology-driven learning framework for the education sector, enabling students to better adapt to future learning and work environments, as well as providing more support and facilitation for teachers in teaching and in the assessment procedure.

Conclusion

The Dual Mandate is one of the biggest reforms in teacher education in Nigeria. It is a teacher education upgrade, it is an expansion of higher education access and a modernization of Nigeria's College of Education system, there is therefore the

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need for new innovations in the teaching and learning of especially science subjects in Nigerian schools. Problem-Based Learning is grounded in several theoretical frameworks, including constructivism, social constructivism, cognitive load theory, and problem-solving theory. By incorporating key components such as real-world problems, learners driven education, collaborative learning, scaffolded support, and feedback and reflection, PBL provides students with opportunities to develop problem-solving skills, construct their own knowledge, and become self-directed learners.

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