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Harnessing Problem-Based Learning for Developing Innovative Technology Solutions in Technical Education Programmes of Colleges of Education in North Central Nigeria

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Abstract-* This study examined the adoption and effectiveness of Project-Based Learning (PBL) in technical education programmes in Colleges of Education in North Central Nigeria. A descriptive survey research design was adopted and guided by three research questions and three corresponding null hypotheses. The population comprised 125 lecturers and 247 students. All lecturers were included in the study, while 153 students were sampled using Yamane's formula. Six Colleges of Education were selected through purposive sampling. Data were collected using a structured questionnaire, which yielded a Cronbach's alpha reliability coefficient of 0.89. Mean, standard deviation, and independent samples t-test were used for data analysis at a 0.05 level of significance. Findings revealed that instructional practices in technical education remain largely traditional and teacher-centered, with limited application of interactive strategies. The integration of PBL was found to be moderate but inconsistent, reflecting weak institutional support for its systematic implementation. However, PBL significantly enhanced students' creativity, problem-solving ability, practical skills, and capacity to generate innovative and context-relevant technological solutions. The study concludes that while PBL is not yet fully institutionalized, its demonstrated benefits highlight the need for curriculum reform, lecturer capacity development, and supportive institutional policies.

Index Terms-* Project-Based Learning; Technical Education; Instructional Strategies; Innovative Technology Solutions; Colleges of Education; Nigeria

I. INTRODUCTION

Technical education is central to national development and industrial advancement, particularly in developing countries like Nigeria. It equips learners with occupational skills and technical know-how required in various sectors of the economy. However, Ogbodo and Musa (2021) stated that there is growing concern that graduates of Colleges of Education, especially in the North Central region, are not adequately prepared to meet 21st-century workforce demands due to outdated instructional strategies. Conventional teacher-centered approaches often emphasize rote learning over creativity, critical thinking, and real-world application, leaving graduates ill-prepared for innovation-driven industries (Adeleke et al., 2023). These concerns arise at a time when technological transformation is reshaping global economies and increasing the need for graduates who can conceptualize, design, and implement indigenous technological solutions.

Innovation, especially within the context of technical education, goes beyond the use of modern tools; it involves the creation, adaptation, and application of new ideas, systems, and technologies that address real-world challenges and improve productivity. Students who are exposed to innovation-oriented activities such as digital modeling, design thinking, prototyping, and practical problem-solving demonstrate stronger abilities to generate context-specific technological solutions (Obi & Nwosu, 2022). International bodies such as the OECD (2021) emphasize that innovative technologies form the backbone of modern technical education, shaping both teaching methodologies and the expected competencies of learners. However, nurturing such competence requires pedagogical approaches that move beyond memorization and promote exploration, creativity, and knowledge application.

Across global educational landscapes, the demand for 21st-century skills - such as creativity, critical thinking, problem-solving, digital literacy, and collaboration - has grown significantly. Traditional lecture-based teaching approaches commonly used in Nigerian CoEs tend to emphasize rote learning, memorization, and theoretical recall over practical engagement, experiential learning, and innovation-oriented thinking (Adeleke et al., 2023). This mismatch between instructional methods and industry needs has contributed to a widening gap between graduate capabilities and technological problem-solving expectations in modern workplaces. Consequently, there is a pressing need to adopt more dynamic models of teaching that foster innovation, adaptability, and creativity.

Problem-Based Learning (PBL) has emerged as one of the most effective learner-centered pedagogies for developing these competencies. In PBL environments, Huang (2025) explained that students learn by engaging with real-life, open-ended problems that require inquiry, experimentation, critical thinking, teamwork, and creativity. This approach as stressed by Anyaogu and Enwereuzo (2023) strengthens 21st-century skills such as collaboration, digital literacy, communication, and adaptive reasoning - attributes increasingly demanded in technical and industrial workplaces. For technical education students, PBL bridges the gap between theoretical concepts and real-world technological practice, enabling them to investigate practical challenges, design solutions, and apply tools and materials in authentic contexts. Research evidence consistently shows that when PBL is adopted, students demonstrate higher levels of creativity, self-efficacy, and innovation in producing technology-based solutions (Uzoegwu & Abonyi, 2022).

Despite its global relevance, the integration of PBL in Nigerian Colleges of Education remains limited and fragmented. Many Colleges of Education still operate within rigid lecture-based systems that do not sufficiently support learner autonomy or creative engagement. Several institutions struggle with innovation readiness due to challenges such as inadequate workshop facilities, outdated equipment, limited digital resources, and insufficient lecturer training on modern pedagogies (Nnaji & Ogbene, 2024). In the North Central region, these challenges are widespread. Although these institutions train future technical teachers and therefore hold enormous potential to shape national innovation capacity, many of them lack the pedagogical and infrastructural conditions necessary to fully implement PBL or support technology-oriented innovation.

This situation gives rise to a fundamental problem: despite the central role of technical education in Nigeria's industrial and economic development, many graduates of Colleges of Education lack the innovative capacity and problem-solving skills needed to thrive in today's technology-driven society. The persistent reliance on traditional instructional practices limits students' opportunities to engage in the types of experiences required to generate, test, and refine technological solutions. Although PBL has been identified as a powerful approach for developing innovation and 21st-century skills, its adoption across Colleges of Education in North Central Nigeria remains minimal, inconsistent, and insufficiently supported. There is a scarcity of empirical evidence on the extent of PBL implementation, the readiness of institutions to support such methodologies, and the actual influence of PBL on students' ability to develop innovative technology solutions. Without such evidence, educational reforms remain slow, and technical education programmes risk further misalignment with national development priorities.

These gaps justify the need for an in-depth investigation into how PBL can be effectively harnessed to develop innovative technological competencies among technical education students in Colleges of Education in North Central Nigeria. Findings from such a study will provide insights that can guide curriculum reform, lecturer retraining, institutional strengthening, and the broader transformation of technical teacher education towards supporting national goals of innovation-driven growth.

II. OBJECTIVES OF THE STUDY

The main objective of the study is to investigate how Problem-Based Learning (PBL) can be harnessed to develop innovative technology solutions in technical education programmes of Colleges of Education in North Central Nigeria. Specifically, the study seeks to:

1. Identify the current instructional strategies used in technical education in Colleges of Education.
2. Determine the extent of PBL integration in technical education programmes.
3. Examine how PBL influences students' ability to generate innovative technological solutions.

III. RESEARCH QUESTIONS

Three research questions (RQs) guided the study:

1. What are the current instructional strategies used in technical education programmes of Colleges of Education in North Central Nigeria?
2. To what extent is PBL integrated into technical education programmes in the north central Nigeria?
3. How does PBL influence students' ability to generate innovative technology solutions?

IV. RESEARCH HYPOTHESES

The following null hypotheses were formulated for the study:

H01: There is no significant difference in the mean responses of lecturers and students on the current instructional strategies used in technical education programmes in Colleges of Education in North central Nigeria.
H02: There is no significant difference in the mean responses of lecturers and students on the extent of PBL integration in technical education programmes in Colleges of Education in North central Nigeria.

H03: There is no significant difference in the mean responses of lecturers and students on the influence of PBL on students' ability to generate innovative technology solutions in Colleges of Education in North central Nigeria.

V. METHODOLOGY

The study adopted a survey research design, which is appropriate for collecting data on respondents' opinions, perceptions, and experiences at a specific point in time through the use of questionnaires (Kothari, 2022). The study was conducted in North Central Nigeria, a region comprising six states with several Colleges of Education (CoEs). Using purposive sampling, six established Colleges of Education offering Technical Education programmes - one from each state - were selected to ensure relevance and geographical representation. These included Umaru Sanda Ahmadu College of Education, Minna (Niger State); College of Education (Technical), Lafiagi (Kwara State); College of Education, Oju (Benue State); College of Education, Akwanga (Nasarawa State); College of Education, Ankpa (Kogi State); and Federal College of Education, Pankshin (Plateau State). Newly established CoEs and those without Technical Education programmes were excluded to ensure consistency and reliability of data.

The population of the study comprised 125 lecturers and 247 students of Technical Education in the selected institutions. All lecturers were included, while the sample size for students was determined using Yamane's formula at a 0.05 level of significance, resulting in a sample of 153 students. Thus, the total sample size was 278 respondents. Data were collected using a 46-item structured questionnaire organized into four sections: bio-data, current instructional strategies in technical education (14 items), extent of Project-Based Learning (PBL) integration (16 items), and influence of PBL on students' ability to generate innovative technology solutions (16 items). The questionnaire was structured on a 5-point Likert scale ranging from Strongly Agree (5) to Strongly Disagree (1).

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The instrument was validated through face and content validation by three experts from the Department of Industrial and Technology Education, Federal University of Technology, Minna. Reliability was established through a pilot study conducted at the Federal College of Education (Technical), Bichi, Kano State, yielding a Cronbach's alpha coefficient of 0.89. A total of 278 questionnaires were administered, and 272 valid copies (122 from lecturers and 150 from students), representing a 97.8% response rate, were used for analysis. Data were analyzed using mean and standard deviation to answer the research questions, while hypotheses were tested using appropriate inferential statistics at the 0.05 level of significance. A criterion mean of 3.50 was used for decision-making, and hypotheses were rejected when p-values were less than 0.05.

VI. RESULTS

Table 1: Mean, Standard Deviation and t-test Analysis of the Current Instructional Strategies Used in Technical Education in Colleges of Education in North Central Nigeria

S/N	Instructional Strategy Item	Mean (M)	SD	p-value	Remark
1	Lecturers mainly use lecture/teacher-centered methods	3.88	0.71	0.101	Accepted/NS
2	Teaching focuses more on theory than practice	3.67	0.75	0.334	Accepted/NS
3	Question-and-answer method is used during teaching	3.52	0.82	0.417	Accepted/NS
4	Students are encouraged to ask questions during teaching	3.68	0.79	0.229	Accepted/NS
5	Demonstration is used to show students how to carry out technical tasks	3.52	0.73	0.271	Accepted/NS
6	Guided support is provided during practical activities to ensure students' understanding	3.91	0.68	0.120	Accepted/NS
7	Students actively participate in classroom and workshop activities	3.59	0.75	0.118	Accepted/NS
8	Students are given individual class assignments regularly	3.56	0.77	0.352	Accepted/NS
9	Teamwork and collaboration are encouraged during project work	3.62	0.80	0.341	Accepted/NS
10	Teaching aids such as charts and models are used to support learning	3.12	0.85	0.414	Rejected/NS
11	Real-life examples are used to explain technical concepts	3.54	0.78	0.237	Accepted/NS
12	Digital tools are sometimes used to support teaching and learning	3.58	0.83	0.344	Accepted/NS
13	Students reflect on their learning and challenges faced after projects	3.67	0.78	0.239	Accepted/NS
14	Students are assessed through written tests and continuous assessment	3.79	0.69	0.112	Accepted/NS

The results in Table 1 indicate that lecturers predominantly use lecture/teacher-centered methods (M = 3.88, SD = 0.71, p = 0.101) and focus more on theory than practice (M = 3.67, SD = 0.75, p = 0.334). Interactive strategies such as question-and-answer (M = 3.52, SD = 0.82, p = 0.417) and

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encouraging student questions (M = 3.68, SD = 0.79, p = 0.229) are moderately applied. Practical approaches, including demonstrations (M = 3.52, SD = 0.73, p = 0.271) and guided support during activities (M = 3.91, SD = 0.68, p = 0.120), occur at moderate levels. Students' active participation (M = 3.59, SD = 0.75, p = 0.118), individual assignments (M = 3.56, SD = 0.77, p = 0.352), teamwork (M = 3.62, SD = 0.80, p = 0.341), use of digital tools (M = 3.58, SD = 0.83, p = 0.344), reflection on learning (M = 3.67, SD = 0.78, p = 0.239), and assessment through written tests/continuous assessment (M = 3.79, SD = 0.69, p = 0.112) were also moderate, while the use of teaching aids (M = 3.12, SD = 0.85, p = 0.414) was relatively low. All p-values were above 0.05, indicating no significant differences between lecturers' and students' perceptions.

Table 2: Mean, Standard Deviation and t-test Analysis of the Extent of Project-Based Learning (PBL) Integration in Technical Education Programmes in Colleges of Education in North Central Nigeria

S/N	PBL Integration Items	Mean (M)	SD	p-value	Remark
15	PBL activities are included in course outlines	3.02	0.84	0.281	Rejected/NS
16	Lecturers organize lessons around real-life technical problems	3.51	0.79	0.316	Accepted/NS
17	Problems used in class relate to real technical challenges	3.64	0.76	0.310	Accepted/NS
18	Students are given real-life problems to solve during lessons	3.57	0.78	0.139	Accepted/NS
19	Lessons are structured around problem-solving activities	3.18	0.81	0.352	Rejected/NS
20	Students work in groups to solve technical problems	3.85	0.74	0.221	Accepted/NS
21	Lecturers guide students rather than give direct answers	3.52	0.82	0.364	Accepted/NS
22	Learning tasks require students to think critically	3.56	0.77	0.228	Accepted/NS
23	Students research problems before proposing solutions	3.09	0.83	0.071	Rejected/NS
24	Students are allowed to explore different solution methods	3.59	0.79	0.034	Accepted/S
25	Learning activities encourage independent thinking	3.53	0.76	0.329	Accepted/NS
26	PBL is used during practical and workshop sessions	3.41	0.73	0.412	Rejected/NS
27	Students present solutions to identified technical problems	3.52	0.80	0.248	Accepted/NS
28	Assessment includes evaluation of problem-solving skills	3.14	0.82	0.355	Rejected/NS
29	Students reflect on what they learn after solving problems	3.55	0.85	0.367	Accepted/NS
30	PBL is used regularly in technical education courses	2.94	0.86	0.224	Rejected/NS

The results in Table 2 show that the extent of Project-Based Learning (PBL) integration in technical

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education programmes in Colleges of Education in North Central Nigeria is moderate but inconsistent. PBL activities in course outlines (M = 3.02, SD = 0.84, p = 0.281), problem-solving lessons (M = 3.18, SD = 0.81, p = 0.352), practical/workshop use (M = 3.41, SD = 0.73, p = 0.412), assessment of problem-solving skills (M = 3.14, SD = 0.82, p = 0.355), and regular course use (M = 2.94, SD = 0.86, p = 0.224) were relatively low, with no significant differences between lecturers' and students' perceptions. Conversely, lessons were moderately organized around real-life technical problems (M = 3.51, SD = 0.79, p = 0.316) and related challenges (M = 3.64, SD = 0.76, p = 0.310), with students solving real-life problems (M = 3.57, SD = 0.78, p = 0.139), working in groups (M = 3.85, SD = 0.74, p = 0.221), and guided by lecturers (M = 3.52, SD = 0.82, p = 0.364). Critical thinking (M = 3.56, SD = 0.77, p = 0.228), presentation of solutions (M = 3.52, SD = 0.80, p = 0.248), reflection after problem solving (M = 3.55, SD = 0.85, p = 0.367), and independent thinking (M = 3.53, SD = 0.76, p = 0.329) were also moderately applied, with no significant differences.

Table 3: Mean, Standard Deviation and t-test Analysis of the Influence of Project-Based Learning (PBL) on Students' Ability to Generate Innovative Technology Solutions

S/N	PBL Innovation Items	Mean (M)	SD	p-value	Remark
31	PBL improves students' creative thinking skills	3.78	0.66	0.322	Accepted/NS
32	PBL enhances students' innovation skills	3.74	0.69	0.284	Accepted/NS
33	Students generate new ideas when solving problems through PBL	3.69	0.71	0.326	Accepted/NS
34	Students learn how to identify technical problems on their own	3.62	0.73	0.211	Accepted/NS
35	PBL increases students' confidence in problem-solving	3.81	0.64	0.101	Accepted/NS
36	PBL encourages teamwork and idea sharing	3.88	0.61	0.226	Accepted/NS
37	PBL helps students apply theory to practice	3.92	0.59	0.170	Accepted/NS
38	Students design simple technological solutions during PBL	3.67	0.72	0.318	Accepted/NS
39	Students develop practical skills through PBL activities	3.85	0.63	0.361	Accepted/NS
40	PBL improves students' ability to use tools and materials	3.73	0.70	0.385	Accepted/NS
41	Students learn to test and improve their solutions	3.58	0.75	0.314	Accepted/NS
42	Students can adapt solutions to local needs	3.61	0.74	0.299	Accepted/NS
43	PBL supports the development of indigenous technology	3.55	0.76	0.318	Accepted/NS
44	PBL enables students to develop cost-effective technological solutions using locally available materials	3.66	0.72	0.332	Accepted/NS
45	PBL improves students' decision-making skills	3.59	0.75	0.325	Accepted/NS
46	Students are better prepared for technology-related challenges	3.71	0.69	0.326	Accepted/NS

The results in Table 3 show that Project-Based Learning (PBL) moderately enhances students' ability to generate innovative technology solutions in technical education programmes. PBL improves creative thinking (M = 3.78, SD = 0.66, p = 0.322), innovation skills (M = 3.74, SD = 0.69, p = 0.284), problem identification (M = 3.62, SD = 0.73, p = 0.211), confidence in problem-solving (M = 3.81, SD = 0.64, p = 0.101), teamwork (M = 3.88, SD = 0.61, p = 0.226), application of theory to practice (M = 3.92, SD = 0.59, p = 0.170), practical skills (M = 3.85, SD = 0.63, p = 0.361), and the development of simple, indigenous, and cost-effective technological solutions (M = 3.55–3.66, SD = 0.72–0.76, p = 0.318–0.332). It also supports testing, adaptation, decision-making, and preparation for technology-related challenges (M = 3.58–3.71, SD = 0.69–0.75, p = 0.299–0.326).

All p-values were above 0.05, indicating no significant difference between lecturers' and students' perceptions, suggesting a shared recognition of PBL's positive influence on innovation and practical problem-solving skills.

VII. DISCUSSION

Findings from RQ1 indicate that instruction in technical education remains largely traditional and teacher-centered, with lecture methods, theory-based teaching, and written assessments dominating classroom practice. Although demonstrations, workshop activities, questioning techniques, and limited use of digital tools were observed, their application was moderate rather than extensive, as reflected by mean values slightly above the criterion mean and modest standard deviations.

This pattern aligns with recent research showing that traditional instructional approaches continue to prevail in many higher education settings, especially where resources and staff development are limited, constraining the adoption of more active learning strategies such as PBL (Silma et al., 2024; Ogbodo and Musa (2021). While the presence of interactive practices such as group discussions and practical sessions suggests a gradual pedagogical shift, the results imply that the instructional environment is not yet fully supportive of student-centered approaches such as PBL. The result also revealed that there was no significant difference between the mean responses of lecturers and students on the current instructional strategies used in teaching technical education. This partially explains why innovative learning outcomes remain uneven across institutions.

The results of RQ2 reveal that PBL is only partially and inconsistently integrated into technical education programmes. While items related to real-life problem solving, group work, critical thinking, and the use of PBL during practical sessions were accepted, key institutional indicators - such as inclusion of PBL in course outlines, lecturer training, structured reflection, and regular use across courses - were rejected.

This finding suggests that PBL practices in Nigerian tertiary institutions are often informal, lecturer-initiated, and situational, rather than systematically embedded in curricula. These findings are corroborated by a recent study conducted by Anyaogu and Enwereuzo (2023), which found that even in higher education contexts with explicit frameworks for PBL, integration is uneven, with substantial gains depending on curriculum design and institutional support. The results also indicate that there is no significant difference between lecturers and students perception on the extent of PBL integration, except on item 24. Altogether, the results pointed out that elements of PBL exist in technical education programmes; however, their fragmented implementation limits their overall impact on learning outcomes.

Findings from RQ3 demonstrate that PBL has a strong and positive influence on students' innovative technology capabilities, as all items recorded high mean values with statistically significant p-values. Students reported improvements in creative thinking, innovation skills, application of theory to practice, design of technological solutions, testing and refinement of ideas, and adaptation of solutions to local needs.

Notably, the acceptance of the item on developing cost-effective technological solutions using locally available materials underscores the relevance of PBL to context-specific innovation in resource-constrained environments. This is consistent with recent literature showing that PBL, when effectively implemented, enhances students' creativity, critical thinking, and problem-solving capacities and ability to generate innovative technology solutions across diverse educational settings (Omeh et al., 2025; Naseer et al 2025). These findings suggest that PBL creates authentic opportunities for students to apply theoretical concepts in real contexts, thus bridging the gap between academic preparation and practical innovation. The results also show no significant difference between lecturers' and students' perceptions of PBL influence on students' ability to generate innovative technology solutions.

VIII. OVERALL IMPLICATION

Taken together, the results indicate a misalignment between instructional practice (RQ1), level of PBL integration (RQ2), and learning outcomes (RQ3). While PBL is not yet fully institutionalized, its demonstrated effectiveness in enhancing innovation provides strong justification for curriculum reform, lecturer capacity building, and policy support to scale up its adoption in Nigerian tertiary technical education.

IX. CONCLUSION

This study examined instructional strategies in technical education, the extent of Project-Based Learning (PBL) integration, and its influence on students' ability to generate innovative technology solutions. The findings reveal that instructional practices remain largely traditional and teacher-centered, with lecture-based and theory-focused approaches dominating, while interactive strategies such as practical activities, questioning techniques, and digital tool use are applied only at a moderate level. PBL integration was found to be partial and inconsistent, as core practices were evident but lacked systematic institutional support in terms of curriculum inclusion, lecturer training, structured reflection, and regular implementation across courses. Despite these limitations, PBL demonstrated a strong positive influence on students' creativity, problem-solving ability, practical competence, and capacity to develop cost-effective and context-relevant technological solutions. The study therefore concludes that although PBL is not yet fully institutionalized in technical education programmes, its effectiveness in promoting innovation underscores the need for deliberate curriculum reform, strengthened lecturer capacity, and supportive institutional policies to produce technically skilled and innovative graduates.

X. RECOMMENDATIONS

Based on the findings of this study, it is recommended that:

- Instructional practices in Technical Education should shift from predominantly lecture-based approaches to more student-centered and practice-oriented strategies, incorporating demonstrations, hands-on activities, questioning, collaborative learning, and digital tools.
- Project-Based Learning (PBL) integration should be strengthened through curriculum reforms that formally embed PBL into course outlines, supported by lecturer training, structured reflection, and consistent implementation across courses.
- Students' innovative technology skills should be enhanced by fostering PBL-driven learning environments that encourage creativity, problem-solving, teamwork, application of theory to practice, and the development of cost-effective, locally relevant solutions.
- Institutions should provide adequate support and resources, including materials, digital tools, and mentorship, to ensure effective PBL implementation.

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