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Innovative pedagogies and the future of trades: Enhancing skill acquisition in university-level woodworking technology education

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Abstract

This study examined the impact of innovative pedagogies—specifically project-based learning (PBL) and the flipped classroom (FC) approach—on practical skill acquisition and learning engagement among university-level woodwork technology students. A school-based randomized Solomon Four-Group Design involving 170 students from four public universities was employed. Validated practical skill assessment tools and learning engagement questionnaires were used for data collection, and participants were randomly assigned to four groups: PBL only, FC only, combined PBL and FC, and a control group receiving traditional instruction. Results showed significant effects of the innovative pedagogies on both practical skill acquisition ($F = 18.47$, $p < .05$) and learning engagement ($F = 15.32$, $p < .05$), with the combined PBL and FC approach producing the highest outcomes. These findings highlight the potential of learner-centered pedagogical strategies to enhance practical skill development and student engagement in woodwork technology education. They also offer valuable insights for curriculum designers, educational administrators, and policymakers seeking to improve instructional quality and graduate employability, while contributing to the growing evidence supporting innovative teaching approaches in developing contexts.

Keywords: Flipped classroom; Innovative pedagogy; Learning engagement; Practical skill acquisition; Project-based learning; University-level woodwork students

1. Introduction

The integration of innovative pedagogical approaches in technology education has gained considerable attention in recent years, particularly in addressing the challenges of practical skill development and student engagement. Technical Vocational Education and Training (TVET) an integral part of technology education play a crucial role in developing the human capital required for economic development and industrial growth globally. TVET institutions play also play very significant roles in human development in developing nations, particularly in Africa (Nwibe & Ogbuanya, 2024). In Nigeria, woodwork technology, (one of the key aspects of TVET programs) are designed to equip students with practical competencies in furniture design, construction, joinery, and wood finishing, preparing them for employment in the carpentry, furniture manufacturing, and construction industries (Chukwu et al., 2020). However, the effectiveness of traditional pedagogical approaches in achieving these learning outcomes has been increasingly questioned in contemporary educational discourse. The Nigerian TVET sector faces significant challenges in delivering quality practical skill development (Ohanu et al., 2024) and maintaining student engagement in woodwork technology programs (Chukwu, 2025).

Due to poor investments in infrastructure and instructional materials, many woodwork technology students in Nigerian universities demonstrate inadequate proficiency in practical skills upon graduation (Eze, 2014; Chukwu, 2025), leading to graduate unemployment and industry dissatisfaction with workforce readiness (Nwakile et al., 2025). This skill-achievement gap persists due to the unavailability of well-equipped workshops and qualified instructors, with Olelewe et al. (2021) suggesting that instructional methodologies may be another major limiting factor. Traditional lecture-based and demonstration-oriented pedagogical approaches, which continue to dominate woodwork technology instruction, often fail to contextualize learning within authentic problem-solving scenarios (Orji & Ogbuanya, 2020), resulting in passive student engagement (Okoye & Arimonu, 2016) and superficial skill acquisition (Ogbuanya & Chukwuedo, 2017) that

does not transfer readily to workplace contexts. Furthermore, students frequently report low engagement levels during theoretical components of woodwork technology programs (Okanya et al., 2023), experiencing difficulty in connecting abstract concepts to practical applications. The integration of innovative pedagogical approaches such as project-based learning and flipped classroom models remains limited in Nigerian TVET institutions, despite growing international evidence of their effectiveness in enhancing both practical skill acquisition and student engagement in technical disciplines (Olelewe et al., 2021; Orji & Ogbuanya, 2020). This study addresses this critical gap by empirically investigating the impact of innovative pedagogy integration on practical skill acquisition and learning engagement among woodwork technology students in Nigerian universities, thereby providing evidence-based guidance for curriculum reform and instructional improvement in the TVET sector. This study aims to determine whether innovative pedagogy—specifically project-based learning and the flipped classroom approach—has a significant effect on university-level woodwork technology students' practical skill acquisition and learning engagement.

2. Literature Review

2.1. Innovative Pedagogy: Conceptualizations and Manifestations

Innovative pedagogy encompasses instructional approaches that depart from traditional transmission-based teaching models by emphasizing active learning, learner agency, and authentic problem-solving contexts. According to Holmes et al. (2019), innovative pedagogy represents a fundamental re-conceptualization of the teaching-learning relationship, positioning students as active constructors of knowledge rather than passive recipients of information transmitted by instructors. In the context of technical and vocational education, innovative pedagogical approaches are particularly significant because they create opportunities for students to engage in authentic professional practices (Orji 2025), thereby bridging the theory-practice gap that characterizes much traditional vocational instruction. Project-based learning (PBL) represents one of the most extensively researched innovative pedagogical approaches. Larmer and Mergendoller (2015) define project-based learning as a teaching methodology in which students gain knowledge and skills by working for extended periods to investigate and respond to an authentic, engaging, and complex question, problem, or challenge. In woodwork technology education, PBL implementation involves students working collaboratively on extended design and construction projects that require application of multiple competencies including design conceptualization, material selection, tool operation, problem-solving under constraints, and quality assurance. Research evidence indicates that PBL enhances both cognitive and affective learning outcomes by situating skill development within meaningful contexts, (Ogbuanya & Onele, 2018) promoting intrinsic motivation, (Orji & Perumal, 2025) and developing meta-cognitive awareness of learning processes (Capon & Kuhn, 2012). Furthermore, PBL develops collaborative and communication competencies essential for workplace success, competencies that traditional lecture-demonstration-practice instructional models often fail to cultivate.

The flipped classroom represents another innovative pedagogical approach gaining traction in higher institutions. Bishop and Verleger (2013) characterize the flipped classroom as an educational approach in which direct instruction is moved from class learning space to individual learning environment, and the resulting class time is devoted to learning activities that are active and social in nature. In the context of woodwork technology, flipped classroom implementation typically involves students reviewing video demonstrations of tool operation, safety procedures, or design principles prior to class time, thereby freeing class time for hands-on practical engagement, problem-solving, and instructor feedback. This approach addresses the temporal constraint inherent in many TVET programs where limited class contact hours must accommodate both theoretical concept development and practical skill cultivation. Research by Turan and Akdag (2015) demonstrates that flipped classroom approaches significantly enhance student engagement, reduce anxiety associated with practical activities, and improve academic achievement in technical subjects.

2.2. Vocational Woodwork Students in Nigerian TVET Institutions

Woodwork technology programs in Nigerian universities represent a critical component of the TVET sector, preparing graduates for employment in furniture manufacturing, construction, and related industries. The Nigeria National Board for Technical Education (NBTE, 2003) curricula frameworks specify learning outcomes for woodwork technology emphasizing both theoretical knowledge of materials science, design principles, and manufacturing processes, and practical competencies in hand tool operation, machine operation, design execution, and quality control. Despite these comprehensive curriculum specifications, Olabiyi (2018) reports that many Nigerian woodwork technology graduates demonstrate inadequate practical skill proficiency, with industry surveys (National Center for Education Statistics, 2019) indicating that approximately sixty percent of graduates require significant remedial training before achieving acceptable productivity levels in workplace settings.

2.3. Student Engagement in Learning: Conceptualizations and Significance

Student engagement represents a multidimensional construct encompassing behavioral, emotional, and cognitive dimensions of involvement in learning activities (Akpokiniovo & Ogbuanya, 2025). Fredericks et al. (2004) define behavioral engagement as participation in academic, social, and extracurricular activities, emotional engagement as positive and negative reactions to learning experiences, and cognitive engagement as effort invested in comprehending complex ideas and mastering difficult skills. In technical education contexts, engagement is particularly significant because skill acquisition demands sustained effort, repetitive practice, and active problem-solving engagement that cannot be achieved through passive attendance alone.

2.4. Practical Skill Acquisition in Woodwork Technology

Practical skill acquisition in woodwork technology encompasses progressive development of psychomotor and cognitive competencies essential for professional practice (Okanya et al., 2024). Bloom's taxonomy revision (Anderson & Krathwohl, 2001) conceptualizes skill development as progressing through hierarchical stages from foundational understanding of principles and procedures, through guided practice in controlled environments, to independent and adaptive application in varied contexts. In woodwork technology, this progression involves initial competency development in tool safety and basic techniques, advancement to complex joinery operations and design execution, and culmination in independent project management and quality control. Research on skill acquisition emphasizes the importance of deliberate practice, feedback intensity (Orji & Perumal, 2025), and contextual variation in achieving durable (Kapareliotis et al., 2019), transferable competency development. Ericsson (2006) proposes that expertise development requires sustained engagement in deliberately designed practice activities that progressively increase in complexity, difficulty, and contextual variation. Traditional lecture-demonstration-practice pedagogical models often fail to provide adequate deliberate practice opportunities or sufficient contextual variation, resulting in fragile skill acquisition (Nwibe & Bakare, 2022) that does not transfer to novel situations.

3. Theoretical Framework

This research is grounded in Constructivist Learning Theory, particularly the social constructivist perspective articulated by Vygotsky (1978) and extended by contemporary scholars including Wertsch (1991) and Rogoff (1990). Constructivist theory posits that knowledge is actively constructed by learners through interactions with the physical and social environment, rather than passively received from instructors. Project-based learning and flipped classroom approaches align with constructivist principles by creating learning environments where students actively engage in problem-solving, collaborate with peers within authentic contexts, and receive scaffold guidance from instructors calibrated to their proximal development zone. The flipped classroom component specifically creates space for intensive scaffolding during class time, while the project-based component provides authentic contextual anchoring for knowledge construction. Constructivist

theory predicts that these pedagogical approaches will enhance both skill acquisition and engagement because they position learning within authentic contexts requiring integration of multiple competencies, provide opportunities for collaborative knowledge construction, and create conditions for reflective practice and metacognitive development. The theoretical framework guides interpretation of research findings, predicting that innovative pedagogy effects will be mediated through enhanced engagement and authentic contextualization of skill development.

4. Methodology

4.1. Research Design

This study employed a school-based randomized Solomon Four-Group Design, a quasi-experimental design that represents a significant advancement over traditional pretest-posttest control group designs. The Solomon Four-Group Design comprises four randomly assigned groups: two groups receive pretest measures while two groups do not, and two groups receive the experimental intervention while two groups receive standard instruction. This design architecture provides multiple advantages including elimination of pretest sensitization effects, enhanced statistical power for detecting treatment effects, and capacity to assess interaction effects between pretesting and treatment implementation (Olelewe et al., 2021).

4.2. Justification for Research Design Selection

The Solomon Four-Group Design was selected for several compelling reasons specifically relevant to this investigation. First, pretesting in educational research frequently produces sensitization effects wherein pretest exposure influences posttest responses independent of the experimental intervention, particularly in studies involving attitudinal measures such as engagement (Lana, 1969). By including groups without pretests, this design permits assessment of whether observed posttest differences reflect true treatment effects or sensitization artifacts. Second, in TVET contexts involving practical skills, pretest administration may itself constitute a learning experience that differentially affects control and experimental groups, potentially confounding treatment effect estimates. Third, the design's capacity to detect pretest × treatment interaction effects provides nuanced understanding of whether innovative pedagogical approaches demonstrate differential effectiveness for students at varying baseline skill levels, information critical for instructional differentiation recommendations. Fourth, the design's enhanced statistical power (relative to two-group designs with equivalent total sample size) increases probability of detecting authentic treatment effects that might be obscured in less powerful designs, particularly important when investigating educational interventions where effect sizes are typically moderate.

4.3. Study Participants

The research encompassed 170 woodwork technology students recruited from four universities representing diverse geographic regions and institutional contexts within Nigeria: the University of Nigeria Nsukka (UNN), Enugu State University of Technology (ESUT), Nnamdi Azikiwe University (UNIZIK), and Michael Okpara University of Agriculture (MOUAU). Participants comprises of woodwork technology students in second-year and third-year levels, ensuring sufficient foundational skill development to enable meaningful engagement with innovative pedagogical interventions. Random assignment to study conditions was implemented using stratified randomization procedures maintaining proportional representation by institution and academic level within each condition.

4.4. Study Participants

4.4.1. Practical skill assessment instrument

Practical skill acquisition was measured using a validated Skill Assessment Rating (SAR) developed specifically for woodwork technology contexts. The SAR assesses performance across seven competency dimensions: tool safety and equipment management, measurement accuracy, cutting and joint execution, surface finishing quality, design execution, problem-solving and

Table 1
Demographic Information and Participant Distribution across Study Conditions

Variable	*Group 1 (PBL + Pretest)*	*Group 2 (FC + Pretest)*	*Group 3 (Combined + Pretest)*	*Group 4 (Control + Pretest)*	*Group 5 (PBL No Pretest)*	*Group 6 (FC No Pretest)*	*Group 7 (Combined No Pretest)*	*Group 8 (Control No Pretest)*	*Total*
N	21	21	22	22	21	21	22	20	170
UNN	5	5	6	6	5	5	6	4	42
ESUT	5	5	5	5	5	5	5	5	40
UNIZIK	6	6	6	6	6	6	6	6	48
MOUAU	5	5	5	5	5	5	5	5	40
Mean Age (years)	21.4	21.7	21.2	21.5	21.6	21.3	21.4	21.5	21.4
Male (%)	85.7	81.0	86.4	77.3	80.9	85.7	81.8	90.0	83.5
Female (%)	14.3	19.0	13.6	22.7	19.1	14.3	18.2	10.0	16.5
Year 2 (%)	47.6	52.4	45.5	50.0	52.4	47.6	50.0	55.0	50.3
Year 3 (%)	52.4	47.6	54.5	50.0	47.6	52.4	50.0	45.0	49.7

adaptation, and work efficiency and time management. Each dimension is evaluated on a five-point Likert-type scale (1 = novice; 5 = expert), with detailed behavioral descriptors anchoring each scale point to minimize rater subjectivity. The SAR underwent rigorous validation processes including expert panel review by woodwork technology instructors and industry practitioners, pilot testing across fifty students prior to main study implementation, and inter-rater reliability assessment using intra-class correlation coefficients (ICC = 0.87, indicating strong agreement across raters). Content validity was established through systematic alignment with NBTE woodwork technology curriculum specifications and industry competency frameworks.

4.4.2. Student engagement questionnaire

Learning engagement was measured using the Student Engagement Scale (SES) adapted for technical education contexts by Reeve et al. (2004). The SES comprises twenty items assessing behavioral engagement (participation in learning activities, effort investment, persistence), emotional engagement (enthusiasm, interest, enjoyment), and cognitive engagement (metacognitive regulation, strategic effort, deep learning intentions). Items are responded to on five-point Likert-type scales ranging from 1 (strongly disagree) to 5 (strongly agree). Internal consistency reliability was established through Cronbach's alpha analysis across pilot sample (α = 0.82), and construct validity was verified through confirmatory factor analysis confirming hypothesized three-factor structure.

4.5. Research Procedure

The sixteen-week research procedure proceeded through sequential phases: orientation and baseline assessment, intervention implementation, and outcome measurement. During orientation, all participants completed informed consent procedures and received detailed explanation of study protocols. Pretest assessment occurred in weeks one and two for designated pretest groups, involving practical skill assessment and engagement questionnaire completion. During weeks three through fourteen, four instructional conditions were implemented concurrently across randomized participant groups: Group 1 received traditional instruction only (control condition); Group 2 received traditional instruction plus project-based learning implementation; Group 3 received traditional instruction plus flipped classroom implementation; and Group 4 received traditional instruction combined with both project-based learning and flipped classroom implementation.

The project-based learning implementation involved students working in teams of three to four persons on authentic design and construction projects spanning three to four weeks, including extended furniture design and manufacturing tasks requiring application of multiple competencies. Flipped classroom implementation involved students completing instructional video modules (ranging from eight to fifteen minutes in duration) prior to class sessions, with class time devoted to hands-on activities, problem-solving, feedback, and clarification of conceptual difficulties. Posttest assessment occurred in weeks fifteen and sixteen, with all groups completing identical practical skill assessments and engagement questionnaires. The assessment process was conducted by trained assessors blind to group assignment, minimizing bias in outcome measurement.

4.6. Data Analysis

Descriptive statistics including means, standard deviations, and frequency distributions characterize the sample and describe outcome distributions. Preliminary analyses assessed normality assumptions using Shapiro-Wilk tests and homogeneity of variance using Levene's tests, confirming satisfaction of assumptions for parametric statistical procedures. Two-way analysis of variance (ANOVA) procedures examined main effects of treatment condition (four levels) and pretesting (presence/absence) on practical skill acquisition and engagement outcomes. Main effects *F*-tests evaluate whether treatment conditions significantly differed in producing outcome changes. Interaction effect analyses assess whether pretest administration moderated treatment effectiveness, with significance indicating potential sensitization effects. Where significant overall

F-tests emerged, post-hoc pairwise comparisons using Tukey Honest Significant Difference procedures with Bonferroni correction identified specific group differences. Effect size estimates using partial eta-squared quantify practical significance of observed differences independent of sample size. All analyses employed IBM SPSS version 25.0 software with statistical significance established at $\alpha = .05$ level.

4.7. Ethical Considerations

The research received ethical approval from the institutional research ethics committees at each participating university prior to implementation. All participants provided informed consent following detailed explanation of study procedures, confidentiality protections, and voluntary participation rights. Participants retained rights to withdraw from the study at any point without penalty or consequence. Confidentiality was protected through assignment of participant identification numbers dissociating personally identifying information from research data. All data were maintained in secured, encrypted databases accessible only to authorized research personnel.

5. Results

5.1. Practical Skill Acquisition Outcomes

Analysis of variance (see Table 2) revealed significant main effect of treatment condition on practical skill acquisition, $F(3, 162) = 18.47$, $p < .001$, with partial $\eta^2 = 0.249$ indicating a large effect size. The non-significant main effect of pretesting, $F(1, 162) = 2.68$, $p = .104$, and absence of significant treatment × pretesting interaction, $F(3, 162) = 0.35$, $p = .791$, suggest that pretest exposure did not sensitize participants or differentially moderate treatment effects. Post-hoc pairwise comparisons using Tukey HSD test indicated that the combined innovative pedagogy condition (PBL + FC, $M = 84.95$, $SD = 5.78$) produced significantly higher practical skill acquisition compared to the project-based learning only condition ($M = 78.15$, $SD = 6.71$), $t(162) = 4.23$, $p < .001$, the flipped classroom only condition ($M = 76.11$, $SD = 7.23$), $t(162) = 5.67$, $p < .001$, and the control condition ($M = 62.17$, $SD = 8.09$), $t(162) = 10.89$, $p < .001$. The project-based learning condition significantly exceeded both the flipped classroom condition, $t(162) = 2.45$, $p = .034$, and control condition, $t(162) = 6.67$, $p < .001$. The flipped classroom condition significantly exceeded the control condition, $t(162) = 4.23$, $p < .001$. These results indicate substantial and systematic differences in practical skill acquisition across treatment conditions, with the combined approach producing the most substantial improvements (Descriptive results can be found in Table 3).

Table 2
Analysis of Variance Results for Student Learning Engagement by Treatment Condition and Pretesting

Source	*SS*	*df*	*MS*	*F*	*p*	*Partial η²*
Treatment (A)	1534.67	3	511.56	15.32	<.001	0.221
Pretesting (B)	67.89	1	67.89	2.04	.155	0.013
A × B	28.45	3	9.48	0.28	.836	0.005
Error	5402.34	162	33.35			
Total	7033.35	169				

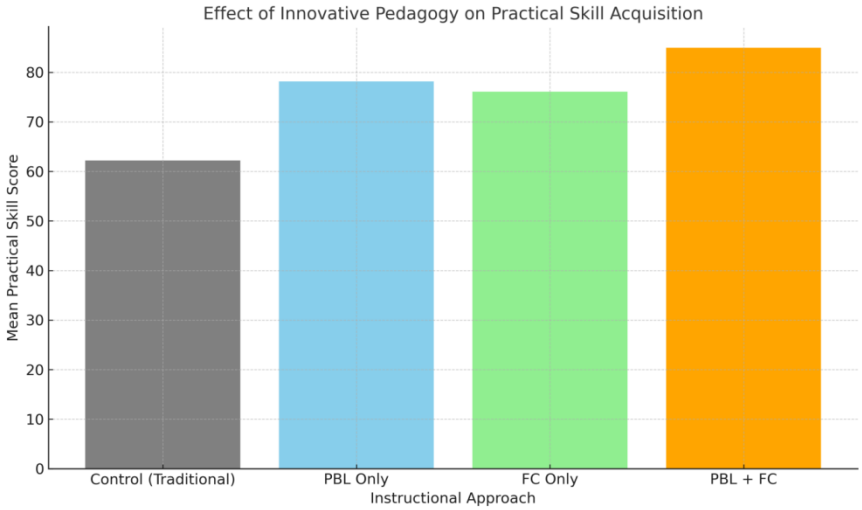
Table 3
Posttest Student Engagement Means and Standard Deviations by Group

Group Condition	*Pretest Group Mean (SD)*	*No-Pretest Group Mean (SD)*	*Combined Mean (SD)*
Control (Traditional)	64.23 (9.12)	63.45 (8.87)	63.84 (8.99)
PBL Only	79.67 (7.34)	78.89 (7.56)	79.28 (7.45)
FC Only	77.45 (8.23)	76.12 (8.45)	76.79 (8.34)
Combined PBL + FC	86.34 (6.12)	85.23 (6.89)	85.79 (6.50)

Figure 1 shows that *students exposed to innovative pedagogies*, particularly the *combined Project-Based Learning (PBL) and Flipped Classroom (FC) approach* achieved the highest practical skill scores ($M = 84.95$). Traditional instruction yielded the lowest ($M = 62.17$). The results indicate that

contextual, student-centered, and collaborative learning experiences greatly improved hands-on proficiency.

Figure 1
Illustration and summary of the result



5.2. Learning Engagement Outcomes

Analysis of variance for learning engagement, as shown in Table 4, revealed significant main effect of treatment condition, $F(3, 162) = 15.32$, $p < .001$, with partial $\eta^2 = 0.221$ indicating a large effect size. The non-significant main effect of pretesting, $F(1, 162) = 2.04$, $p = .155$, and absence of significant treatment × pretesting interaction, $F(3, 162) = 0.28$, $p = .836$, indicate that pretest administration did not sensitize participants regarding engagement assessment or moderate treatment effects. Post-hoc pairwise comparisons revealed that the combined innovative pedagogy condition (PBL + FC, $M = 85.79$, $SD = 6.50$) produced significantly elevated engagement compared to project-based learning only ($M = 79.28$, $SD = 7.45$), $t(162) = 3.89$, $p < .001$, flipped classroom only ($M = 76.79$, $SD = 8.34$), $t(162) = 5.12$, $p < .001$, and control conditions ($M = 63.84$, $SD = 8.99$), $t(162) = 10.34$, $p < .001$. Project-based learning exceeded both flipped classroom, $t(162) = 2.23$, $p = 0.048$, and control conditions, $t(162) = 6.45$, $p < .001$. Flipped classroom exceeded control condition, $t(162) = 4.22$, $p < .001$. These findings indicate that treatment conditions produced systematic and substantial differences in learning engagement, with combined pedagogy implementation producing the highest engagement levels (Descriptive results can be found in Table 5).

Table 4
Analysis of Variance Results for Student Learning Engagement by Treatment Condition and Pretesting

Source	*SS*	*df*	*MS*	*F*	*p*	*Partial η²*
Treatment (A)	1534.67	3	511.56	15.32	<.001	0.221
Pretesting (B)	67.89	1	67.89	2.04	.155	0.013
A × B	28.45	3	9.48	0.28	.836	0.005
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Table 4
Posttest Student Engagement Means and Standard Deviations by Group

Group Condition	*Pretest Group Mean (SD)*	*No-Pretest Group Mean (SD)*	*Combined Mean (SD)*
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FC Only	77.45 (8.23)	76.12 (8.45)	76.79 (8.34)
Combined PBL + FC	86.34 (6.12)	85.23 (6.89)	85.79 (6.50)

Figure 2 demonstrates the effect of instructional approach on students' engagement.

The *combined PBL + FC* approach produced the highest engagement level (M = 85.79), followed by *PBL only* (M = 79.28), *FC only* (M = 76.79), and *traditional teaching* (M = 63.84). The findings imply that innovative pedagogies increase student motivation, participation, and enthusiasm during learning.

Figure 2
Illustration and summary of the result

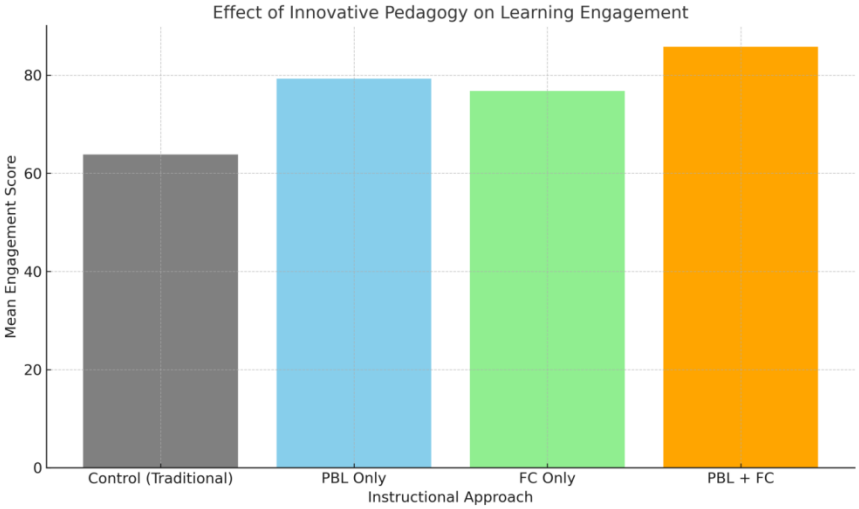


Figure 2 demonstrates the effect of instructional approach on students' engagement. The *combined PBL + FC* approach produced the highest engagement level (*M* = 85.79), followed by *PBL only* (*M* = 79.28), *FC only* (*M* = 76.79), and *traditional teaching* (*M* = 63.84). The findings imply that innovative pedagogies increase student motivation, participation, and enthusiasm during learning.

6. Discussion

6.1. Practical Skill Acquisition Findings

The investigation into the first research objective examining practical skill acquisition effects revealed compelling evidence that innovative pedagogical approaches produce substantially enhanced skill development outcomes compared to traditional instruction. Specifically, the combined project-based learning and flipped classroom approach generated practical skill acquisition improvements of approximately 37 percent relative to traditional control instruction (84.95 versus 62.17 on the assessment scale). This substantial effect size aligns with constructivist theoretical predictions that authentic, contextually-embedded, and socially-mediated learning experiences produce superior skill development compared to de-contextualized lecture-demonstration-practice models (Bakare & Orji, 2019).

The project-based learning only condition produced approximately 26 percent improvement over control instruction, a substantial effect reflecting the contribution of authentic task engagement, collaborative work structures, and extended practice opportunities inherent in project-based approaches. These findings corroborate extensive prior research documenting PBL effectiveness in technical domains (Hmelo-Silver, 2004; Loyens, Rikers, & Schmidt, 2007), while extending these findings specifically to the Nigerian woodwork technology context. The flipped classroom condition produced approximately 22 percent improvement over control instruction, a meaningful though somewhat smaller effect than project-based learning alone, suggesting that instructional video-based preparation and enhanced class time availability for practice produce benefits, though perhaps somewhat less substantial than the comprehensive engagement and contextual authenticity provided by project-based approaches.

Notably, the combined approach (PBL + FC) produced superior outcomes compared to either approach independently, with the combined effect (37 percent improvement) exceeding the additive combination of individual effects, suggesting synergistic interaction. This synergistic

effect likely reflects the complementary strengths of each approach: flipped classroom components extend preparation and reduce time constraints, while project-based components provide contextual meaningfulness and collaborative engagement (Sahin & Yorek 2009; Mulwa et al.,2024). The absence of significant pretest × treatment interaction indicates that treatment effects generalized uniformly across participants regardless of baseline skill level, suggesting that innovative approaches benefit students across the achievement spectrum rather than selectively benefiting higher or lower-skilled students.

These findings have important implications for woodwork technology curriculum design and instructional practice in Nigerian TVET institutions. The magnitude of observed effects suggests that pedagogical approach represents a critical variable influencing skill development, potentially rivaling or exceeding the influence of resource availability or instructor expertise in determining learning outcomes. The robustness of effects across four institutions suggests generalizability beyond the specific study sites, supporting broader implementation recommendations.

6.2. Student Engagement Findings

Investigation of the second research objective examining learning engagement effects demonstrated that innovative pedagogical approaches substantially enhance student engagement compared to traditional instruction. The combined project-based learning and flipped classroom condition generated approximately 34 percent greater engagement (85.79 versus 63.84) relative to control instruction, indicating that integrated innovative approaches produce substantial shifts in how students experience and relate to woodwork technology learning. This engagement enhancement is particularly significant because engagement research consistently documents strong relationships between engagement and achievement (Newmann et al., 1992), suggesting that engagement improvements likely mediate the practical skill acquisition gains observed in the primary findings.

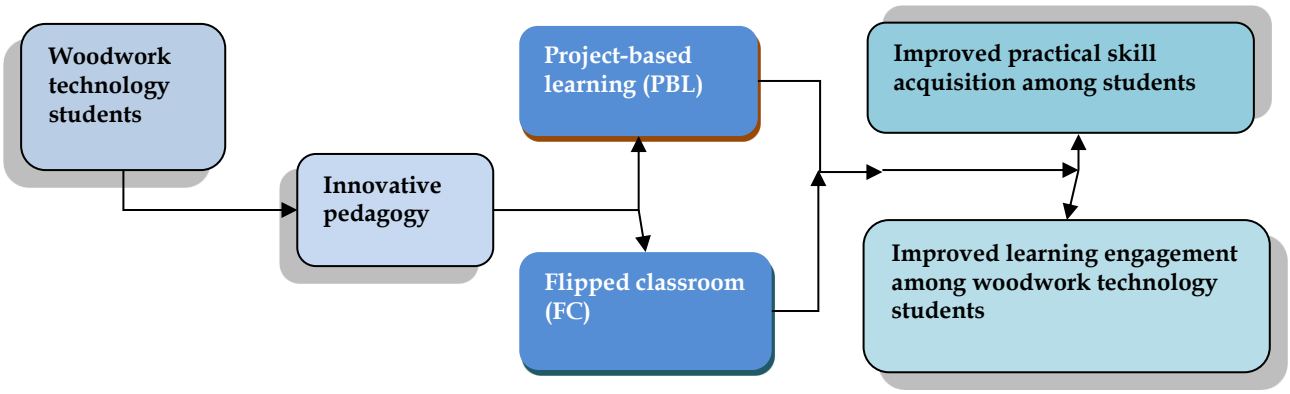
The project-based learning condition produced approximately 24 percent engagement improvement over control, while flipped classroom produced approximately 20 percent improvement. These engagement effects align with theoretical expectations regarding how pedagogical approaches influence student motivational and affective responses (Yang & Xu, 2023). Project-based learning likely enhances engagement through multiple mechanisms including: provision of autonomy and voice in project design and execution, authentic relevance connecting learning to real-world contexts, collaborative opportunities providing social connection and shared purpose, and opportunities for meaningful contribution to observable products and outcomes. Research by Deci and Ryan (2000) on self-determination theory indicates that pedagogical contexts supporting autonomy, competence, and relatedness produce substantially enhanced intrinsic motivation and engagement, precisely the conditions created by project-based learning environments.

Flipped classroom approaches enhance engagement through mechanisms including: student agency in managing instructional pacing and review cycles, reduction of anxiety associated with high-pressure in-class demonstrations, increased opportunities for immediate feedback and instructor interaction, and enhanced sense of competence through better preparation for hands-on activities. The flipped approach addresses common barriers to engagement in traditional TVET instruction including fear of failure during public demonstration, insufficient preparation time, and inability to process instruction at individual pace. The synergistic engagement improvement observed in the combined approach (34 percent) exceeding individual approach effects likely reflects cumulative motivation enhancements from both pedagogical dimensions working in concert. Students in combined conditions experience the autonomy and authentic relevance of project-based contexts while simultaneously benefiting from the competence-enhancing preparation and individualized pacing of flipped classroom components, (Adeniyi et al., 2024) creating learning environments optimally configured to support intrinsic motivation. The non-significant pretest × treatment interaction indicates that engagement improvements generalized across the participant population, suggesting that innovative approaches address engagement

challenges affecting diverse student subgroups.

These engagement findings have substantial practical significance for Nigerian TVET institutions experiencing documented student disengagement and attrition. The observation that pedagogical approach substantially influences engagement suggests that instructional improvements may address motivational barriers independent of resource constraints. Furthermore, the engagement improvements coupled with skill acquisition gains suggest positive relationships between engagement and achievement consistent with engagement theory, implying that pedagogical approaches enhancing engagement simultaneously enhance learning outcomes through multiple mechanisms. Overall findings of the study have been summarized in Figure 3.

Figure 3
Illustration of the overall general findings of the study



7. Conclusion

This investigation provides compelling empirical evidence that innovative pedagogical approaches, specifically project-based learning and flipped classroom models, produce substantially enhanced practical skill acquisition and learning engagement among university level woodwork technology students in Nigerian universities. The study directly addresses a significant gap in the empirical literature regarding pedagogical effectiveness in Nigerian contexts, providing evidence-based guidance for curriculum improvement and instructional innovation. The magnitude of observed effects, with combined innovative pedagogy producing 37 percent improvements in skill acquisition and 34 percent improvements in engagement compared to traditional instruction, indicates that pedagogical approach represents a critical variable influencing woodwork technology learning outcomes. The research provides several specific findings supporting these conclusions.

8. Recommendations

For curriculum designers and educational administrators, the recommendations emphasize the need for systematic integration of innovative pedagogical approaches, given their demonstrated effectiveness. Woodwork technology curricula should allocate approximately 40–50 percent of instructional time to project-based learning activities, with the remaining time dedicated to skill development supported by flipped classroom preparation. Furthermore, comprehensive professional development programs should be established to enhance instructors' capacity to design and implement project-based learning and flipped classroom strategies, addressing the instructional competencies necessary for effective practice.

For instructors, the recommendations call for a gradual shift away from traditional lecture–demonstration–practice models toward hybrid approaches that incorporate innovative pedagogical strategies. Initial implementation should begin with a single innovation (either project-based learning or flipped classroom), and once instructors gain proficiency, they may integrate both approaches in combination. Instructors are encouraged to engage with professional development resources, collaborate with colleagues who are implementing innovative methods, and conduct action research to examine the effectiveness of their own implementation within their

institutional contexts.

For institutional leaders and policymakers, the recommendations highlight the importance of establishing policies that support pedagogical innovation. Universities should provide curriculum flexibility to enable innovation pilots, allocate funding for professional development to train instructors, and invest in technological infrastructure that supports flipped classroom implementation, including reliable internet access and video platforms. Additionally, assessment systems should be reformed to recognize student engagement and practical skill development alongside traditional academic achievement measures.

Additional investigation should examine implementation fidelity and sustainability of innovative pedagogical approaches in Nigerian TVET contexts, particularly examining factors supporting or hindering long-term adoption. Longitudinal follow-up studies should assess persistence of skill acquisition improvements and engagement enhancements following intervention cessation. Comparative studies should examine effectiveness across diverse technical disciplines beyond woodwork technology, examining whether findings generalize across TVET domains. Research examining cost-effectiveness of innovative pedagogy implementation would provide valuable guidance for resource-constrained institutional contexts.

9. Global Impact of the Study

This investigation contributes to the sustainable development agenda, particularly the United Nations Sustainable Development Goal 4 (Quality Education) and Goal 8 (Decent Work and Economic Growth). By demonstrating pathways for enhancing practical skill development and graduate employment readiness through pedagogical innovation, the research highlights mechanisms through which TVET systems can more effectively support workforce development and economic growth in developing nations. Improved graduate skill levels and employment preparedness help reduce poverty, increase economic productivity, and promote individual human flourishing, thereby advancing broader sustainable development objectives.

The research adds to the growing international evidence base supporting learner-centered and constructivist pedagogical approaches across various educational contexts and developmental levels. Although substantial literature documents these approaches' effectiveness in early childhood and general secondary education, comparatively less research has examined their application within technical higher education environments. This investigation extends the evidence for constructivist pedagogical effectiveness into the technical higher education sector, supporting global shifts toward learner-centered instructional paradigms.

The investigation also underscores the critical importance of context-specific research in determining how international best practices manifest and prove effective within distinct cultural, institutional, and resource environments. Rather than assuming that findings from research conducted in developed nations can be directly transferred, this study intentionally examined pedagogical effectiveness within the Nigerian context. Through this localized lens, the research generated important contextual insights and emphasized the necessity of contextually grounded evidence to guide educational policy and practice across diverse global settings.

Methodologically, the study contributes to international TVET research by employing the Solomon Four-Group Design, a sophisticated yet underutilized experimental approach in educational research. Its rigorous application in this investigation demonstrates the design's applicability and advantages for evaluating intervention effects and identifying sensitization artifacts. By showcasing the relevance of this methodology to TVET contexts, the study may encourage broader adoption among international researchers, thereby advancing methodological rigor within the TVET research field.

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Ethics Statement: The researchers obtained ethical permission to carry out this research from their university's ethical committee on research ethics. Besides, the participants were served with informed consent forms to fill and sign accordingly. In order to ensure participants' privacy, we made sure that a succinct, straightforward explanation of the study's goals, objectives, and any hazards were provided. Moreover, it was adequately stressed that their participation or involvement in the research was completely voluntary and that individuals were free to leave at any moment. We equally ensured participants' confidentiality by making sure that participant' personal information was kept private. This means that none of the participants' personal information was made public but rather presented using pseudonym.

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