Effects of Innovative Pedagogical Strategies in Science, Technology, Engineering, and Mathematics (STEM) Education on Promotion of Entrepreneurial Innovation Among University Students

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ABSTRACT:

Background: The ongoing push to promote economic innovation has made it even more pressing for universities to adopt innovative pedagogical approaches, particularly in STEM education.

Objective: This study examines the effects of the innovative pedagogical approach in STEM education on entrepreneurial innovation.

Method: The study adopted a one-group pretest-posttest quasi-experimental research design. The study population consisted of 1,412 third-year students enrolled in Science, Technology and Engineering at Joseph Sarwuan Tarka University. The sample size was 123 intact year three STEM students from Joseph Sarwuan Tarka University, Makurdi. The instrument for data collection was a performance test using the Innovative Pedagogical Strategies Performance Test (IPSPT) and the Entrepreneurial Innovation Performance Test (EIPT). The instrument was validated by three experts, with coefficient indices of 0.72 for IPSPT and 0.70 for EIPT, respectively. The data collected were analysed using a paired t-test to test hypotheses.

Key Results: The study revealed a significant difference between students' pre-test and post-test scores, indicating that experiential learning in STEM education promotes entrepreneurial innovation. It was found that there is a significant difference between students' pre-test and post-test scores in promoting entrepreneurial innovation after exposure to Project-based learning (STEM) education, and that collaborative learning in STEM education significantly promotes entrepreneurial innovation among university students, as evidenced by pre-test and post-test assessments.

Conclusion: This research concluded that when innovative pedagogical strategies are used in STEM education, such as experiential, project-based, and collaborative learning, they develop students' practical thinking and abilities.

Keywords: Innovative pedagogy, STEM education, entrepreneurial innovation, experiential learning, project-based learning, collaborative learning.

1. Introduction

Universities are generally institutions of higher learning, expected to equip students with the skills needed for economic development and growth. The need for such a skill would help them generate innovative ideas essential for entrepreneurship development (Amirmahmood et al., 2022). The rapid economic development and advances in technology have made STEM education an important factor in innovation and entrepreneurship. Universities are therefore adopting innovative pedagogical strategies to improve students' ability to deliver solutions to societal challenges. Innovation is the lifeblood of entrepreneurship, and EE acts as a catalyst by fostering creativity and opportunity-driven thinking (Etzkowitz & Zhou, 2018; Dutta et al., 2020). Innovative pedagogies, encompassing novel and nontraditional approaches to teaching and learning, deviate from conventional, memorisation-centric instructional methods (Johnson et al., 2020). These pedagogical strategies span a broad spectrum, encompassing experiential, project-based, and collaborative learning, as well as the strategic use of technology (Chandraja et al., 2024).

Several barriers impede university students' teaching and learning of entrepreneurial innovation, preventing the development of knowledge in entrepreneurship education. These barriers have been identified by Ruseva et al. (2023) and relate to resource constraints, problems with standardised curricula, and educator training. Prior to the advent of STEM, the teaching and learning of entrepreneurial innovation were conducted in an old-fashioned manner, centred on lecturing, memorising facts, and imparting academic knowledge to students. Further, according to a study by Chagi et al. (2025), students experienced a disconnect between classroom knowledge and real-world application during this period. Also, there was a lack of internships, incubation, and project-based learning, which reduces innovation skills. Students were taught concepts, but they were not applied to help them better understand.

To address this challenge, several methods have been developed, such as innovative STEM pedagogy to promote entrepreneurial innovation among students. According to Chandraja et al. (2024), the significance of innovative pedagogies lies in their transformative potential to optimise educational outcomes and prepare learners for success in an increasingly intricate and interconnected world. Innovative pedagogies nurture critical thinking, creativity, collaboration, and problem-solving abilities-attributes vital for navigating contemporary challenges and opportunities.

Innovation in entrepreneurship is a multidimensional phenomenon that requires developing the entrepreneurial mindset and behaviour needed to recognise, analyse, and exploit opportunities (Fayolle & Gailly, 2019). This innovation is not necessarily about imparting knowledge on how to start businesses but rather entails developing the creativity and innovativeness individuals need to respond positively to environmental changes (Onwu et al., 2023). The European Commission (2022) defines entrepreneurial innovation as "a set of learning experiences that equip individuals with the knowledge, skills, and attitudes to transform ideas into action. In many developing economies like Nigeria, this definition yields better results because it addresses the structural joblessness among youths by enabling them to achieve self-fulfilment and become job creators.

Experiential learning activities comprise hands-on, real-world experiences that actively engage students in learning the subject matter (Smith, 2017). The activities are usually conducted outside the conventional classroom setting and prompt students to practice theoretical knowledge in practical scenarios. The students shall benefit from an experiential learning exercise because they will not only gain valuable insights into ecology, but also important skills of

observing and conducting scientific inquiry. According to Chandraja et al. (2024), "experiential learning involves motivating individuals to learn by doing, solving problems, and being creative." In support of this claim, Kolb's Experiential Learning Theory (1984) asserts that experiential pedagogy enables learners to gain deeper learning through emotional, cognitive, and physical involvement in the learning process. According to Mohammad and Amir (2024), there are considerable differences in the entrepreneurial learning system (ELS) among students. Further, the VR-based entrepreneurship training course was reported to have the greatest impact on students' EIs. Similarly, Arfiyanti et al. (2017) also report that the experiential learning method improves students' rational prescribing skills.

In project-based learning programs, learners undertake long-term, multifaceted projects in which teamwork, critical thinking, and problem-solving skills are essential (Taylor et al., 2019). The method entails having learners solve real-world problems or answer complex questions through research and experimentation. For example, in a history course, learners can undertake a project to make a documentary film about a particular historical event (Anderson & Smith, 2020). According to Chularee et al. (2024), a project-based learning intervention plays a vital role in developing learners' entrepreneurial qualities and competencies. From the very start through the completion of the assignment, students conduct research, analyse sources, and synthesise data to create a compelling documentary on the issue. Similarly, according to Pearce et al. (2025), project-based learning proved quite effective in developing entrepreneurial competencies, underscoring the significance of experience-based learning. Higher education institutions should integrate entrepreneurship into the curriculum, collaborate with industry, foster strong team dynamics, and ensure quality control. The mentioned strategy might prove useful in promoting innovation and preparing people to start their own businesses. As Pearce et al. note, "project-based learning proved to be very effective in developing entrepreneurial competencies", which indicates the importance of experience-based learning. Siraprapa and Kobsook (2025) observe that the activity plans of Project-Based Learning and digital tools promote entrepreneurial skills, which involve five steps: define, plan, do, review, and presentation, and that the quality of these activity plans is higher in Project-Based Learning. These strategies have the potential to foster innovation and better prepare students for self-employment opportunities. Paľová et al. (2020) demonstrate how virtual laboratories and project-based learning can enhance entrepreneurial education, using two of our faculty members' courses as examples. It is imperative to note that project-based learning supports entrepreneurship education in developing entrepreneurial abilities.

In addition, Brown and Johnson (2016) observe that collaborative learning projects involve students working together in cluster form to achieve common learning goals. These programmes encourage peer interaction, communication, and teamwork while fostering a sense of shared responsibility for learning outcomes. For example, in a language class, students may collaborate on a writing project where each group member contributes ideas, drafts, and edits to produce a cohesive piece of writing (Zhang, 2018). Not only do students improve their writing skills, but they also gain insights into the subject through their fellow students' perspectives and experiences, resulting in a deeper understanding of the topic. According to Latha et al. (2025), active learning and collaboration have become increasingly significant pedagogical constructs, based on constructivist and sociocultural theories of learning. In Niveen's (2026) view, active learning methods, such as collaborative learning, help students develop practical skills in opportunity recognition, problem-solving, and risk-taking. According to Walter and Block (2016), Fayolle and Gailly (2015) and Almahry et al. (2018), the relevant, clear, organised, and logically structured information enhances students' understanding and engagement, thereby fostering the development of entrepreneurial skills.

Although the literature demonstrates that innovative pedagogies such as experiential learning, project-based learning, and collaborative learning can improve various dimensions of entrepreneurship education, existing research remains fragmented in several important respects. Much of the entrepreneurship education literature has concentrated on evaluating conventional entrepreneurship curricula that primarily emphasise theoretical instruction, entrepreneurial awareness, or entrepreneurial intentions rather than the simultaneous development of entrepreneurial knowledge, practical skills, and innovation capabilities (Fayolle & Gailly, 2019; Dutta et al., 2020; Onwu et al., 2023). Several studies, such as Mohammad and Amir (2024), Pearce et al. (2025), and Chularee et al. (2024), have explored individual pedagogical approaches, particularly experiential or project-based learning, in isolation, without considering how multiple innovative pedagogical strategies collectively foster entrepreneurial innovation within STEM education. However, there is limited empirical evidence on the combined effects of innovative STEM pedagogies on entrepreneurial innovation outcomes, especially in developing-country contexts.

This constraint appeared to be evident in Nigeria situation, where entrepreneurship education has been widely adopted as a strategy to address graduate unemployment and stimulate innovation-driven economic development. Existing Nigerian studies have largely examined entrepreneurship education in terms of curriculum implementation, entrepreneurial intention, self-employment aspirations, or general entrepreneurial competencies, with comparatively little attention to how innovative STEM pedagogies influence students' acquisition of entrepreneurial knowledge, practical skill development, creativity, collaboration, and innovation capabilities. Moreso, investigations on integrating experiential learning, project-based learning, collaborative learning, and technology-supported pedagogies within STEM education remain scarce, particularly in public universities in Benue State. This represents an important contextual and pedagogical gap because STEM disciplines provide authentic opportunities for innovation, problem-solving, product development, and venture creation that extend beyond conventional entrepreneurship classroom instruction.

Despite the growing importance of STEM education in fostering entrepreneurial innovation, some universities in Nigeria, especially in Benue State, still rely on conventional modes of instruction, such as lectures, which limit opportunities for practice and experimentation. As a result, graduates have only theoretical knowledge, while lacking the entrepreneurial skills and innovative ability necessary to discover and implement opportunities for sustainable businesses. Even though universities in Benue State offer a few STEM programs, there are not enough empirical studies examining how innovative educational approaches, such as experiential learning, project-based learning, collaborative learning, and technology-enhanced learning, affect university students' entrepreneurial innovation. This research gap needs to be filled as a step toward curricular reform and improvement of entrepreneurship education in Nigerian higher educational institutions. Against this background, the present study aims to investigate the effect of innovative pedagogical approaches in STEM education on the entrepreneurial innovation of university students in Benue State, Nigeria.

Purpose of the Study

The main purpose of the study was to examine the effects of innovative pedagogical strategies in STEM education on promoting entrepreneurial innovation among university students in Benue State. The study sought to:

1. Examine the effect of experiential learning in STEM education on promoting entrepreneurial innovation among university students in Benue State.
2. Ascertain the effect of project-based learning (STEM) education on promoting entrepreneurial innovation among university students in Benue State.

3. Verify the effect of collaborative learning in STEM education on promoting entrepreneurial innovation among university students in Benue State.

Hypotheses

1. There is no significant difference between students' pre-test and post-test scores on promoting entrepreneurial innovation after exposure to experiential learning in STEM education.
2. There is no significant difference between students' pre-test and post-test scores on promoting entrepreneurial innovation after exposure to Project-based learning (STEM) education.
3. Collaborative learning in STEM education does not significantly improve the promotion of entrepreneurial innovation among university students based on pre-test and post-test assessment.

Literature Review

Theoretical Framework

Within the theoretical framework, the study adopted Jean Piaget's constructivist theory (1964). Piaget views cognitive development as a process of successive restructuring of intellectual plans, which results from the student's regular socialisation with the environment. According to Jean Piaget, students assimilate new information into existing schemas and accommodate their schemas when new experiences do not fit. Within STEM education, this theoretical stance has profound implications for classroom practice.

In the constructivist classroom, the lecturer transforms himself from a mere transmitter of information to a facilitator who designs experiences and challenges that prompt learners to engage with science and mathematics concepts. Instead of getting learners to memorise formulae, the constructivist lecturers in science and mathematics classrooms have them participate in activities that involve exploration, experimentation, and the modification of their hypotheses. The active nature of constructivist education makes it highly compatible with experiential learning (EL), project-based learning (PBL), and collaborative learning (CL). The relevance of the theory to the study is that, in the constructivist theory, students are provided with practical knowledge rather than theoretical knowledge. For instance, in constructivist theory, students could be asked to write a proposal on paper to establish a small production plant, detailing the costs of procuring machinery, installation, raw materials, and staff, including laboratory personnel, engineers, and management. The study may be conducted at a production plant to observe how it is managed. Instead of relying on friction as a static concept. In constructivism, students are allowed to uncover guiding principles and compare predicted with actual results. This fosters more profound conceptual change as the new knowledge is integrated into existing cognitive frameworks. Furthermore, constructivism highlights the need to link new content to learners' existing knowledge.

Conceptualisation

Stem and Entrepreneurship

Entrepreneurial STEM Education builds on the foundations of two educational traditions: STEM, which emphasises scientific literacy and problem-solving, and entrepreneurship, which fosters initiative, innovation, and business acumen. Their convergence enables students to apply STEM knowledge in practical, socially and economically meaningful ways (Bacigalupo et al., 2016; Deveci & Seikkula-Leino, 2023). Definitions of Entrepreneurial STEM Education typically include formal and informal learning experiences such as interdisciplinary coursework, project-based learning, hackathons, and E-STEM frameworks that engage learners in both technical challenges and entrepreneurial thinking.

The rising interest in Entrepreneurial STEM Education is driven by both economic imperatives and educational reform. Many nations view entrepreneurial STEM integration as a strategy to stimulate innovation and address workforce needs (Panizzon & Corrigan, 2017), while educators see it to bridge the gap between theoretical knowledge and real-world application (Waite & McDonald, 2019; Ahmad & Siew,

2022). Studies also suggest that entrepreneurship-infused STEM learning can enhance engagement and expand participation, particularly among underrepresented student groups (Ahmad & Siew, 2022; Shahin et al., 2021).

Experiential Learning in STEM Education on Promoting Entrepreneurial Innovation

Experiential learning can offer students the practical skills and networks needed to become entrepreneurs through direct exposure to the business environment. In fact, it was established in several studies that participation in internships, trade fairs, and entrepreneurship competitions would make a student more likely to develop an interest in entrepreneurship compared to those taught just theoretical instruction (Oladele, Ogunyemi, & Egbeyemi, 2022; Oyinlola et al., 2024)

Olalekan (2024) reports that internships and SIWES are more robust drivers of entrepreneurial intention than trade fairs. This is because structured, immersive learning is crucial for instilling an entrepreneurial mindset. Ajzen's Theory of Planned Behaviour posits that an individual's intention is a direct antecedent of behaviour (Ajzen, 2020). It locates experiential learning within key constructs such as attitude toward entrepreneurship, perceived behavioural control, and subjective norms. According to Olalekan (2024), students who experience the experiential learning activities are more likely to develop a favourable attitude toward entrepreneurship, have a heightened level of confidence in their ability to start a business, and be influenced by their peers/mentors to pursue an entrepreneurial career.

The growing interest in integrating experiential learning into entrepreneurship education probably reflects a broader appreciation of how education systems can foster entrepreneurial intentions. Entrepreneurship in general has been recognised as one of the main sources of economic growth, especially in developing markets where the conventional job market is too small to absorb the fast-growing labour force (Kritikos, 2014). Experiential learning has been shown to significantly influence the development of entrepreneurial skills and behaviours, as students learn through participatory teaching and by practising real-world business experiences (Motta & Galina, 2023).

Project-based learning (STEM) education on promoting entrepreneurial innovation among university students

The project-based learning (PBL) Model arranges learning around a project. Leal Filho et al. (2016) state that a project contains complex tasks, based on challenging questions or problems, which involve students in the design, problem-solving, decision-making, or investigation activities; provides students with the opportunity to work relatively independently for a long period of time; and ends with a realistic product or presentation. PBL includes learning from authentic content, authentic evaluations, unguided teacher facilitation, explicit educational goals, cooperative learning, reflection, and the integration of adult skills. It uses authentic questions (guiding), has an investigative community, and utilises technology-based cognitive instruments and "expedition learning", which is comprehensive, community service-based, and with a multidisciplinary theme (Recke & Perna, 2021).

Project-Based Learning (PBL) has become one of the most effective pedagogical approaches for integrating STEM education with entrepreneurial innovation. Unlike traditional lecture-based instruction, PBL engages students in solving authentic, real-world problems through collaborative inquiry, design thinking, experimentation, and prototype development (Lavado-Anguera et al., 2024). This experiential approach enables learners to acquire not only scientific and technical knowledge but also entrepreneurial competencies, including creativity, opportunity recognition, critical thinking, leadership, risk-taking, and business problem-solving.

Recent literature indicates that STEM-based PBL enhances innovation by encouraging students to identify societal challenges, develop technological solutions, and transform ideas into market-oriented products or services. Through

multidisciplinary projects, learners integrate concepts from science, technology, engineering, and mathematics while simultaneously developing the entrepreneurial mindsets necessary for venture creation and sustainable innovation. According to Yu et al (2024), PBL shifts STEM education from knowledge acquisition to innovation-driven learning that prepares graduates for the knowledge economy.

Furthermore, Santhosh et al. (2023) state that Project-based STEM learning promotes higher-order thinking skills, collaboration, communication, digital competence, and self-directed learning, all of which are essential entrepreneurial capabilities. A recent meta-analysis found that project-based STEM education significantly improves students' academic achievement, problem-solving ability, creativity, and innovation outcomes compared with conventional instructional methods. These competencies strengthen students' confidence in recognising business opportunities and developing entrepreneurial intentions.

However, successful implementation of STEM-PBL requires adequate institutional support, teacher preparedness, industry partnerships, and access to innovation resources such as makerspaces, laboratories, and digital technologies. Recent review by Chen and Hui (2024) indicates that inadequate teacher training, limited interdisciplinary collaboration, insufficient funding, and assessment challenges remain barriers to fully realising the entrepreneurial potential of STEM-PBL. Strengthening these enabling conditions can enhance innovation ecosystems within higher education institutions and improve graduate employability and enterprise creation.

Collaborative learning in STEM education on promoting entrepreneurial innovation among university students

Collaborative learning is a learner-centred pedagogical approach in which students work together in teams to solve complex problems, exchange knowledge, and develop innovative solutions (Davies et al., 2024). Within STEM education, collaborative learning integrates interdisciplinary knowledge from science, technology, engineering, and mathematics while fostering teamwork, communication, creativity, and critical thinking (Lorente et al., 2024). These competencies are fundamental to entrepreneurial innovation because modern entrepreneurship increasingly depends on collaborative problem-solving, multidisciplinary expertise, and collective knowledge creation rather than individual effort alone.

Recent studies such as Bardales-Cárdenas et al. (2024) demonstrate that collaborative learning environments significantly enhance entrepreneurial competencies by enabling students to co-create ideas, share diverse perspectives, and develop innovative products through teamwork. In STEM classrooms, collaborative projects encourage learners to identify societal and industrial challenges, generate creative solutions, test prototypes, and refine business ideas through continuous peer interaction (Eltanahy & Mansour, 2024). This collaborative process strengthens opportunity recognition, innovation capability, leadership, and entrepreneurial self-efficacy, thereby increasing students' readiness for venture creation and technology commercialisation.

Furthermore, collaborative STEM learning promotes interdisciplinary integration, where students from different academic backgrounds combine technical expertise with entrepreneurial thinking to solve authentic problems. Such learning environments mirror real-world innovation ecosystems in which entrepreneurs, engineers, scientists, and business professionals work collectively to transform ideas into marketable products and services (Bardales-Cárdenas et al., 2024). Consequently, collaborative learning enhances not only technical competence but also entrepreneurial behaviours such as adaptability, negotiation, communication, and collective decision-making, all of which are essential for innovation-driven enterprises.

The emergence of technology-supported collaborative learning has further strengthened entrepreneurial innovation in higher education.

Digital collaboration platforms, virtual laboratories, makerspaces, and immersive learning technologies facilitate knowledge sharing, peer feedback, and collaborative design regardless of geographical location. According to Li et a. (2024). These digital environments promote active engagement, collaborative creativity, and rapid knowledge exchange, enabling university students to develop innovative entrepreneurial solutions while improving their digital competencies and collaborative problem-solving skills. Despite these benefits, effective implementation of collaborative STEM learning requires intentional instructional design, trained facilitators, supportive institutional policies, and assessment methods that recognise both individual and team contributions (Eltanahy & Mansour, 2024).

2. Methodology

The study employed a one-group pretest-posttest quasi-experimental research design involves measuring the effect of a therapy on the same subjects before and after the therapy. This research design lacks control subjects and participant randomisation, which are present in an experimental research design. According to Capili and Anasasi (2024), any difference between pretest and posttest scores must have been caused by the intervention, even though the absence of a control group means that alternative causes cannot be completely ruled out. This research design is frequently used in educational research, particularly when randomisation may be unethical or impractical. The research design is simple in its order:

$$\mathbf{O_1 \rightarrow X \rightarrow O_2}$$

Where:

- $\mathbf{O_1}$ = Pretest (baseline measurement)
- $\mathbf{X}$ = Intervention or treatment
- $\mathbf{O_2}$ = Posttest (outcome measurement)

Population

The study population consisted of 1,412 third-year students enrolled in Science, Technology and Engineering at Joseph Sarwuan Tarka University, Makurdi (Office of the Registrar, 2025). The choice of the third-year students is because they have acquired a good knowledge of STEM and entrepreneurship studies. The university was chosen purposefully because of the emphasis and involvement in STEM.

Sample and Sampling Techniques

The study included 123 intact Year 3 **STEM students** from Joseph Sarwuan Tarka University, Makurdi. These students participated in the study's pre-test and post-test. Initially, 137 students participated in the pre-test; however, only 123 participated in the post-test. This is due to attrition during the study. The study employed a purposive sampling technique to select four Departments, one each from STEM, that is, the Departments of Physics, Technical Education, Mechanical Engineering, and Mathematics and Statistics. The choice of these Departments is based on their students participating in entrepreneurial courses taught at the university, as directed by the National Universities Commission (NUC).

Instrumentation

The instrument for data collection was performance test using Innovative Pedagogical Strategies Performance Test (IPSPT) in STEM which consist of 15 questions developed by the researchers which were multi-choices with five (5) options out of which only one is the correct response to the item(s) was based:

a. Experiential Learning (EL)

b. Project-Based Learning (PBL)

c. Collaborative learning (CL)

The second instrument was a performance test titled "Entrepreneurial Innovation Performance Test (EIPT)" that consisted of 10 questions developed by the researchers, all multiple-choice with five (5) options, only one of which was the correct response to the item(s). These questions were selected based on areas such as creativity, problem-solving, and the ability to recognise opportunities amid entrepreneurial challenges.

Validation of the Instrument

The Innovative Pedagogical Strategies Performance Test (IPSPT), Entrepreneurial Innovation Performance Test (EIPT), and Instructional Lecture Plans for Teaching students were validated by three experts, two in Entrepreneurship (Centre for Entrepreneurship Studies) and one in Measurement and Evaluation, Department of Guidance and Counselling, Joseph Sarwuan Tarka University, Makurdi. The experts assessed the instrument in terms of content validity, face validity, clarity and simplicity of language, relevance of items to the research topic, objectives, research questions and hypotheses and scope of coverage. The validation was based on criteria to ensure that the instrument measured what it was intended to measure. Based on their comments and suggestions, some questions were revised to improve the quality and validity. One of the experts suggested that the instructional lecture plans are very detailed and address innovative pedagogical strategies and entrepreneurial innovation; however, the lecture duration should be extended to 5 weeks. This recommendation was accepted, and the lecture plan was extended to five weeks.

Reliability

A trial test of the instrument was conducted with 50 second-year students at Fr. Moses Orshio Adasu University in Makurdi who are currently undergoing entrepreneurship training. The trial test aimed to establish the reliability coefficients of the research instruments and determine the internal consistency of the items. The instrument was administered to the respondents on a single day with assistance from one research assistant. The Richardson-20 (KR-20) was used to calculate the reliability of the IPSPT and EIPT. The choice of KR-20 was made because it enables the researchers to test the internal consistency of the performance test. The reliability coefficients of IPSPT and EIPT were 0.72 and 0.70, respectively. These coefficients were considered adequate for data collection in this study, as they fell within the acceptable reliability range of 0.70 (DeVellis, 2016).

Experimental procedure

Before the treatment, a pre-test using the Innovative Pedagogical Strategies Performance Test (IPSPT) and the Entrepreneurial Innovation Performance Test (EIPT) was administered to the students the week before. This was to establish the students' entry behaviour. Each question was worth 1 mark, and there were 25 questions: 15 from the (IPSPT) and 10 from the (EIPT). After the pre-test, all the students received treatment for five (5) weeks. The innovative pedagogical strategies used were:

a. Experiential Learning (EL)

d. Project-Based Learning (PBL)

b. Collaborative learning (CL)

The students were all assigned tasks, such as executing projects, writing a business plan, resolving conflicts in a business setting, overcoming challenges, serving as customer care agents, and learning to leverage business opportunities to drive success. They were also grouped to work as a team and meet others for a partnership. The procedure for treatment was divided into five weeks as follows:

Week 1: Pre-test administration

- Here, the researcher administered a test to all students without treatment. The test was administered within 552-568 minutes, as required by the university's teaching-hours standards.

Week 2: Experiential Learning (EL)

- Students were actively experimenting with new ideas, honing skills in a new experience.
- concrete experience engaging directly in an authentic situation
- Abstract conceptualisation into abstract concepts
- teaching students to have observation, noticing what happened, and relating to experience and conceptual understandings.

Week 3: Project-Based Learning (PBL)

- Teach students that working in collaboration fosters teamwork.
- Teach students communication and interpersonal skills.
- Teach students to share ideas, discuss strategies, and delegate tasks.
- Teach how to work effectively with others. These skills are invaluable not only in school but also in the workplace.

Week 4: Collaborative learning (CL)

- Encourage peer interaction,
- Communication skills and teamwork
- Fostering a sense of shared responsibility for learning outcomes.
- Students collaborating on a writing project where each group member contributes ideas, drafts, and edits to produce a cohesive piece of writing

Week 5: Post-Test Administration

Post-test was administered to all students again to measure their performance against the 'Entrepreneurial Innovation Performance Test (EIPT). The questions given to them during the pre-test were also administered during the post-test. The questions were 25, 15 questions from (IPSPT) and 10 from (EIPT). Each question was worth 1 mark, for a total of 25 marks. Both the pre-test and post-test were collated and analysed to arrive at the mean difference and gain.

Data Analysis

Data were analysed using a paired t-test to test hypotheses at the 0.05 level of significance. A paired t-test was appropriate in this study, as it aimed to determine whether there were mean changes or improvements among students exposed to pedagogical strategies that promote entrepreneurial innovation in STEM education. The decision rule was to reject the null hypothesis if the P-value was less than or equal to 0.05. On the other hand, hypotheses were not rejected if the P-value was greater than 0.05.

Ethical Consideration

The study received ethical approval from the College of Education Research Ethical Committee at the University of South Africa (Ref #: 12172). Earlier, students were fully informed of the study's objective, procedures, and voluntary nature. They all agreed to participate in the study and were assured that their responses would be used only for the study. Hence, the researchers also maintained the confidentiality and anonymity of all their responses throughout the study.

3. Results

Hypothesis 1: There is no significant difference between students' pre-test and post-test scores on promoting entrepreneurial innovation after exposure to experiential learning in STEM education.

Table 1:

Paired Sample T-Test Results of Significant Difference Between Students' Pre-Test and Post-Test Scores on Promoting Entrepreneurial Innovation After Exposure to Experiential Learning in STEM Education.

Variable	N	M	SD	Mean Diff.	t	df	P.value	Remark
Pre-test	123	8.07	2.703					
Post-test	123	19.03	3.157	-10.96	-27,739	122	0.000	Significant

Table 1 indicates that the pre-test mean score (M = 8.07, SD = 2.70) and the Post-test mean score (M = 19.03, SD = 3.16) differ significantly, with the pre-test much lower than the post-test for the

same group of 123 respondents. The mean difference between the two tests is -10.96, indicating an increase in scores from pre-test to post-test. It also reveals that the paired-samples t-test indicates a statistically significant difference, $t(122) = -27.74$, $p < 0.05$. The null hypothesis, which states that there is no significant difference, is therefore rejected. This indicates a significant improvement in students' performance after the treatment. This means that there is a significant difference between students' pre-test and post-test scores on promoting entrepreneurial innovation after exposure to experiential learning in STEM education.

Hypothesis 2: There is no significant difference between students' pre-test and post-test scores on promoting entrepreneurial innovation after exposure to Project-based learning (STEM) education.

Table 2:

Paired Sample T-Test Results of Significant Difference Between Students' Pre-Test and Post-Test Scores Promoting Entrepreneurial Innovation after Exposure to Project-Based Learning (STEM) Education

Variable	N	M	SD	Mean Diff	df	T	P.value	Remark
Pre-test	123	11.65	2.686					
Post-test	123	19.24	3.115	-7.59	122	-18.401	0.001	Significant

Table 2 shows that the pre-test mean score ($M = 11.65$, $SD = 2.686$) and the post-test mean score ($M = 19.24$, $SD = 3.115$) differ significantly, indicating that the pre-test mean score is much lower than the post-test mean score for the same group of 123 respondents. The mean difference between the two tests is -7.59, indicating an increase in scores from pre-test to post-test. It also reveals that the paired-samples t-test indicates a statistically significant difference ($t(122) = -18.401$, $p < 0.05$). The null hypothesis, which states that there is no significant difference, is therefore rejected. This indicates a significant improvement in students' performance after the treatment. This means that there is a significant difference between students' pre-test and post-test scores in promoting entrepreneurial innovation after exposure to Project-based learning (STEM) education.

Hypothesis 3: Collaborative learning in STEM education does not significantly improve the promotion of entrepreneurial innovation among university students based on pre-test and post-test assessment.

Table 3:

Paired Sample T-Test Results of Significant Difference Between Students' Pre-Test and Post-Test Scores on improving the promotion of entrepreneurial innovation among university students based on pre-test and post-test assessment.

Variable	N	M	SD	Mean Diff.	t	Df	P.Value	Remark
Pre-test	123	11.85	2.862					
Post-test	123	19.22	2.521	-7.37	-22.611	122	.001	Sign.

Table 3 indicates that the pre-test mean score ($M = 11.85$, $SD = 2.862$) and the Post-test mean score ($M = 19.03$, $SD = 3.16$), showing that the pre-test is much lower than the post-test for the same group of 123 respondents. The mean difference between the two tests is 7.37,

indicating an increase in scores from pre-test to post-test. It also reveals that the paired-samples t-test indicates a statistically significant difference ($t(122) = -22.611$, $p < 0.05$). The null hypothesis, which indicates that there is no significant difference, is therefore rejected. This indicates a significant improvement in students' learning performance after the treatment. This indicates a significant improvement in promoting entrepreneurial innovation among university students, as evidenced by pre- and post-test assessments.

4. Discussion

The result shows a significant difference between students' pre-test and post-test scores, indicating that experiential learning in STEM education promotes entrepreneurial innovation. According to Smith (2017), experiential learning provides hands-on, real-world experiences that enable students to actively engage with the subject matter. These activities often take place outside the traditional classroom setting and encourage students to apply theoretical knowledge in practical contexts. This result aligns with that of Johnson and Brown (2018), who found that experiential learning pedagogical innovations enable lecturers to organise field trips for students to observe, analyse, and interact with various environments. Through experiential learning, learners deepen their understanding of concepts and develop critical observation skills and scientific inquiry techniques. This result corroborates the findings of Chandraja et al. (2024), which report that experiential learning encourages students to learn by doing through hands-on activities, real-world problem-solving, and creative expression. To support this result, Kolb's Experiential Learning Theory (1984) states that experiential pedagogical approaches foster deep-rooted learning by absorbing students psychologically, critically and physically in the learning process. This finding also confirms the findings of Mohammad and Amir (2024), who reported substantial differences in the entrepreneurial learning system (ELS) among students. Further, the VR-based entrepreneurship training course was reported to have the greatest impact on students' EIs. Similarly, Arfiyanti et al. (2017) also report that the experiential learning method improves students' rational prescribing skills. Experiential learning enables students to develop a clear understanding of the experiential learning method and its role in improving rational prescribing skills.

The finding indicates a significant difference between students' pre-test and post-test scores in promoting entrepreneurial innovation after exposure to Project-based learning (STEM) education. The above finding is contrary to those of Pearce et al. (2025), whose results indicate that the application of project-based learning in the learning process fully develops learners' entrepreneurial abilities, thus emphasising the importance of experiential learning. Universities that adopt project-based learning in their entrepreneurial courses enhance group dynamics and emphasise quality control. This strategy has the potential to foster innovation and better prepare students for self-employment opportunities. This study also supports the early findings by Siraprapa and Kobsook (2025), who found that the activity plans of Project-Based Learning and digital tools promote entrepreneurial skills, which involve five steps: define, plan, do, review, and presentation, and that the quality of these activity plans is higher in Project-Based Learning. These digital tools that promote entrepreneurial skills are most suitable for the highest-level students in grade 12. This finding also supports the results of Chularee et al. (2024), who also confirm that the project-based learning intervention has a significant and strong impact on entrepreneurial skills and characteristics. According to this study, students can develop entrepreneurial traits and skills through project-based learning, which can be applied to a variety of academic fields.

As such, collaborative learning in STEM education has played an instrumental role in promoting entrepreneurial innovation among university students, as illustrated by the pre- and post-tests. These findings agree with the findings of Moore (2017) where collaboration and innovation have a positive relationship. Further, this study shows that models are significantly

affected by collaboration in students' spaces, suggesting that student work is a driving force in business model development and innovation. This finding aligns with Niveen (2026), who firmly believes in the value of maintaining a proper balance among harnessing high-quality content, presenting engaging pedagogy, and fostering an environment that maximises key learning outcomes in entrepreneurship education. Niveen (2026) observes that active learning methods, such as collaborative learning, help students develop practical skills for opportunity recognition, problem-solving, and risk-taking. This finding is consistent with previous research by Walter and Block (2016), Fayolle and Gailly (2015), and Almahry et al. (2018), which reports that relevant, clear, organised, and logically structured information enhances students' understanding and engagement, thereby fostering the development of entrepreneurial skills. This result shows that students prefer course content that applies to their real-world scenarios. For example, entrepreneurship education in practical settings, such as case studies, problem-based learning, applied project work, and industry-relevant examples, can help students prepare for their future careers. According to the authors, in the development phase of entrepreneurship education, the positive results of this study suggest that even a modest shift away from traditional lecturing toward a more applied, student-centred approach can have significant impacts on skill development. It was realised that the efficacy of the teaching methodology depended on the extent to which the teacher incorporated learners' learning preferences and on the structures for mentoring and feedback.

Limitations

Despite accomplishing its aims, the study has several constraints. This paper primarily relies on three innovative pedagogical approaches in STEM education to promote entrepreneurial innovation, which may hinder the capacity to arrest current advances in addressing Nigeria's unemployment challenges. The study relied on structured assessment questions developed by lecturers, which may be subject to bias response. In addition, the study was restricted to students at Joseph Sarwuan Tarka University in Makurdi and could not be generalised to all universities in Benue State or Nigeria. The study used only three variables, which are experiential, project-based, and collaborative learning; this excluded other innovative pedagogical strategies in STEM education that may promote entrepreneurial innovation

5. Conclusion

Entrepreneurial innovation is very crucial to the development of any nation. No country can develop without integrating innovation into its economy. This is because it provides the jobs needed to stabilise the economy. In this regard, many scholars recognised entrepreneurship as the engine room of any nation's economy. However, this entrepreneurship cannot survive unless it is passed down from one generation to another. This could be achieved through innovative teaching approaches. This research concluded that when innovative pedagogical strategies are used in STEM education, such as experiential, project-based, and collaborative learning, they develop students' practical thinking and abilities. The implications of this study are that entrepreneurial innovation is significant in developing countries of Africa, particularly in Nigeria, where the government cannot provide jobs for all citizens. Universities in Nigeria should therefore adopt innovative pedagogical strategies to inculcate practical knowledge in students through lecturers and to create supportive learning environments that foster active participation and the real-world presentation of knowledge. This energy could enable students to complete tasks more quickly and easily, with less effort, especially when they are equipped with the skills to become job creators and grow the economy.

Recommendations

Based on the findings of the study, it was recommended that:

1. Universities in Nigeria should go beyond giving students theoretical information or knowledge and develop a curriculum that will give students practical knowledge that would

encourage them to learn by doing through hands-on activities, real-world problem-solving, and creative expression.

2. The National University Commission (NUC) should introduce at least one project- based learning strategy in university curricula in each STEM course, in each semester. This will enable students to identify practical challenges and develop innovative solutions within the crucial venture value chain. This could be achieved by outlining the PBL framework, including problem classification, skills, ideas, prototyping, assessment, and demonstration.
3. Students should also integrate structured collaborative learning into STEM education to enhance their entrepreneurial innovations. Students can achieve when they learn as a team, fostering a sense of teamwork and collaboration, using a clear learning standard that enables them to demonstrate practical skills through the mentorship and support they have received. Moreover, students should create platforms, such as innovation showcases or hackathons, to further improve their capacity to develop and grow current innovative entrepreneurial ideas.

Contribution to knowledge

This study contributes to the body of knowledge on entrepreneurship education and STEM education in several important ways.

In addition to theoretical research, empirical evidence shows that new educational methods, such as experiential learning, project-based learning, and collaborative learning, are effective in enhancing entrepreneurial innovation skills among college-level STEM students. Although other studies have analysed these educational methods individually, the present study has demonstrated their effectiveness under quasi-experimental conditions. The study extends the application of Jean Piaget's Constructivist Theory to entrepreneurship education within STEM programmes. By establishing that entrepreneurial innovation is fostered more effectively through experiential, collaborative, and project-based learning activities, the study affirms the importance of constructivist learning theory in developing entrepreneurial competencies beyond classroom teaching alone.

This research shows that entrepreneurial innovation is not only a product of entrepreneurship content taught in school but also the learning methods used. Thus, this research moves the focus from what is taught in entrepreneurship to how it is taught. Consequently, this contributes to current debates on entrepreneurship education in significant ways. Overall, the significance of this research lies in demonstrating that innovative teaching methods effectively foster entrepreneurial innovation among STEM students, thereby helping universities produce employable graduates with creative, innovative thinking skills.

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Confirm originality of work

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State no conflicts of interest

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