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Integrating Artificial Intelligence into Entrepreneurship Education for Engineering Graduates in Nigeria

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Abstract— Artificial Intelligence (AI) is rapidly transforming the world of education, innovation and entrepreneurship; in the field of engineering education, AI has become an accelerator and a mediator - helping eliminate the divide between theory and practice, as well as between academic knowledge and that which is applicable in industry. The study examines the possibility of artificial intelligence integration in order to expand entrepreneurial skill, human capital, and innovation systems within Nigerian tertiary institutions. The study explores the effect of cluster formation, enabling environments, workforce retention, and AI adoption on entrepreneurial performance through a mixed-method approach, where quantitative data reveal that AI-enriched learning environments and the use of AI-enhanced learning environments have a strong positive relationship with entrepreneurial performance, and qualitative information indicates that intelligent systems are enabling factors influencing entrepreneurial performance in terms of creativity, employability, and collaboration. The results of the study show that AI-based entrepreneurship education can increase the application of practical problem-solving, intelligent mentoring, and data-based policy design of sustainable development. The research concludes that implementing AI in engineering programs has the potential to revolutionize Nigeria human capital base by eliminating skills shortages and enhancing the growth of an innovation-driven economy.

Keywords: Artificial Intelligence, Engineering Education, Entrepreneurship, Human Capital Development, Innovation Ecosystem.

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1. Introduction

AI is the technology that is changing the world of knowledge, innovation, and entrepreneurship in a way that it has never been seen in the history of humanity. Previously, the technology was considered to be a niche phenomenon in the sphere of technological development, but now it is at its center, transforming even the essence of education and manufacturing. In developed economies, AI is transforming and revolutionizing design, production, decision-making, and value creation by integrating computational accuracy with human creativity [1],[2]. In education, AI is no longer just an instructional aid, but a strategic force of learning, innovation, and job seek ability. It makes adaptive learning systems possible, promotes intelligent mentorship, and allows translation of academic theory into practice, which is essential in training an innovation-focused workforce [3],[4]. Entrepreneurship continues to be a pillar in the sustainable development and social growth of a global economy, and is thus flourishing when education systems are capable of producing creative, resilient, and opportunity-driven individuals capable of transforming ideas into viable businesses. Entrepreneurship has become one of the key drivers of sustainable development and societal growth in the global economy, and has proven successful when education systems are structured to produce graduates who are creative, resilient, and opportunity-driven, and which can transform their ideas into viable businesses [5],[6],[7].

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Such systems are immensely dependent on technological enablers, and AI is the most disruptive and enabling one of them by streamlining recognition of opportunities, risk analysis, and resource deployment, AI-driven entrepreneurship has become a driver of sustainable economic growth bridging the gap between education and enterprise [8],[9],[10]. In Nigeria, however, the relationship between education and entrepreneurial performance remains weak. Although entrepreneurship education has been introduced in tertiary institutions, graduate unemployment rates continue to rise, indicating a lack of connection between the classroom setting and what the labor market requires [11],[12],[13]. The problem is more worrying in the field of engineering where the skills acquired by these graduates are more technical and not entrepreneurial, failing to convert technical training into a business enterprise, negating the idea of training job makers and not job takers [14]. Micro, Small and Medium Enterprises (MSMEs) form a major portion of the employment sector in Nigeria, which has long been a pillar of the economic structure of the country, nearly half of the gross domestic product (GDP) [15],[16],[17], [18], [19]. Women and the youth dominate in this sector with 43% of the entrepreneurs being women and 67% of them being youths with states such as Edo registering up to 65% of the new businesses being owned by women [20],[21]. This trend of participation is indicative of the hidden entrepreneurial potentials in the country but also reveals how the training, mentoring, and innovation infrastructure is hindered.

Artificial intelligence provides a strategic solution to these issues because it can be used to enhance entrepreneurship education in tertiary institutions in Nigeria by personalizing learning, forecasting skills deficiencies, and creating real-time feedback to promote experiential learning. For engineering students, AI-based learning environment can model complex problem-solving situations, offer data-driven business analytics, and develop innovation-oriented thinking [22],[23],[24],[25]. Outside the classroom, AI can become a coordination agent between education, industry, and policy, therefore, facilitating a holistic entrepreneurial ecosystem that facilitates development of skills, identification of opportunities, and workforce sustainability. The example of successful innovation hubs in the world, including the Silicon Valley in the United States and the system of start-ups in Finland, teaches how the organized cooperation of universities, private companies, and government agencies can help to grow and innovate [6],[7]. In the case of Nigeria, these qualities include knowledge-sharing, common infrastructure, and constant adjustment, which are essential to the country. The increasing amount of innovation hubs and start-up incubators in the country is an early sign of shift to innovation hubs and start-up incubators, many of which are adopting AI to improve operational efficiency and scalability [26],[27]. Nonetheless, there are still substantial obstacles: the lack of proper infrastructure, finances, institutional support, and skills shortage among the engineering graduates [28],[29],[30].

These challenges highlight the necessity of a combined attitude towards the education of entrepreneurs, or in other words, the association of cluster formation, enabling environments, and labor retention in an AI-driven framework, where interconnected networks create localized innovation and a feedback loop that persists [31],[32],[33]. Consequently, the grouping of engineers, entrepreneur, and educators can establish vibrant surroundings that facilitate the exchange of knowledge, collaborative solutions, and the creation of new venture enterprises [34]. Work experience, mentorship, and exposure to the industry preceding business formation are also found to contribute to entrepreneurial confidence and success [35]. The introduction of AI into the process adds an additional layer of intelligence to predictive views of market opportunities and the adaptive support structures that allow entrepreneurial talent to be [36],[37]. In the case of Nigeria with engineering education, the implication is enormous. An AI-driven model of academic entrepreneurship education has an opportunity to align curriculum development with the needs of the industry, to uplift creative skills, and to perpetrate innovation-driven ecosystems that promote inclusive growth. As is demonstrated in previous studies, such integration presents a strategic channel to human capital development, mitigating unemployment, and promoting resilience in an unstable economic environment [38],[39],[40]. This paper therefore presents artificial intelligence as not just a technological device but an enabling technology of sustainable entrepreneurship and innovation driven development.

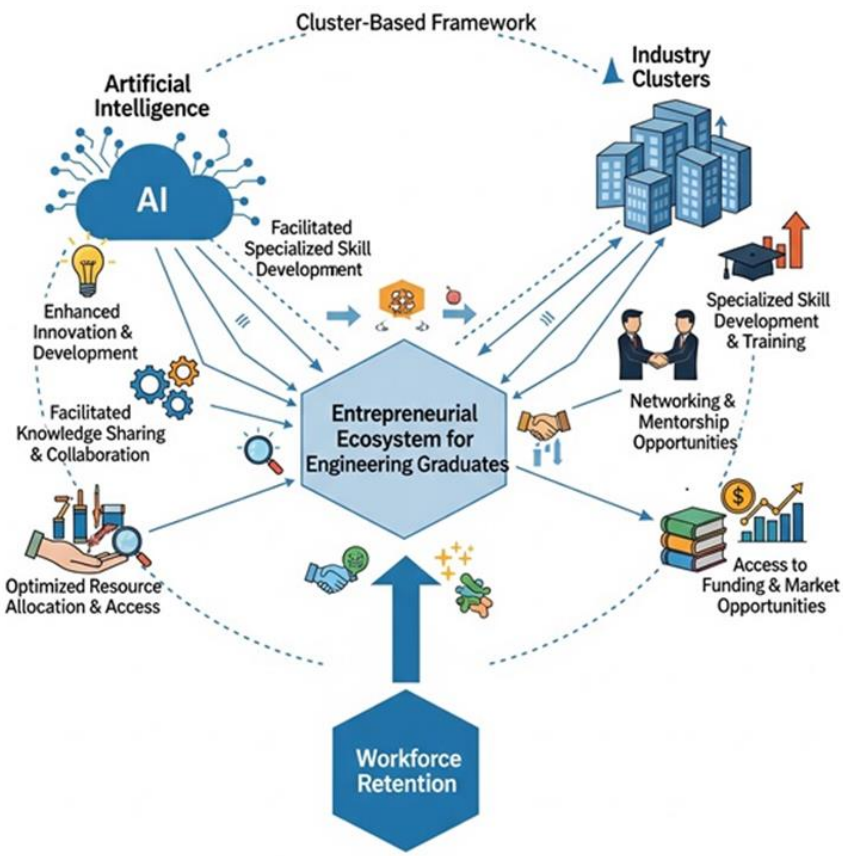

Figure 1. AI & Cluster-Driven Entrepreneurial Ecosystem Framework

The conceptualization of the entrepreneurial ecosystem around the graduates of the engineering disciplines in Figure 1 positions artificial intelligence as the central component that can bring about innovation, spreading the knowledge, and expanding the access to the indispensable resources. Within the industry clusters, AI can be used as a networking tool to its members and aid in skill development being more focussed or precise through latent skill identification, so the graduates in the field will find themselves to be more self-reliant and able to adapt to a technology driven economy; that is, creating employment, not merely seeking it.

Research Objectives

A. To identify the effect of cluster building on entrepreneurial activity among engineering graduates.
B. To investigate the role of a supportive and enabling environment in the success of the entrepreneurial activities of engineering graduates and the society at large.
C. To assess the variables which contribute to retainment of workforce in graduate-led entrepreneurial ventures.
D. To determine the connection between clusters, enabling environments and workforce retention in unlocking sustainable entrepreneurial potential.
E. To determine effective policies and strategies that have the potential of enhancing entrepreneurship by incorporating clusters, enabling environments, and workforce retention strategies.

2. Method

This paper explores how cluster formation, enabling environments, workforce retention, and the use of artificial intelligence affect entrepreneurial ecosystem in engineering graduates, a mixed-methods

methodology was used, balancing quantitative data with qualitative insight to develop a holistic view of entrepreneurial ecosystem.

2.1 Research Design

The data was gathered through the survey design consisting of a descriptive approach to quantify the essential trends in the entrepreneurial ecosystem of Nigeria using structured questionnaires, whereas semi-structured interviews were applied to find deeper insights into AI and its impact on strengthening clusters, improved skill retention, and long-term entrepreneurial activity.

2.2 Population and Sampling

The study population consisted of:

- Engineering graduates (1 to 10 years after graduation) in entrepreneurship.
- Institutional based incubators, innovation hubs, and entrepreneurship development centers staff members.
- Representatives of national agencies, such as NITDA, BOI, and NASENI.
- Faculty members of engineering departments.

To achieve national representativeness, a multi-stage sampling method was used whereby six tertiary institutions and their respective hubs were purposely selected across the six geopolitical zones in Nigeria. 180 respondents were sampled including 120 engineering graduates and 60 key stakeholders, including institutional staff, incubator managers, and policymakers.

2.3 Data Collection Instruments

Two instruments were used:

- **Structured Questionnaire:** The questionnaire was developed to include five sections that could be aligned with the research objectives and the questions were designed to measure perceptions of cluster effectiveness, enabling environments, workforce retention, and AI integration into entrepreneurial practices. Responses were recorded on a scale of 5 points.
- **Semi-structured Interviews:** A total of 15 key informants were interviewed, comprised of 5 entrepreneurs, 5 incubator managers and 5 policymakers. This interview was held with 15 key informants (5 entrepreneurs, 5 incubator managers, 5 policymakers) and focused on the aspects of AI and its use in streamlining entrepreneurial operations, obstacles to its use, and the collective ways to develop robust entrepreneurial ecosystems.

To test instrument validity, pilot research was carried out in a single non-sampled school, which produced a Cronbach's alpha of 0.81, which indicates good internal consistency.

2.4 Data Analysis

- **Quantitative Data:** The responses were summarized using descriptive statistics (frequencies, percentages, means, and standard deviations) and graphs and tables were used to provide the key findings.
- **Qualitative Data:** Interview transcripts were subject to thematic content analysis to identify patterns and insights, where thematic clusters were based on the objective of the study with specific emphasis on how AI can improve clusters, enabling environments, and workforce retention.

The cross-verification of the results was made possible by the integration of both datasets to give a balanced interpretation.

2.5 Analytical Scope

The study took into account the following factors in order to provide a subtle analysis:

- Geographic location- urban and rural clusters.
- Type of institutions: public or private.
- Policy and regulatory environment- federal and state support.
- Industry sector - manufacturing, ICT, energy, and related ventures.
- Graduate characteristics (gender, years since graduation, level of education).

2.6 Expected Contribution

The methodological approach is aimed at generating findings that:

1. Elucidate that clusters, enabling environments, and workforce retention are enablers to intrepreneurial growth.
2. Show that adoption of AI is a requirement and not an option in entrepreneurial ecosystems.
3. Provide both the theoretical and policy implications to the entrepreneurial ecosystems of Nigeria and other regions.

3. Result and Discussion

3.1 Demographic Characteristics of Respondents

Table 1 summarizes the demographic characteristics of the 180 respondents. The population mostly consisted of engineering graduates (66.7%), with institutional stakeholders constituting the rest 33.3% of the population to ensure a talent and ecosystem perspective. The percentage of females was 31.1%, and that of males was 68.9%. The majority of the respondents were young and mid-career: 47.2% of them were aged 30-39 and 26.7% were aged 40-49. A high percentage of 46% had graduated between 4-10 years ago and this means moderate career maturity and only 5% had graduated over a decade ago. Out of these stakeholders, over 50% were associated with engineering faculties or entrepreneurship centers, government policy agencies made 28.3% and institutional incubators 20%. All six geopolitical zones were represented regionally, with the South West (25.0%) and North Central (19.4%) giving the highest shares, which may be deemed as a wide and even coverage.

Table 1. Demographic Profile of Respondents

Demographic Variable	Category	Male	Female	Total
Respondent Category	Engineering Graduates	86	34	120
	Institutional Stakeholders (Incubators, Policy)	38	22	60
Gender	Male	124	–	124
	Female	–	56	56
Age Group	20–29 years	25	11	36
	30–39 years	59	26	85
	40–49 years	28	20	48
	50 years and above	8	3	11
Years Since Graduation	1–3 years	18	5	23
	4–6 years	25	11	36
	7–10 years	37	15	52
	10 years and above	6	3	9
Institutional Affiliation (Stakeholders only)	Institutional-based Incubator	–	–	12
	Government Policy Agencies (NITDA, BOI, NASENI)	–	–	17

	Engineering Faculty / Entrepreneurship Centre	–	–	31
Region (Geo-political Zone)	North Central	21	14	35
	North East	16	9	25
	North West	21	9	30
	South East	15	5	20
	South South	13	12	25
	South West	34	11	45

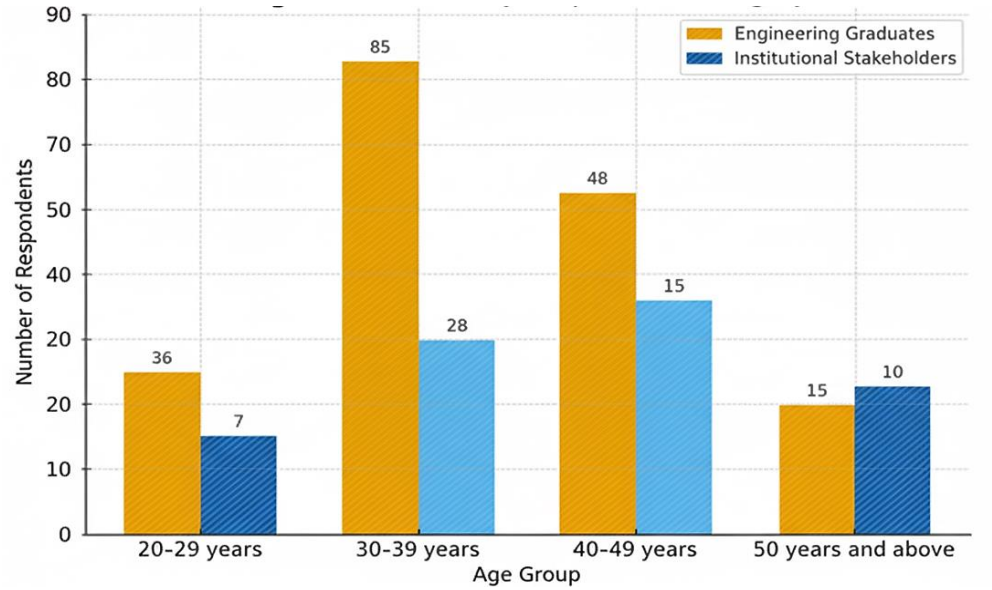

Figure 2. Age Distribution by Respondent Category

The age distribution of the respondents has been presented in Figure 2 between engineering graduates and institutional stakeholders. The majority of the respondents in both categories were between the age of 30-39 which comprised of a large mid-career work force. The number of graduates in the 20 29 age bracket was also high, which is a sign of a large number of new entrants to the profession. Stakeholders on the other hand were clustered in the 40-49 age range. There were not many respondents aged 50 years and above, and this indicates that there were few seniors involved, but it underscored the involvement of younger professionals.

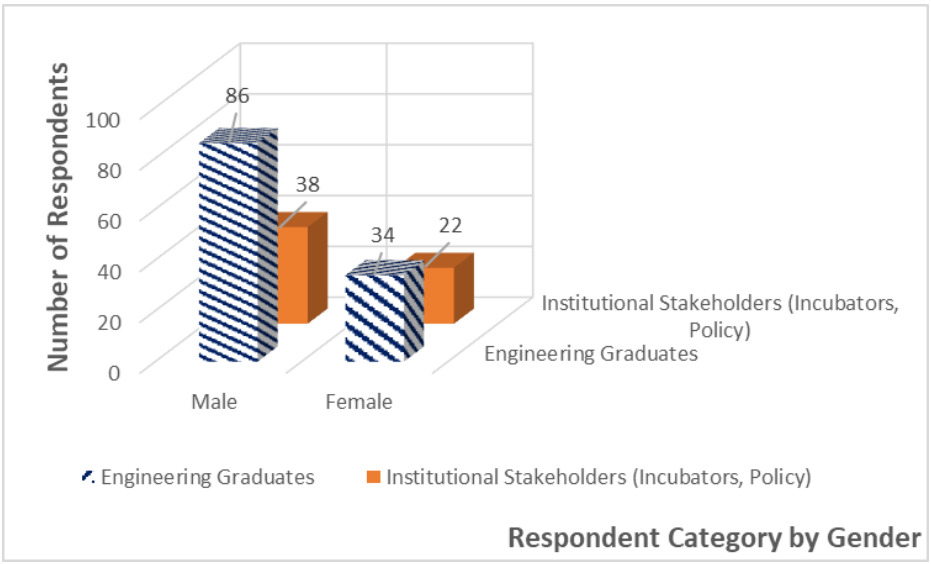

Figure 3. Gender Distribution by Respondent Category

Figure 3 presents the gender distribution of respondents within the two main categories. Males represented a clear majority of the engineering graduates, but females represented almost one-third of the total, which points to the continued gender imbalance between the two groups, as well as to the gradual inclusivity of women to technical and policy-related fields of the engineering ecosystem.

3.2 Impact of Cluster Formation on Entrepreneurial Activities

The respondents were requested to rate the perceived benefits of cluster formation on a five-point Likert scale. The findings are summarized in Table 2.

Table 2. Perceived Benefits of Cluster Formation

Cluster Benefit	SA (5)	A (4)	N (3)	D (2)	SD (1)	Total Agreement (SA + A)	% Agreement
Collaboration opportunities	80	53	20	17	10	133	74.0
Shared infrastructure	70	54	25	21	10	124	68.9
Peer mentoring	62	55	30	22	11	117	65.0
Market visibility	58	53	32	25	12	111	61.7

Table 2 indicates the significance of cluster in promoting entrepreneurship among the engineering graduates. The most important benefits were of collaboration (74%), and access to shared infrastructure (69%), next in line were peer mentoring (65%) and market visibility (62%). These results indicate that clusters are not merely support systems but they also constitute the foundation of entrepreneurial ecosystems. Clusters, resources, networks, and social capital that are not easily obtained individually are offered by clusters. The outcome of the results directly confirms the Objective A, which underlines the collaboration between universities, industry, and government as a source of innovation. An innovative requirement among the respondents is the creation of AI-powered clusters based on digital infrastructure, foresightful collaboration software, and virtual incubation. This vision reinvents clusters as digitally connected ecosystems that increase the opportunities beyond geography, promote collaboration, and speed up the results of entrepreneurship.

3.3 Entrepreneurial Enabling Environment

The enabling environment factors were assessed on a five-point scale (1=Very Low, 5=Very High). Table 3 shows the raw distributions of responses; Table 4 summarizes the calculated means and standard deviations.

Table 3. Raw Response Distributions for Enabling Environment Factors

Factor	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Policy Support	10	20	50	60	40
Access to Finance	18	32	60	45	25
Institutional Support	12	22	45	65	36
Market Access	22	40	55	40	23
Digital/AI Infrastructure	30	45	50	35	20

Table 4. Computed Mean Ratings of Enabling Environment Factors

Factor	Mean ($\bar{x}$)	SD
Policy Support	3.6	1.0
Access to Finance	3.3	1.1
Institutional Support	3.6	1.0

Market Access	3.2	1.1
Digital/AI Infrastructure	2.8	1.2

Tables 3 and 4 depict the effects of enabling environment on engineering graduates in entrepreneurship. The institutional support and policy support had the highest scores (mean 3.6 each) which means that institutional and regulatory frameworks are starting to offer substantial support. Moderate ratings were achieved on access to finance (3.3) and market access (3.2), which evidences a continuing lack of funding and a challenge in scaling innovations especially outside local markets. The lowest score (2.8) was on digital and AI infrastructure, which indicates a fatal flaw in the entrepreneurial ecosystem. Therefore, although the policy and institutions backing are getting better, insufficient digital infrastructure, funding, and market access are still significant obstacles. It is evident that the immediate investment in AI empowered infrastructure, with the improved financial and market systems, is essential to facilitate graduate entrepreneurship, and promote long-term growth.

3.4 Skills Development and Retention of Workforce

The qualitative data reveal that retention of engineering graduates in the workforce is negatively affected by lack of growth opportunities as well as the lack of correlation between academic practice and market requirements. Stakeholders have observed that the AI-based adaptive learning systems and labor-market predictive tools may decrease the rate of attrition through ongoing reskilling.

As an illustration, an incubator manager in the North West commented: "*Graduates are likely to exit startups when they do not feel their careers developing. Training platforms that are based on AI can ensure that they are competitive and committed*." One of the policy stakeholders in the South West stated: "*The key to retention is the AI-driven reskilling that will address the gap between the academic learning and industries".* These observations touch upon Objective C and the discussion can be progressed by suggesting AI-based ongoing learning as a retention strategy. Even though reskilling is underlined as a crucial element in global studies, the Nigerian setting highlights that the integration of such systems into clusters is required to gain relevancy and retain engineering graduates in the nation.

3.5 Integration of Artificial Intelligence Across the Ecosystem

Respondents were requested to name the main advantage of AI integration in the entrepreneurial ecosystems. The findings are presented in Table 5.

Table 5. Distribution of Perceived Benefits of AI Integration

AI Benefit	Frequency	Percentage (%)
Efficiency (process automation, predictive analytics)	63	35.0
Innovation (new products/services, AI-driven R&D)	49	27.2
Networking (digital matchmaking, collaboration tools)	36	20.0
Scalability (expansion, virtual ecosystems)	22	12.2
Workforce Retention (AI-enabled upskilling, career alignment)	10	5.6
Total	180	100

Table 5 demonstrates the perception of the respondents on the positive outcomes of AI integration. Efficiency was the top-ranked item and process automation and predictive analytics were the most valuable results with 35 %. The second technology at 27.2% revealed that AI was important in the innovation of new products, services, and research discoveries. 20% was networking, which indicates the growing importance of online collaboration tools in entrepreneurial networks. Scalability contributes 12.2% which is an indication of the recognition of AI in facilitating expansion via virtual ecosystems. The lowest retention feature is 5.6% of workforce, which indicates poor knowledge regarding the ability of AI to enhance upskilling and career alignment. These results are directly connected to Objective D and Objective E as those reflect the role of AI in influencing ecosystem interrelationships and informing sensible entrepreneurship policies.

3.6 Policy and Practical Implications

The study shows three priority actions:

1. **Policy Integration:** incorporate AI implementation in entrepreneurship policies in both national and sub-national levels and carry it out through agencies like NITDA, BOI and NASENI.
2. **Curriculum Reform:** introduce AI-based modules of entrepreneurship in engineering programmes to ensure that the graduates learn skills that suit market needs.
3. **Cluster Digitalisation:** convert the physical clusters into hybrid ecosystems by networking, sharing resources with the help of AI platforms and improving access to markets.

These recommendations offer both immediate policy and practical strategies that offer solutions to the current challenges of the academia and the policy and also lead to the theoretical background on the entrepreneurial ecosystems.

3.7 Proposed Framework for AI-Enabled Entrepreneurial Ecosystems

Following the findings of the study, Figure 4 introduces a conceptual model that introduces clusters, enabling environments, and workforce retention as the three fundamental pillars of entrepreneurship, which are reinforced by the combination of Artificial Intelligence.

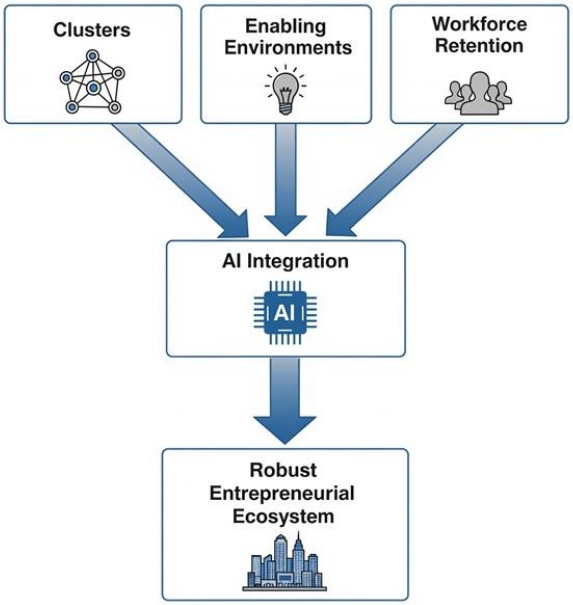

Figure 4. Conceptual Model of AI-Enabled Entrepreneurial Ecosystems

The framework depicted in Figure 4 emphasizes the unique contribution of the study by demonstrating AI as a pivotal factor of sustainable entrepreneurship among engineering graduates. It provides an intersection between the understanding of theory and policy, and a strategic guide on how to intensify entrepreneur ecosystems in Nigeria and other emerging markets. Incorporating AI within the developed pillars, the model demonstrates how technology can be used to promote collaboration, provide more access to resources, and assist in talent development to achieve long-term entrepreneurial success.

4. Conclusion

This research confirms that Artificial Intelligence (AI) is not only a technological tool but also a revolutionary idea that can radically change the course of engineering education and entrepreneurship

in Nigeria. AI in engineering entrepreneurship education offers a human capital development and innovation strategy. By facilitating data-driven decision-making and experiential learning to support intelligent automation, predictive analytics, and adaptive learning, AI will ease the transition between education and economic development through multiple aspects: Within a classroom environment, AI fosters employability, entrepreneurial competence, and workforce sustainability; Outside the classroom, AI will encourage innovators to collaborate in innovation clusters, build industry-academia connections, and share knowledge that is crucial to the maintenance of a robust entrepreneurial ecosystem. However, in order to guarantee that Nigeria does not increase its innovation and capacity disparities, a coordinated campaign among government, academia, industry, and civil society will be necessary to institutionalise AI as an offensive element of national development. It is not only that adopting AI-driven engineering education will produce a new generation of technically skilled entrepreneurs, but it will also enable them to transform the national competitiveness in the global innovation economy.

5. Recommendations

Based on the results of the research, the recommendations are as follows:

1. To prepare graduates with an appropriate combination of entrepreneurial and technical skills in emerging industries, learning institutions should incorporate AI in their programmes.
2. The government agencies must focus more on investing in digital infrastructure and institute policies that promote AI implementation in industrial sectors, start-ups, and institutions of learning.
3. The means of access to finance by the entrepreneur are to be expanded by developing AI-driven funding services and facilitating friendly regulative frameworks that reduce barriers to innovative enterprises.
4. The collaboration between universities, polytechnics, and the industry stakeholders needs to be reinforced to make sure that graduate training would be responsive to the needs of the labour market and it would contribute positively to the overall entrepreneurial ecosystem.
5. The industry members are advised to adopt AI in their workforce development and retention policies, which encourages continuous learning and minimizes losses of skills among the graduates.
6. The integration of government, academia, industry, and civil society in building a unified ecosystem in utilizing AI to achieve sustainable entrepreneurship should be further strengthened.
7. AI-based solutions must be adopted in innovation hubs and cluster initiatives to improve mentorship, experimentation, and responsive reactions to technology and change in market demands.

To advance the findings of this work, the following research directions should be pursued in the future:

- Carry out long-term research to determine the impact of AI-supported clusters on startup sustainability and labour sustainability.
- Find applications of AI to agriculture, healthcare and renewable energy (sector specific) to determine their applicability as entrepreneurs.
- Make comparative analyses of Nigeria and other African territories in order to come up with continentalize models of AI-enabled entrepreneurial ecosystems.
- Investigate the role of AI-based policies, training programmes and digital infrastructure in facilitating the rapidity of innovation and in Shared Entrepreneurship Support Systems among graduates.

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