APTISI Transactions on Management (ATM)
Vol. 9, No. 3, 2025, pp. 244∼255
E-ISSN: 2622-6804 P-ISSN: 2622-6812, DOI:10.33050

Integrating Edupreneurship and Digital Transformation to Enhance Creative Thinking in Learning Design

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Article Info

Article history:

Submission September 03, 2025
Revised October 10, 2025
Accepted October 12, 2025

Keywords:

Artificial Intelligence
Competitive Advantage
SMEs
Digital Transformation

ABSTRACT

The increasing urgency to address climate change has positioned Sustainable Development Goal 13 (Climate Action) as a priority for governments and businesses worldwide. Technological innovations such as Artificial Intelligence (AI), the Internet of Things (IoT), and Blockchain have emerged as transformative tools for reducing environmental impacts, improving energy efficiency, and promoting ethical and sustainable business practices. However, the extent to which these technologies contribute to climate action remains underexplored. **This study aims** to investigate the role of AI, IoT, and Blockchain in helping businesses achieve SDG 13 by optimizing resources, reducing waste, and enhancing supply chain transparency. A mixed-methods approach was adopted, combining qualitative and quantitative techniques. Semi-structured interviews were conducted with key stakeholders from businesses implementing these technologies, while a survey of 150 businesses was administered to capture broader adoption patterns. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to test the proposed hypotheses. **The findings** reveal that AI and IoT have significant positive effects on energy management and sustainability outcomes, while Blockchain plays a supportive role by improving transparency and ethical practices, though its adoption remains limited. The combined integration of these technologies yields the most substantial impact. This study concludes that businesses should adopt a holistic strategy to fully leverage technological innovations for advancing SDG 13 and combating climate change.

DOI: https://doi.org/10.33050/atm.v9i3.2533

1. INTRODUCTION

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, provide a comprehensive framework for addressing global challenges such as poverty, inequality, climate change, and environmental degradation. With a 2030 deadline, these goals emphasize the importance of collective action by governments, businesses, and individuals to achieve sustainable development. Among the 17 SDGs, technological innovation has emerged as a critical driver for systemic change and long-term sustainability [1].

Technological advancements, including AI, blockchain, the IoT, and renewable energy, offer significant potential to transform industries and business practices [2]. These technologies enable organizations to optimize operations, reduce resource consumption, and develop environmentally responsible products and services. For example, AI can improve supply chain efficiency and predictive analytics for energy management, while blockchain enhances transparency and ethical practices, particularly in sectors such as finance, agriculture, and logistics [3]. IoT, on the other hand, facilitates real-time monitoring of energy and resource usage, contributing to more efficient production systems [4].

Despite their potential, many organizations, especially small and medium-sized enterprises (SMEs), face challenges in integrating these technologies into their sustainability strategies. Barriers include high implementation costs, lack of digital infrastructure, limited technical expertise, and resistance to organizational change [5]. These challenges align with the *Innovation Diffusion Theory (IDT)*, which explains the varying rates at which innovations are adopted across different contexts. Moreover, understanding the interplay between technological innovations and sustainability objectives can be guided by the *Triple Bottom Line (TBL)* framework, which emphasizes balancing economic performance (profit), environmental stewardship (planet), and social responsibility (people) [6].

This study explores the relationship between technological innovation and SDG 13 (Climate Action), focusing on how businesses can strategically integrate AI, IoT, and blockchain to enhance energy efficiency, reduce waste, and promote sustainable practices [7, 8]. By combining theoretical perspectives with empirical data, this research addresses a gap in the literature and provides actionable recommendations for organizations and policymakers [9, 10]. Furthermore, it highlights successful case studies where these technologies have been applied effectively, offering practical insights into overcoming barriers and fostering technology-enabled sustainable business practices.

2. LITERATURE REVIEW

The concept of SDGs was introduced by the United Nations in 2015 as a global agenda to address urgent social, environmental, and economic challenges. The SDGs aim to achieve a better and more sustainable future for all by 2030 [11]. In the context of business practices, companies are increasingly expected to align their strategies with these goals to ensure that operations support global sustainability efforts. Technology plays a crucial role in this transition, as it enables greater efficiency, transparency, and reduction of environmental impact [12]. The relationship between technological innovation and sustainability can also be examined through the lens of the *Triple Bottom Line (TBL)* framework, which emphasizes balancing environmental stewardship (planet), social responsibility (people), and economic performance (profit) [13, 14].

2.1. Technological Innovations and Their Role in Achieving SDGs

Technological innovation is a primary driver in advancing the SDGs [15, 16]. Over the past decade, emerging technologies such as AI, the IoT, and blockchain have demonstrated significant potential to support sustainability initiatives across industries. AI has been widely applied in predictive analytics for resource management, climate change modeling, and supply chain optimization [17, 18]. For instance, AI-powered algorithms can help organizations identify inefficiencies and develop strategies to reduce carbon footprints [19, 20].

Similarly, IoT enables real-time data collection, allowing businesses to monitor energy consumption and optimize resource use. These capabilities directly contribute to SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) [21, 22]. IoT has been particularly useful in smart manufacturing and energy management systems, where connected sensors provide actionable insights to minimize waste and improve operational efficiency [23, 24].

Blockchain technology, known for its transparency and decentralization, is being adopted in sectors such as agriculture, finance, and supply chain management [25, 26]. It facilitates secure and traceable transactions, ensuring integrity in business processes and reducing corruption risks. This supports SDG 16 (Peace, Justice, and Strong Institutions), especially in industries where supply chain transparency is critical [27, 28]. However, despite its potential, blockchain adoption remains relatively low compared to AI and IoT [29, 30], largely due to high implementation costs, complex infrastructure requirements, and a lack of regulatory clarity [31, 32].

Furthermore, renewable energy technologies such as solar and wind power are advancing rapidly, offering scalable solutions that align with SDG 7 and SDG 13. When integrated with digital technologies, these innovations can significantly accelerate the transition to sustainable energy systems [33, 34].

2.2. Business Practices and Technological Adoption for Sustainability

Businesses worldwide are increasingly adopting technological solutions to improve sustainability outcomes [35, 36]. However, the pace of adoption varies across sectors and regions. Large corporations often have the resources and infrastructure necessary to implement advanced technologies, while small and medium-sized enterprises (SMEs) face considerable barriers, including high costs, limited technical expertise, and inadequate digital infrastructure [37, 38]. According to [39], SMEs in developing countries struggle to integrate green technologies due to limited access to capital and training opportunities [40, 41].

The adoption process can also be understood through the *(IDT)*, which explains how innovations spread within organizations and industries [42, 43]. Companies with visionary leadership and a culture of innovation are more likely to adopt digital technologies aligned with SDGs [44, 45]. Integrating sustainability into corporate strategy is increasingly viewed as a competitive advantage. Businesses that effectively communicate their sustainability initiatives through digital platforms can attract environmentally conscious consumers and investors, thereby increasing profitability while contributing to global sustainability goals [46].

2.3. Challenges in Technological Integration for SDGs

Despite the potential benefits, integrating new technologies into business practices presents significant challenges. One of the most critical barriers is the high cost associated with implementation, particularly for SMEs. Many smaller firms are hesitant to invest in technologies such as AI, IoT, and blockchain due to perceptions of complexity and uncertainty regarding return on investment [47]. Blockchain, in particular, faces adoption hurdles including the need for specialized technical skills, interoperability issues, and concerns about data privacy and cybersecurity. These barriers limit its widespread application, despite its potential to revolutionize supply chain transparency and accountability [48].

Regulatory challenges also play a crucial role. Different countries have varying environmental standards, data privacy regulations, and technology policies, resulting in a lack of harmonized global frameworks. This creates inefficiencies for businesses operating across multiple jurisdictions and discourages investment in sustainable technologies. Collaborative policy development is needed to address these issues and create an enabling environment for technological adoption [49].

2.4. The Future of Technological Innovations in Achieving SDGs

Looking ahead, there is significant potential for further technological advancements to support the achievement of SDGs. The rise of smart cities driven by IoT, big data, and AI promises to enhance urban sustainability by improving energy efficiency, waste management, and public services. These technologies can transform how resources are managed, creating interconnected systems that minimize environmental impact and improve quality of life [50].

In addition, advancements in biotechnology and materials science are poised to revolutionize sustainable agriculture. Precision agriculture techniques, supported by AI and IoT, can increase food production while reducing resource consumption and environmental footprints. These innovations directly contribute to SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production).

As businesses and governments continue to innovate, collaboration between the public and private sectors will become increasingly essential. Such partnerships can foster ecosystems that promote technology-enabled sustainability, accelerate scaling of sustainable solutions, and ultimately contribute to the realization of the SDGs by 2030. This collaborative approach is critical to overcoming barriers and ensuring that technological advancements translate into meaningful and measurable progress toward global sustainability goals.

3. METHODOLOGY

This study explores how technological innovations can be leveraged to achieve the SDGs in business practices. A mixed-methods approach was employed, combining qualitative and quantitative methods to provide a comprehensive understanding of the relationship between technology adoption and sustainability within organizations. This section outlines the research design, data collection methods, analytical techniques, variables, hypotheses, ethical considerations, and limitations.

3.1. Research Design

The research utilized a mixed-methods design that integrates qualitative case studies with quantitative surveys. This approach enables an in-depth exploration of contextual factors influencing technology adoption while also providing statistical insights into broader trends. The qualitative component identifies key challenges and opportunities, while the quantitative component measures the impact of technological innovations on achieving SDGs across industries.

3.2. Data Collection

The qualitative data were gathered using a case study approach to investigate how businesses from various sectors such as manufacturing, agriculture, and services implement technological innovations to support SDGs. Semi-structured interviews were conducted with business leaders, sustainability managers, and technology experts. The interviews focused on four main areas: types of technologies adopted, challenges faced during adoption, perceived benefits and limitations, and strategies used to overcome barriers. Each interview lasted 45–60 minutes, was recorded with consent, transcribed, and thematically analyzed to identify recurring patterns.

For the quantitative data, a structured survey was distributed to a broader sample of 150 businesses. The survey measured the extent of technology adoption and perceived impact on SDGs using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Participants were selected using a stratified random sampling method to ensure diversity in industry sectors, company sizes, and geographical locations. The survey design was informed by insights from the qualitative phase and relevant literature.

3.3. Data Analysis

Qualitative data were analyzed using thematic analysis, which involves identifying, analyzing, and interpreting recurring patterns within the interview transcripts. This method provided a deeper understanding of factors influencing technology adoption and its relation to SDGs.

Quantitative data were analyzed using PLS-SEM with SmartPLS software. PLS-SEM was chosen due to its suitability for modeling complex relationships involving multiple independent and dependent variables. The measurement model was used to assess reliability and validity, while the structural model examined the relationships between technological adoption (AI, IoT, blockchain) and SDG outcomes such as energy efficiency, waste reduction, and transparency. Model fit was evaluated using the Goodness of Fit (GoF) index, R-squared values (R^2), and path coefficients.

3.4. Variables and Hypotheses

The study includes three independent variables and one dependent variable. The independent variables represent technological innovations adopted by businesses to enhance sustainability:

1. AI adoption aims to optimize resource management, improve efficiency, and support decision-making.
2. IoT is utilized for monitoring and managing energy consumption, optimizing production, and reducing waste.
3. Blockchain Technology is integrated to enhance transparency, security, and ethical practices in supply chains.

The dependent variable is the achievement of SDG 13 (Climate Action), which includes reducing carbon emissions, promoting energy efficiency, and mitigating climate change through technological innovations.

Based on these variables, the following hypotheses were developed:

1. H1 Adoption of AI positively impacts the achievement of SDG 13 by optimizing energy use and reducing carbon emissions.
2. H2 Adoption of IoT positively impacts the achievement of SDG 13 by improving energy management and reducing waste.
3. H3 Adoption of blockchain positively influences SDG 13 by enhancing transparency and promoting sustainable practices in supply chains.

4. H4 The combined adoption of AI, IoT, and blockchain has a synergistic positive impact on achieving SDG 13 by fostering energy efficiency, waste reduction, and sustainable business practices.

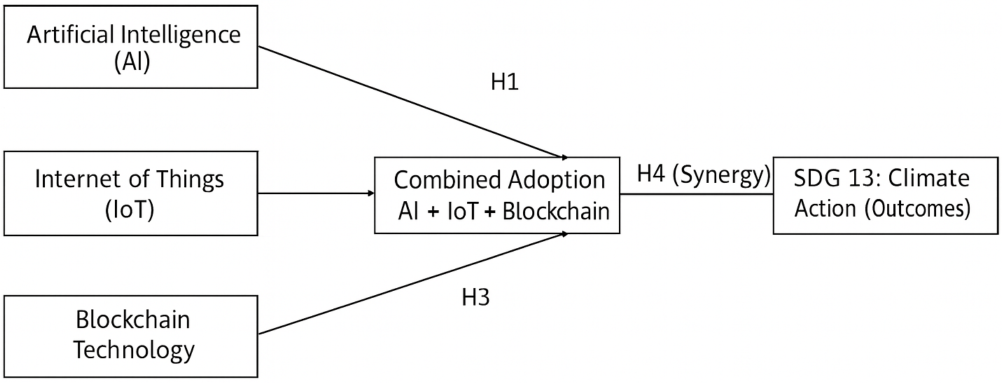

Figure 1. Hypothesized Model

Figure 1 illustrates the hypothesized model, showing the direct effects (H1–H3) and the synergistic combined effect (H4) of technological adoption on achieving SDG 13 outcomes.

3.5. Ethical Considerations

This study followed strict ethical guidelines. All participants were informed about the research purpose and provided consent prior to participation. Confidentiality and anonymity were ensured throughout the process, with data securely stored and used exclusively for academic purposes.

3.6. Limitations

While this study provides valuable insights, several limitations must be acknowledged. The case studies were limited to selected industries, which may not fully capture the diversity of businesses adopting sustainable technologies. The survey sample, though stratified, may not represent all businesses globally, particularly those with limited digital access. Future research should expand the sample size and include a wider range of industries and geographic regions to improve generalizability.

4. RESULTS AND DISCUSSION

This section presents the key findings of the study and their implications for leveraging technological innovations to achieve SDG 13 (Climate Action). The analysis was performed using PLS-SEM to evaluate the relationships between technology adoption (AI, IoT, and Blockchain) and sustainability outcomes.

4.1. Results

Table 1. Descriptive Statistics for Technology Adoption

Technology	Mean	Standard Deviation
AI	4.12	0.78
IoT	4.05	0.82
Blockchain Technology	3.56	0.95

The results are presented in three stages: descriptive statistics, model assessment, and hypothesis testing. First, descriptive statistics were calculated to provide an overview of the adoption levels for each technology, as shown in Table 1, where AI and IoT show higher mean values compared to Blockchain, indicating that these two technologies are more widely adopted while Blockchain adoption remains relatively limited, especially among small and medium-sized enterprises (SMEs).

Table 2. Measurement Model Results for Reliability and Validity

Construct	Factor Loadings	Cronbach's Alpha	CR	AVE
AI	0.78–0.89	0.86	0.91	0.68
IoT	0.75–0.88	0.84	0.90	0.65
Blockchain Technology	0.71–0.82	0.80	0.87	0.60
SDG 13 Outcomes	0.76–0.88	0.85	0.91	0.67

The results indicate that AI and IoT have higher levels of adoption compared to Blockchain, suggesting that businesses are more familiar with and confident in implementing these two technologies to enhance their operational efficiency and sustainability practices. In contrast, the lower mean value for Blockchain reflects its limited implementation among businesses, particularly small and medium-sized enterprises (SMEs), due to factors such as high costs, technical complexity, and regulatory uncertainties. To verify the reliability and validity of the measurement model, key statistical metrics such as factor loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) were evaluated. As shown in Table 2, all values met or exceeded the recommended thresholds, confirming that the constructs used in this study are both reliable and valid for further analysis of their relationship with the achievement of SDG 13.

Table 3. PLS-SEM Results: Path Coefficients and R-squared Values

Hypothesis	Path Coefficient	R^2 Value
H1: AI $\rightarrow$ SDG 13	0.45 ($p < 0.01$)	0.20
H2: IoT $\rightarrow$ SDG 13	0.40 ($p < 0.05$)	0.16
H3: Blockchain $\rightarrow$ SDG 13	0.25 ($p < 0.10$)	0.06
H4: Combined Technologies $\rightarrow$ SDG 13	0.55 ($p < 0.01$)	0.42

Table 3 presents the structural model results. AI and IoT both have strong, significant positive effects on achieving SDG 13, indicating that these technologies are crucial drivers of energy efficiency, waste reduction, and overall climate action performance within organizations. In contrast, Blockchain has a weaker but still positive influence, which reflects its potential to enhance transparency and accountability, though its adoption remains limited due to barriers such as high implementation costs and regulatory uncertainties. The combined adoption of these three technologies demonstrates the highest effect, highlighting a strong synergy where the integration of AI, IoT, and Blockchain enables businesses to simultaneously optimize operations, improve sustainability practices, and create ethical, transparent supply chains. This synergy suggests that a holistic approach to technology adoption is far more effective than implementing each innovation in isolation, emphasizing the importance of cross-technology strategies for achieving long-term sustainability goals.

These results confirm H1, H2, and H4, while H3 is only partially supported. The combined effect of all three technologies explains 42% of the variance in SDG 13 outcomes, demonstrating the value of integrated adoption. This finding highlights that when AI, IoT, and Blockchain are implemented together, they create a synergistic impact that is significantly greater than the sum of their individual contributions. Such integration enables businesses to address multiple aspects of sustainability simultaneously, including energy efficiency, waste reduction, and supply chain transparency. Furthermore, the partial support for H3 suggests that while Blockchain plays an important role, its true potential may only be realized when it is combined with other technologies and supported by proper infrastructure, technical expertise, and regulatory frameworks. These insights emphasize the need for businesses and policymakers to focus not only on adopting advanced technologies independently but also on creating strategies that encourage holistic, cross-technology integration to achieve long-term climate action goals.

4.2. Discussion

The findings highlight the pivotal role of digital technologies in achieving climate action goals, with AI emerging as the most influential factor due to its ability to optimize energy consumption, predict maintenance needs, and reduce carbon emissions. IoT also demonstrated a significant positive impact by enabling real-time monitoring of energy use, production efficiency, and waste management, allowing businesses to make data-driven decisions that improve sustainability. Together, AI and IoT work synergistically to enhance operational efficiency and environmental performance. Although Blockchain had a weaker effect, it remains valuable for ensuring transparency and accountability in business operations, particularly in supply chain management.

However, its lower impact is largely due to barriers such as high costs, technical complexity, and regulatory uncertainties, as summarized in Table 4, which explains its limited adoption among businesses, especially small and medium-sized enterprises (SMEs).

Table 4. Barriers to Blockchain Adoption

Barrier	**Description**
High Costs	Initial setup and operational expenses are too high for SMEs.
Technical Complexity	Requires specialized skills for deployment and maintenance.
Interoperability Issues	Lack of standardized systems across industries.
Regulatory Uncertainty	Inconsistent or absent regulations hinder confidence in adoption.

The strongest effect was observed for the combined adoption of AI, IoT, and Blockchain, supporting H4. This synergy demonstrates that integrating multiple technologies leads to more comprehensive sustainability outcomes, from efficient energy management and waste reduction to transparent supply chains and ethical business practices. Businesses that view these technologies as interconnected systems rather than isolated tools are better positioned to achieve long-term climate action goals.

4.3. Policy Implications

The results suggest several practical actions for policymakers and businesses to accelerate the adoption of sustainable technologies. Governments should provide financial incentives, such as tax breaks, grants, and subsidies, to lower the costs associated with adopting green technologies, particularly for small and medium-sized enterprises (SMEs) that often face resource constraints. In addition, training and capacity-building programs are essential to equip businesses with the necessary skills to effectively implement and manage AI, IoT, and Blockchain technologies. Policymakers should also focus on developing harmonized regulatory frameworks that address data privacy, security, and interoperability issues, especially for Blockchain applications, to build trust and encourage widespread adoption. Furthermore, fostering collaboration through public-private partnerships will be crucial to scaling innovative solutions more rapidly, enabling shared resources and collective action toward achieving SDG 13 and broader sustainability goals. These combined efforts can create a supportive ecosystem where advanced technologies drive meaningful progress in climate action and sustainable business practices.

4.4. Summary of Hypotheses

Table 5. Summary of Hypothesis Testing Results

Hypothesis	**Statement**	**Result**
H1	AI has a positive effect on SDG 13.	Supported
H2	IoT has a positive effect on SDG 13.	Supported
H3	Blockchain has a positive effect on SDG 13.	Partially Supported
H4	Combined adoption produces a synergistic effect.	Supported

Table 5 shows the summary of all four hypotheses tested in this study. The analysis confirms that AI and IoT are the primary drivers of climate action, demonstrating strong and consistent positive effects on achieving SDG 13. Blockchain, while having a positive impact, is only partially supported due to its limited adoption and the presence of barriers such as high costs and regulatory uncertainty. The combined adoption of AI, IoT, and Blockchain produces a synergistic effect, offering the greatest potential for achieving sustainable environmental outcomes by enhancing efficiency, transparency, and overall organizational sustainability performance.

5. MANAGERIAL IMPLICATIONS

The findings of this study offer valuable guidance for managers and business leaders seeking to leverage technological innovations to achieve sustainability objectives, particularly SDG 13 (Climate Action). These implications are divided into several key areas to help organizations implement effective strategies for sustainable transformation.

5.1. Prioritizing AI and IoT Investments

The strong positive effects of AI and IoT indicate that these technologies should be prioritized in sustainability initiatives. AI can be used to optimize operational processes through predictive analytics, energy consumption forecasting, and data-driven decision-making. IoT provides real-time monitoring of energy use, production efficiency, and waste management, enabling managers to identify inefficiencies and implement corrective actions quickly. By integrating AI and IoT, organizations can reduce costs, improve environmental performance, and gain a competitive advantage in eco-conscious markets.

5.2. Strategic Use of Blockchain Technology

Although Blockchain showed a weaker effect compared to AI and IoT, it remains a valuable tool for ensuring transparency and accountability in business operations, particularly in supply chain management. Managers should view Blockchain adoption as a strategic investment to enhance brand reputation and build stakeholder trust. Given the barriers of high costs and regulatory uncertainty, businesses are advised to begin with small-scale pilot projects to evaluate Blockchain's impact and gradually expand its use once benefits are proven.

5.3. Holistic and Integrated Technology Strategy

The results demonstrate that the combined adoption of AI, IoT, and Blockchain produces the most significant sustainability outcomes. Managers should therefore focus on developing integrated technology strategies rather than implementing each innovation separately. For instance, IoT sensors can be used to collect real-time environmental data, which AI systems can analyze for actionable insights, while Blockchain can verify and secure data for transparency. This synergy creates comprehensive solutions that address multiple aspects of climate action simultaneously.

5.4. Building Organizational Capabilities and Partnerships

Technology adoption must be supported by strong organizational capabilities. Managers should invest in workforce training programs to develop digital skills and foster a culture of innovation that encourages experimentation with new technologies. Additionally, collaborations with external stakeholders such as government agencies, NGOs, and technology providers are essential to overcoming barriers and scaling sustainable innovations. By building these capabilities and partnerships, businesses can position themselves as leaders in sustainability while driving long-term value for both the organization and society.

5.5. Long-Term Strategic Positioning

Finally, managers should view sustainable technology adoption not only as a compliance requirement but also as a source of long-term strategic value. Proactive investment in AI, IoT, and Blockchain can help businesses meet regulatory demands, attract environmentally conscious consumers, and differentiate themselves in competitive markets. By aligning sustainability efforts with core business objectives, organizations can contribute meaningfully to global climate action while securing their future growth and resilience.

6. CONCLUSION

This study explored the role of technological innovations specifically AI, the IoT, and Blockchain in achieving Sustainable Development Goal 13 (Climate Action) through sustainable business practices. The findings reveal that AI and IoT are the most influential technologies for driving sustainability initiatives. AI enables businesses to optimize energy consumption and resource management, directly improving efficiency and reducing waste, while IoT provides real-time data for monitoring environmental impact and improving operational decision-making. Blockchain, although having a positive influence, demonstrated a weaker effect due to its lower adoption rate and existing barriers such as cost, technical complexity, and regulatory uncertainty. However, its unique ability to enhance supply chain transparency and ethical business practices makes it a valuable complementary tool. Most importantly, the combined adoption of AI, IoT, and Blockchain showed the strongest impact on SDG 13, emphasizing the importance of an integrated, cross-technology approach to address environmental challenges comprehensively and effectively.

The results provide important implications for both businesses and policymakers. Businesses that adopt AI and IoT can expect improved energy efficiency, waste reduction, and enhanced sustainability outcomes, while early adoption of Blockchain can strengthen transparency and trust within supply chains. To maximize these benefits, organizations must invest in infrastructure, workforce training, and technical expertise to successfully implement and manage these technologies. Policymakers, on the other hand, should create supportive environments through incentives, subsidies, and regulatory frameworks that encourage sustainable technology adoption, particularly among small and medium-sized enterprises (SMEs). Future research should focus on identifying and overcoming barriers to Blockchain adoption, exploring the long-term impacts of technology-driven sustainability, and examining other emerging technologies such as renewable energy innovations and advanced manufacturing systems. Overall, this study highlights that technological innovation, combined with strategic collaboration between businesses and governments, is crucial for accelerating progress toward global climate action and achieving SDG 13.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: KV and HH; Methodology: HH, SW, SN, and WO; Software: SW and KV; Validation: HH and SW; Formal Analysis: HH, WO, and SN; Investigation: SN and KV; Resources: KV; Data Curation: HH and WO; Writing Original Draft Preparation: HH and SN; Writing Review and Editing: HH and SW; Visualization: SW; All authors, HH, SW, SN, WO, and KV, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7.4. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

[1] I. Sasono and M. Aman, "Framework of master data management in banking using consolidation and jaro winkler algorithm," *International Journal of Cyber and IT Service Management (IJCITSM)*, vol. 5, no. 2, 2025.

[2] Ministry of Education, Culture, Research, and Technology. (2024) Digitalisasi pembelajaran percepat pemerataan mutu pendidikan. Accessed: 2025-09-28. [Online]. Available: https://www.kemendikdasmen.go.id/berita/13670-digitalisasi-pembelajaran-percepat-pemerataan-mutu-pendidika

[3] C. Liu, H. Yang, J. Fu, and X. Qian, "Learning trajectory-aware transformer for video super-resolution," in *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, 2022, pp. 5687–5696.

[4] J. Chavez, "Space-time in the study of learning trajectories," *Learning: Research and Practice*, vol. 7, no. 1, pp. 36–53, 2021.

[5] D. E. Rose, J. Van Der Merwe, and J. Jones, "Digital marketing strategy in enhancing brand awareness and profitability of e-commerce companies," *APTISI Transactions on Management*, vol. 8, no. 2, pp. 160–166, 2024.

[6] F. Bensalah, M. P. Daniel, I. Patra, D. S. García, S. Irgasheva, and R. Tsarev, "Implementation of individual learning trajectories in lms moodle," in *Proceedings of the Computational Methods in Systems and Software*. Springer, 2023, pp. 159–174.

[7] A. B. Ellis, "Decentering to build asset-based learning trajectories." *North American Chapter of the International Group for the Psychology of Mathematics Education*, 2022.

[8] S. Tu, R. Frostig, and M. Soltanolkotabi, "Learning from many trajectories," *Journal of Machine Learning Research*, vol. 25, no. 216, pp. 1–109, 2024.

[9] R. Ahli, M. F. Hilmi, and A. Abudaqa, "Moderating effect of perceived organizational support on the relationship between employee performance and its determinants: A case of entrepreneurial firms in uae," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 6, no. 2, pp. 199–212, 2024.

[10] Ministry of Education, Culture, Research, and Technology. (2024) Kemendikdasmen gelar workshop pembelajaran mendalam bagi pimpinan sekolah. Accessed: 2025-09-28. [Online]. Available: https://www.kemendikdasmen.go.id/berita/13675-kemendikdasmen-gelar-workshop-pembelajaran-mendalam-bagi-pim

[11] K. A. Wibawa, I. Payadnya, R. E. Jenaman, D. Safira, G. I. Gunawan, N. L. Lestari, and P. Y. Prawesti, "Preliminary learning design based realistic mathematics education on entrepreneurship arithmetic content in junior high school," 2021.

[12] K. Fenyvesi, C. S. Brownell, J. Sinnemäki, and Z. Lavicza, "Activating creativities by emphasising health and wellbeing: A holistic pedagogical practice from finland," in *Sculpting New Creativities in Primary Education*. Routledge, 2021, pp. 123–145.

[13] V. Agarwal, M. Lohani, A. S. Bist, L. Rahardja, M. Hardini, and G. Mustika, "Deep cnn–real esrgan: An innovative framework for lung disease prediction," in *2022 IEEE Creative Communication and Innovative Technology (ICCIT)*. IEEE, 2022, pp. 1–6.

[14] A. Zulkarnain, N. Achsani, M. Siregar, and I. Beik, "Enhancing accountability in hajj fund governance through regulatory impact analysis and value chain model," *International Journal of Cyber and IT Service Management (IJCITSM)*, vol. 5, no. 2, 2025.

[15] H. Nufus, H. B. Mardikantoro, R. Pristiwati, H. Zainarthur *et al.*, "Empowering edupreneurship through ai-based creative journalism education," *Journal of Computer Science and Technology Application*, vol. 2, no. 2, pp. 12–22, 2025.

[16] D. Septyawati, F. P. Oganda, Y. Durachman, V. T. A. Faturahman, Z. Nanle *et al.*, "Edupreneurship learning framework for improving technological literacy among creativepreneurs," in *2025 4th International Conference on Creative Communication and Innovative Technology (ICCIT)*. IEEE, 2025, pp. 1–6.

[17] T. K. Andiani and O. Jayanagara, "Effect of workload, work stress, technical skills, self-efficacy, and social competence on medical personnel performance," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 5, no. 2, pp. 118–127, 2023.

[18] M. Muthmainnah, A. Al Yakin, M. Massyat, E. Lulaj, and G. E. Bayram, "Developing students' life skills through edupreneurship in the digital era," in *The new digital era: Digitalisation, emerging risks and opportunities*. Emerald Publishing Limited, 2022, pp. 169–190.

[19] S. Shagirbasha, "Journey of an edupreneur—design-thinking approach," *Vikalpa*, vol. 49, no. 2, pp. 121–128, 2024.

[20] F. Sutisna, N. Lutfiani, E. Anderson, D. Danang, and M. Syaidina, "E-commerce and digital marketing strategies: Their impact on startupreneur performance using pls-sem," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 6, no. 2, pp. 215–223, 2025.

[21] B. Salu, G. Markus *et al.*, "Integrating steam and edupreneurship in primary education to improve science literacy and student creativity," *Jurnal Cakrawala Pendas*, vol. 11, no. 3, pp. 657–666, 2025.

[22] R. Sunarjo, T. Pujiati, D. Apriliasari, and M. Hardini, "Digital onboarding in agricultural platforms and its impact on agricultural productivity," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 6, no. 2, pp. 205–214, 2025.

[23] S. T. S. Alfian, F. Ichsanudin, N. Ndruru *et al.*, "Bitcoin and digital currency: Difficulties, open doors and future works," *Blockchain Frontier Technology*, vol. 2, no. 1, pp. 50–57, 2022.

[24] S. Nurhayati, T. Y. Hendrawati, R. Permatasari, Z. A. Shomad, and F. Yuberta, "Digital edupreneurship training for teachers: Fostering innovation and sustainability in education," *International Journal of Community Care of Humanity (IJCCH)*, vol. 2, no. 11, 2024.

[25] S. Watini, L. Magdalena, T. W. Wirjawan, A. Gunawan, D. Julianingsih, and N. Ivanov, "Social media

as a tool for transforming childhood learning mechanisms in edupreneurship," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 1, pp. 109–119, 2025.

[26] C.-L. Mărunţelu, "The edupreneur: Empowering education through entrepreneurial innovation," *Journal of Romanian Literary Studies*, no. 33, pp. 88–94, 2023.

[27] Q. Aini, D. Manongga, U. Rahardja, I. Sembiring, and Y.-M. Li, "Understanding behavioral intention to use of air quality monitoring solutions with emphasis on technology readiness," *International Journal of Human–Computer Interaction*, pp. 1–21, 2024.

[28] N. Santoso, R. Nurmala, and U. Rahardja, "Corporate leadership in the digital business era and its impact on economic development across global markets," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 6, no. 2, pp. 188–195, 2025.

[29] S. Syifauzakia, M. S. Sumantri, N. Dhieni, and S. Wulan, "Fostering professionalism in prospective early childhood teachers through practice-based edupreneurship," *GENIUS: Indonesian Journal of Early Childhood Education*, vol. 6, no. 1, pp. 71–88, 2025.

[30] S. O. Makinde, M. Y. Kolawole'Abdulsalam, and S. O. Rasheedat, "Emerging technology and innovative pedagogy for entrepreneurship education in the digital age," in *HYBRID CONFERENCE*, p. 533.

[31] A. Nuche, O. Sy, and J. C. Rodriguez, "Optimizing efficiency through sustainable strategies: The role of management and monitoring in achieving goals," *APTISI Transactions on Management*, vol. 8, no. 2, pp. 167–174, 2024.

[32] R. Hayati, D. Nurdin, E. Prihatin, and C. Triatna, "Quality analysis of pdca-based edupreneurship in 21st-century higher education," *AL-ISHLAH: Jurnal Pendidikan*, vol. 16, no. 1, pp. 460–475, 2024.

[33] E. Yulianti, M. U. Reksadini, I. Andriyanto, and I. Khafidoh, "Edupreneurship in early childhood education: Teachers' perceptions of entrepreneurship in the digital era," *AWLADY: Jurnal Pendidikan Anak*, vol. 11, no. 1, pp. 92–101, 2025.

[34] A. Kadim, I. Yusnita, A. Sutarman, R. Lesmana, and F. Ramahdan, "Assessing the impact of corporate governance and strategic leadership on economic growth and market stability," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 6, no. 2, pp. 177–187, 2025.

[35] M. Ajokpaniovo, F. A. Okesina, A. O. Awoyemi, A. A. Adegoke, and F. Anyanwu, "Role of counselling in promoting edupreneurship among students as perceived by counsellors in kwara state," *Ilorin Journal of Education*, vol. 45, no. 1, pp. 299–312, 2024.

[36] W. L. Mangundjaya and S. A. Wicaksana, "Edupreneur: Developing boardgame as a product of university entrepreneurial activities," *International Journal of Entrepreneurship and Business Development*, vol. 5, no. 2, pp. 187–197, 2022.

[37] Z. Zainol, G. Brotosaputro, S. Chen, and E. Natasya, "Designing ethical ai systems for sustainable technology development," *ADI Journal on Recent Innovation*, vol. 6, no. 2, pp. 201–211, 2025.

[38] W. Yunita, Y. Rozimela, and Y. Zainil, "Transforming entrepreneurship education through islamic values: A needs assessment at an islamic higher education institution in indonesia," *Nazhruna: Jurnal Pendidikan Islam*, vol. 8, no. 2, pp. 480–495, 2025.

[39] O. L. Badamas, I. O. Ifinju, B. O. Olawuyi, and E. O. Uyanne, "Scaling special education: Challenges and opportunities for edupreneurs," *Ilorin Journal of Education*, vol. 45, no. 1, pp. 178–197, 2024.

[40] F. Putra, M. Khasanah, and M. Anwar, "Optimizing stock accuracy with ai and blockchain for better inventory management," *ADI Journal on Recent Innovation*, vol. 6, no. 2, pp. 190–200, 2025.

[41] H. Syam and H. Nur, "The utilization of monitoring information system which is practically used to improve teacher performance and creativity in the entrepreneurial process at smk," *Proceeding*, vol. 1, no. 2, p. 140, 2022.

[42] E. T. Combatting, "Investigating dynamics of social edupreneurship towards combatting educational marginalization in the mena region," Ph.D. dissertation, Hamad Bin Khalifa University, 2021.

[43] M. Siahaan, R. Sunarjo, R. Sebastian, and S. Wahid, "The role of natural language processing in enhancing chatbot effectiveness for e-government services," *Journal of Computer Science and Technology Application*, vol. 2, no. 1, pp. 65–74, 2025.

[44] B. A. Oludare, "Assessment of edupreneurship skills acquisition among pre-service english language teachers in the 21st century in adeyemi federal university of education, ondo," *Ilorin Journal of Education*, vol. 45, no. 1, pp. 455–468, 2024.

[45] H. Hetilaniar, I. Zulaeha, H. B. Mardikantoro, T. Yuniawan, and N. Lachlan, "Phonological variation technology integration for indonesia cultural preservation and edupreneurship," *Aptisi Transactions on*

Technopreneurship (ATT), vol. 7, no. 1, pp. 158–168, 2025.

[46] D. N. U. Rahmawati, Z. Trinova, and R. A. Indana, "Study of edupreneurship opportunities for students through the scientific entrepreneurs," in *Iqtishaduna International Conference Proceeding*, vol. 1, 2024, pp. 178–182.

[47] A. A. Attah, "Harnessing artificial intelligence for transformative growth in entrepreneurial education: Enhancing experiential learning and innovation," 2025, unpublished manuscript.

[48] E. Agung Rizky, A. Gunawan, M. A. Komara, and M. Madani, "Optimization of machine learning algorithms for fraud detection in e-payment systems," *Journal of Computer Science and Technology Application (CORISINTA)*, vol. 2, no. 1, p. 10, 2025.

[49] Ministry of Education, Culture, Research, and Technology. (2024) Pendidikan bermutu dimulai dari pendidikan karakter sejak dini. Accessed: 2025-09-28. [Online]. Available: https://www.kemendikdasmen.go.id/berita/13655-pendidikan-bermutu-dimulai-dari-pendidikan-karakter-sejak-di

[50] A. Rizky, R. W. Nugroho, W. Sejati, O. Sy *et al.*, "Optimizing blockchain digital signature security in driving innovation and sustainable infrastructure," *Blockchain Frontier Technology*, vol. 4, no. 2, pp. 183–192, 2025.