Integrating Artificial Intelligence and Green Intellectual Capital to Foster Sustainable Development in Higher Education

Farid BEN ABID[1] and Adel BOUMEDJANE[2] and
Taieb ABDELLAOUI[3]

[1] Mohamed Khider University, Biskra BP 145 RP, 07000 ,Algeria , farid.benabid@univ-biskra.dz

[2] Mohamed Khider University, Biskra BP 145 RP, 07000 ,Algeria

[3] Mohamed Khider University, Biskra BP 145 RP, 07000 ,Algeria

Abstract. This paper explores the integration of Green Intellectual Capital (GIC) and Artificial Intelligence (AI) as a strategic pathway for promoting sustainable development in Arab universities. Drawing on contemporary literature, the study develops a conceptual understanding of how the core dimensions of GIC—green human capital, green structural capital, and green relational capital—can be enhanced through AI-enabled technologies. The analysis highlights the role of AI-driven systems, such as big data analytics, decision support systems, and predictive analytics, in strengthening knowledge creation, eco-innovation, and efficient resource management within higher education institutions. By linking AI capabilities with green intellectual assets, universities can improve environmental performance, support data-driven decision-making, and advance smart campus initiatives. The paper argues that the AI–GIC integration acts as a catalyst for sustainability-oriented institutional transformation, aligning digital innovation with environmental responsibility. Finally, the study offers practical implications for higher education leaders and provides a theoretical foundation for future empirical research on AI-enabled green universities in the MENA region.

Keywords: First Artificial Intelligence (AI), Green Intellectual Capital, Sustainable Development, Higher Education Institutions, Smart Campus, Arab Universities, MENA Region.

1 Introduction

Higher education institutions are increasingly challenged to respond to growing environmental concerns, digital transformation, and rising expectations for societal impact. Universities are no longer viewed solely as centers of teaching and research, but also as key actors in advancing sustainable development through knowledge creation, innovation, and responsible resource management. In this context, the concept of Green Intellectual Capital (GIC) has gained prominence as a strategic asset that enables universities to develop environmental capabilities through human expertise, supportive institutional structures, and collaborative external relationships.

At the same time, Artificial Intelligence (AI) has emerged as a transformative technological force reshaping higher education. AI applications—ranging from big data analytics and decision

D. Agti et al. (eds.), *Proceedings of the International Conference on Artificial Intelligence Applications in Business Administration in MENA Region (ICAIABA 2026)*, Advances in Economics, Business and Management Research 393,
https://doi.org/10.2991/978-94-6239-711-8_2

support systems to machine learning and predictive analytics—are increasingly used to enhance academic performance, administrative efficiency, and strategic decision-making. When aligned with sustainability objectives, these technologies offer powerful tools for optimizing resource use, supporting eco-innovation, and enabling smart campus initiatives.

This paper proposes a conceptual perspective on integrating Artificial Intelligence with Green Intellectual Capital to foster sustainable development in universities. By examining the interaction between AI technologies and the three dimensions of GIC—green human, structural, and relational capital—the study highlights how knowledge-based and digital capabilities can be combined to strengthen environmental performance, support data-driven governance, and advance sustainability-oriented transformation in higher education institutions.

2 Artificial Intelligence Technologies

Organizations increasingly integrate AI, big data analytics, and decision support systems to address complex challenges, improving forecasting, environmental performance, and strategic agility.

2.1 Big Data Analytics for Environmental and Operational Data

Big Data Analytics enables data-driven environmental decision-making by converting complex, high-volume data into actionable insights that improve strategic and operational performance [1].

Environmental Monitoring and Management

Data analytics enhances environmental decision-making through early risk detection, accurate prediction, and continuous monitoring, while requiring careful attention to data quality, ethics, and organizational capacity.

Environmental decision-making is closely linked to monitoring and management through several key characteristics:

- ✓ Iterative and adaptive decision-making based on continuous feedback,
- ✓ Long-term objectives supported by short-term actions,
- ✓ Data-driven decision-making that reduces uncertainty,
- ✓ Risk-based approaches and early warning systems,
- ✓ Continuous improvement through feedback loops .

Table 1. Environmental decision-making framework: monitoring and management stages .

Stage	Description
Data collection	Gathering information on environmental issues through field measurements, remote sensing, citizen science, and existing databases
Data analysis	Processing, cleaning, and analyzing data using statistical methods, modeling, and visualization
Decision-making	Selecting environmental management strategies, setting goals, and prioritizing actions based on analyzed data
Management actions	Implementing actions such as pollution control, habitat restoration, resource management, or policy enforcement
Monitoring and evaluation	Assessing the effectiveness of actions through continued monitoring and adjusting strategies as needed

Source. [2]

Overall, the adoption of data analytics enables efficient handling of large datasets from diverse sources, overcoming traditional limitations and supporting evidence-based, adaptive environmental management.

Big Data Analytics and Corporate Environmental Performance:

Corporate environmental performance (CEP) has become a strategic priority as stakeholder pressure drives firms to improve resource efficiency, emissions control, and sustainable supply chains, generating operational and competitive benefits [3] In this context, big data analytics

(BDA) enables CEP by converting large-scale environmental data into actionable insights that enhance monitoring, forecasting, compliance, and proactive environmental decision-making, thereby reducing environmental risks and supporting long-term sustainability [4]

2.2 Decision Support Systems (DSS) for strategic planning

Decision Support Systems (DSS) integrate data, analytical models, and user interfaces to improve organizational decision-making [5] , and recent advances in AI and big data have transformed them into intelligent, adaptive systems. By incorporating machine learning, natural language processing, and predictive analytics, AI-driven DSS enable real-time analysis, anticipatory insights, and proactive strategic planning, thereby enhancing organizational adaptability under uncertainty [6] .

Table 2. Environmental decision-making framework: monitoring and management stages

Component	Role in Decision-Making
Data Acquisition	Collecting relevant, real-time data from multiple sources such as databases and sensors.
Data Processing	Cleaning and structuring data to ensure it is ready for analysis and interpretation.
Machine Learning (ML)	Analyzing historical data to identify trends, predict future outcomes, and learn from past decisions.
Natural Language Processing (NLP)	Enabling the system to understand and process unstructured textual data, such as reports and social media.
Predictive Analytics	Forecasting potential future scenarios to assist with proactive decision-making.
Decision-Making Support	Providing actionable insights and recommendations based on data analysis

Source: [5]

2.3 Machine Learning & Predictive Analytics for Sustainable Decision-Making

Machine learning and predictive analytics support sustainable decision-making by optimizing resource use, reducing environmental impacts, and advancing sustainability goals across various sectors.

Energy Management

Advanced analytics and AI enhance energy management by enabling efficient, low-waste, and accurate energy demand forecasting across energy systems.

Machine Learning Models;

Machine learning provides a unified approach to prediction and decision-making by identifying patterns in data through models such as artificial neural networks and evolutionary algorithms. In energy systems, neural networks are particularly effective at modeling complex relationships and improving forecasting and optimization for sustainable decision-making [7]. As shown in Fig. 1.

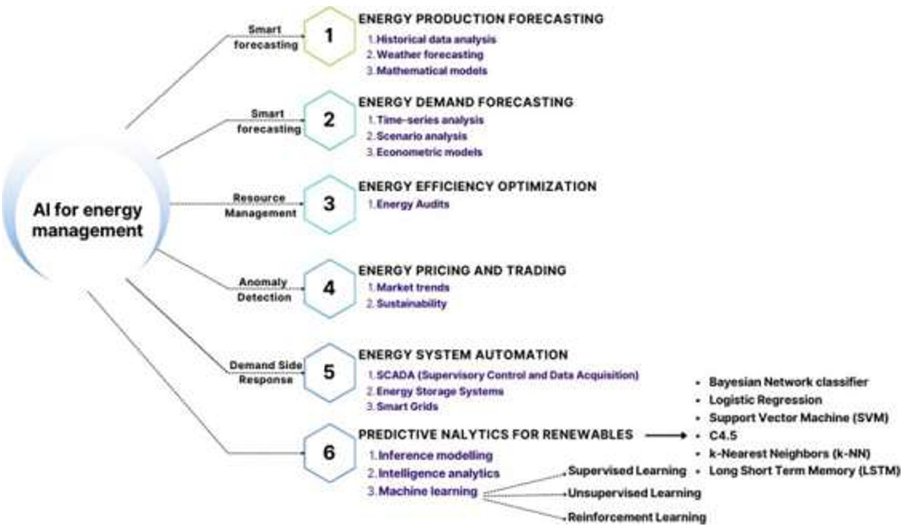

Fig. 1. Taxonomy of artificial intelligence (AI) for energy management is depicted.
Source: [7].

A structured taxonomy of AI for energy management classifies methods, functions, and application domains, clarifying how techniques such as machine learning, deep learning, optimization, and hybrid approaches support forecasting, monitoring, and decision-making across energy systems. This framework highlights AI's contribution to improving efficiency, reliability, and sustainability in modern energy management [7].

Urban and Environmental Planning

Artificial intelligence and predictive modeling enable smart, resilient, and sustainable urban systems through data-driven planning and resource management.

Predictive modelings:

Predictive modeling applies machine learning and AI to forecast outcomes from historical and real-time data, enabling data-driven decision-making across multiple sectors.

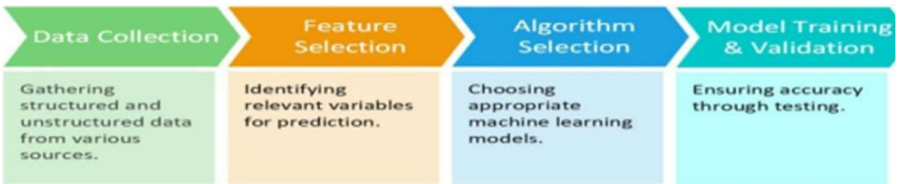

Fig. 2. the stages of predictive modeling in urban development.
Source: [8]

Towards Intelligent Urban Systems: The Role of Predictive Modeling

Predictive modeling enables proactive planning and optimized resource management in smart cities by forecasting key urban risks and demands using real-time and historical data. Integrated with AI, IoT, and big data, it enhances urban efficiency, resilience, and sustainability [7].

3 Green Intellectual Capital (GIC)

Green intellectual capital extends traditional intellectual capital by focusing knowledge and capabilities on environmental protection and green innovation. It is usually decomposed into three interrelated components: green human, green structural, and green relational capital.

3.1 Green Human Capital in Higher Education: Skills, Competencies, and Environmental Knowledge

Green human capital in universities encompasses the environmental knowledge and skills of faculty, staff, and students that support sustainability through interdisciplinary and holistic competencies for addressing complex environmental challenges.

Key Competencies and Skills in Green Human Capital

Green human capital comprises sustainability-oriented knowledge, skills, and values such as environmental awareness, systems thinking, and eco-innovation that enable organizations to achieve long-term environmental and economic value. Developing these competencies in students, including the core sustainability skills identified by UNESCO, is essential for shaping future professionals capable of addressing complex sustainability challenges.

Development and Measurement of Green Competencies

Green competencies are defined as a higher-order construct integrating green knowledge, skills, abilities, attitudes, behaviors, and awareness, with strong empirical validit. Green training plays a central role in developing these competencies and translating green human capital into pro-environmental behavior, resource efficiency, and improved environmental performance [9].

Institutional and Pedagogical Strategies

Effective integration of green human capital in higher education requires institutional commitment and learner-centered pedagogies focused on real-world sustainability. While active learning enhances key competencies, gaps remain in addressing social and partnership dimensions holistically [10].

3.2 Green Relational Capital: Partnerships and collaborations with communities, government, and industry to support eco-initiatives

Green relational capital reflects the strategic value of sustainability-oriented relationships with external stakeholders, enhancing competitiveness and performance through collaboration, knowledge exchange, and co-creation of sustainable solutions in corporate and higher education contexts [9]

Types and Structures of Partnerships

Sustainability innovation thrives through Triple Helix collaboration in living labs, integrating competitiveness, inclusion, and environmental goals in line with the SDGs [11].

Community Partnerships;

University–community partnerships foster reciprocal, participatory collaboration to address local sustainability challenges and enable inclusive, socially responsive innovation [12].

Mechanisms and Benefits

Knowledge & Technology Transfer;

University–industry partnerships boost green innovation through knowledge access and absorptive capacity, supported by social capital that enables effective collaboration across institutional differences [13].

Policy and Governance Support:

Government policy stabilizes sustainable development by reducing uncertainty through regulation, incentives, and coordinated governance, thereby fostering long-term collaboration and enabling sustained socio-economic and environmental impact [14].

Societal Impact:

Open environmental collaborations drive societal impact by enabling technological innovation, business development, and policy evolution, while shaping complex socio-technical systems and environmental transformation at local and regional scales [15].

3.3 Green Structural Capital in Universities: Systems, Infrastructure, Policies, and Technologies for Sustainability

Universities leverage green structural capital to embed sustainability across operations, education, and engagement, amplifying environmental and societal impact .

Key Components of Green Structural Capital

Infrastructure & Operations

Infrastructure and operational initiatives form a core pillar of university sustainability, encompassing energy-efficient buildings, renewable energy, sustainable mobility, and resource conservation, with integrated management and monitoring frameworks enhancing environmental performance and long-term impact across institutional contexts [16].

Policies & Governance

The institutionalization of sustainability in higher education depends on aligned leadership, formal sustainability policies, and dedicated governance structures that provide strategic direction, coordination, and accountability, ensuring continuity and preventing fragmented or short-lived initiatives [17].

Technological Innovation

Digital technologies and data-driven management—leveraging IoT, smart infrastructure, and analytics—enable real-time monitoring, predictive maintenance, and evidence-based decision-making, thereby enhancing operational efficiency, transparency, and resilience while advancing institutional sustainability and alignment with the SDGs [18].

Education & Stakeholder Engagement

Sustainability programs and stakeholder engagement embed sustainability in universities, extending impact beyond campus and highlighting green structural capital differences and challenges.

The following table compares green structural capital in universities, highlighting key institutional differences and sustainability-related challenges.

Table 3. Comparison of green structural capital focus areas, common practices, and key challenges in universities

Focus Area	Common Practices	Key Challenges / Needs
Infrastructure	Energy efficiency, water management, waste reduction, sustainable transport	High implementation costs; need for integrated systems
Policy & Governance	Sustainability offices, institutional policies	Systemic governance approaches; strong leadership commitment
Technology	Smart buildings, IoT applications, digital platforms	Investment requirements; data management capabilities
Education & Engagement	Sustainability curricula, workshops, outreach programs	Broader participation; deeper stakeholder engagement

Source; Adapted from [17] [16].

4 AI–GIC Integration

AI strengthens green intellectual capital by managing knowledge, interpreting environmental data, and delivering strategic insights.

4.1 How AI Enhances Green Intellectual Capital (GIC)

Artificial intelligence strengthens green intellectual capital by enhancing its components and driving green innovation and sustainability performance in firms.

AI-Driven Enhancement of Green Human Capital

AI-enabled training, knowledge management, and analytics enhance employees' environmental competencies by transforming environmental data into actionable insights and supporting evidence-based sustainability decision-making and eco-innovation, thereby strengthening green human capital within organizations [19].

AI Support for Green Structural Capital Development

AI strengthens green structural capital by embedding sustainability into organizational systems through environmental data integration, automated reporting and compliance, and data-driven optimization of processes and business models, thereby institutionalizing sustainable practices and improving environmental performance [20].

AI-Enabled Strengthening of Green Relational Capital

AI strengthens green relational capital by enhancing sustainability-oriented collaboration, transparency, and trust with external stakeholders through data-driven supply chain analytics, ESG reporting, and digital engagement platforms, thereby reinforcing green reputation and long-term eco-innovation partnerships [21].

4.2 Strategic Effects of AI–GIC Integration

Recent studies show that AI's impact on sustainability-oriented innovation is largely mediated by green intellectual capital (GIC), as AI enhances green skills, embeds sustainability in organizational structures, and strengthens stakeholder relationships [22]. AI adoption further drives radical green innovation through advanced analytics and intelligent decision-making, improving environmental and financial performance [23] . Additionally, AI-based environmental analytics enhance ESG data processing and sustainability investment decisions [24], while AI-powered knowledge management reinforces green structural and relational capital, supporting continuous sustainable transformation [25].

5 Sustainable Resource Management: AI supports energy efficiency, waste reduction, and operational optimization

AI enhances energy efficiency, reduces waste, and streamlines operations, often delivering substantial resource savings across sectors..

5.1 How AI Improves Energy Efficiency

Recent evidence shows that AI enhances energy efficiency in industrial, building, and urban systems through forecasting, predictive maintenance, and advanced control, reducing energy use and waste while supporting renewable integration [26]. Green AI architectures further lower energy consumption via resource-aware design (Ranpara, 2025). In buildings, AI- and IoT-based HVAC optimization reduces energy use and CO_2 emissions [27] , while deep-learning smart frameworks improve community-level energy and water management through real-time forecasting and adaptive allocation [28].

The following table synthesizes the empirical impacts of these AI applications, highlighting reported gains in energy and resource efficiency across domains.

Table 4. Summary of reported impacts of AI-driven optimization on energy and resource efficiency across application domains.

Domain / Use Case	Reported Impact
AI-optimized enterprise AI workloads	~30.6% less energy, ~0.7% accuracy loss
Circular economy Green AI (waste & recycling)	25–35% less energy, 28–30% fewer emissions
Smart buildings (AI+IoT)	25–45% less HVAC waste
Smart communities (LSTM/CNN)	18.7% resource, 16.2% cost reduction
Waste logistics in cities	Up to 36.8% less distance, 13.35% cost savings
Wastewater pumping optimization	~12% power savings

Source: Adapted from [26], [28], [29].

5.2 Waste Reduction and Circular Resource Use

Artificial intelligence supports waste reduction and circular resource use by optimizing sorting, recovery, and resource flows. Computer vision improves recycling accuracy [30], while Green AI enhances recovery efficiency and lowers emissions across circular systems [31]. AI-driven water and wastewater optimization further reduces energy and chemical use, strengthening low-emission circular infrastructure [32].

5.3 Operational Optimization

Artificial intelligence advances both efficiency and sustainability by enabling predictive maintenance, intelligent planning, and smart routing that reduce energy use, waste, and downtime while extending asset lifecycles. In manufacturing, embedding resource efficiency into AI optimization enhances sustainability outcomes [26]. At the system level, AI supports real-time resource allocation and demand forecasting, strengthening operational resilience and environmental performance [33].

6 AI-Enabled Eco-Innovation and Smart Campuses: Programs, research, and practice

AI is emerging as a core enabler of eco-innovation, from city-scale "eco-city brain" systems to smart campuses functioning as living laboratories, integrating technological experimentation with governance, policy, and green AI research initiatives .

6.1 AI-Driven Eco-Innovation Programs and Research

Artificial intelligence is increasingly viewed as a key enabler of eco-innovation and sustainability research, supporting integrated urban management, pollution monitoring, and climate resilience in eco-cities. It also enhances environmental governance through evidence-based policy and adaptive regulation. Simultaneously, Green AI initiatives aim to reduce AI's environmental footprint while applying AI to climate mitigation and conservation efforts [24].

6.2 Smart Campus Solutions for Sustainability

Smart Campus 4.0 integrates AI, IoT, and digital twins to operationalize sustainability through real-time monitoring, simulation, and data-driven planning, functioning as living labs aligned with the SDGs [34]. Machine-learning–enhanced campus systems improve efficiency and reduce energy use, while AI-based ecological footprint assessment supports targeted decarbonization. Additionally, AI-driven resource allocation enables predictive planning and sustainability-oriented university governance .

7 Sustainable digital universities

Studies converge on three outcomes: improved environmental performance, enhanced environmental innovation, and smart campus development for sustainability.

7.1 Improved environmental performance at institutional level;

Institutional environmental performance improves when leadership, governance, and operational practices align around sustainability. Green HRM and leadership foster pro-environmental behavior, while structured governance embeds environmental management into policies and monitoring systems. Targeted initiatives such as LED retrofits enhance energy and cost efficiency, and integrated sustainability strategies across environmental, economic, social, and digital dimensions further strengthen institutional performance and resilience [35].

7.2 Enhanced environmental innovation

Sustainability performance depends on the coordinated alignment of human, organizational, and technological resources rather than isolated initiatives. Green orchestration aligns leadership, dynamic capabilities, and green HRM to advance sustainability, while green digital innovation translates this coordination into measurable environmental outcomes. These effects are reinforced by ecodesign and life-cycle assessment approaches and by green technologies such as LED systems that integrate operational efficiency with sustainable campus development .

7.3 Smart, digitally transformed university operations

Sustainability transitions in higher education are increasingly enabled by digital transformation that integrates smart campus management, AI, and data-driven governance to optimize resources and support sustainability-oriented education [36]. When combined with a strong green university culture and leadership commitment, these digital initiatives further enhance environmental, financial, and social performance while accelerating progress toward the SDGs.

8 Knowledge-Driven Decision-Making: Strategic planning and risk management

Knowledge-driven decision-making uses data and analytics to improve strategic choices and manage uncertainty.

8.1 Data-Informed Strategic Planning

The literature conceptualizes data-informed strategic planning as the integration of analytics capabilities, knowledge management, and organizational processes. Business intelligence, ERP, and big data systems enhance planning quality when embedded in managerial routines, while descriptive, predictive, and prescriptive analytics reduce uncertainty and improve resource allocation. Effective use of analytics also requires integration with knowledge management to contextualize insights and support shared understanding, with phased models showing how data capabilities can progressively shape strategic decision-making [37].

Table 5 integrates these strands by illustrating the alignment of analytics, knowledge integration, and organizational change in supporting sustained data-driven strategy.

Table 5. Core strands of data-informed strategic planning in organizations

Focus	Typical tools/approach	Strategic value
Market & operations	BI, big data, AI/ML	Forecast trends, optimize processes
Knowledgeintegration	KM systems, collaboration platforms	Better decision quality, innovation
Organizational change	Culture, skills, governance	Sustained data-driven behavior

Source: Adapted from [38].

8.2 Risk Management and Policy Optimization

The literature conceptualizes risk-informed decision-making as the integration of optimization, simulation, and data-driven learning with strategic and institutional principles to manage uncertainty. Methods such as stochastic optimization, reinforcement learning, and hybrid simulation–optimization frameworks support robust policy design, infrastructure planning, and organizational decision-making under risk. These approaches align with governance principles that emphasize evidence, precaution, and proportionality in regulatory choices, while automated data-driven systems operationalize risk control in digital environments [39].

9 Impacts of AI-enabled sustainability initiatives in universities

Universities are emerging as sustainable innovation hubs that develop AI-skilled talent and drive regional green innovation, supported by strong leadership and capacity building.

9.1 Impacts on universities themselves

More sustainable, efficient, innovative operations

The literature portrays universities as integrated systems where sustainable leadership, environmental innovation, and education-driven knowledge creation collectively shape institutional and regional sustainability outcomes. Sustainable leadership embeds sustainability in governance and innovation , while green campus initiatives and systemic academic changes improve environmental efficiency and resilience; within broader education–innovation–economy–environment systems, these activities generate regional sustainability spillovers. To synthesize these strands, Table 6 summarizes the core impact areas through which sustainability- and AI-oriented initiatives influence university performance and conceptualizes the pathways linking institutional practices to regional green innovation.

Table 6. How sustainability and AI initiatives shape university impacts

Impact area	What research shows
Sustainability &efficiency	Campus greening, renewable energy, and systemic innovation improve environmental and economic performance.
Academic excellence & research impact	Leadership capabilities and excellence schemes boost research output, meta-capacity, and policy influence

Green, AI-literate human capital	Universities instil environmental values and innovation skills; sustainability education shapes future decision-makers
Regional green innovation leadership	Universities act as institutional drivers of regional innovation ecosystems and smart specialization

Source: Adapted from [40].

9.2 AI, green capabilities, and human capital

Recent studies show that AI capabilities strengthen green intellectual capital—human, structural, and relational—which supports sustainability-oriented innovation. AI-driven knowledge systems enhance environmental skills and embed sustainability into organizational routines, while AI-enabled green HRM integrates environmental criteria into recruitment, training, and performance management to develop environmentally conscious talent.

9.3 Regional leadership in green innovation ;

Universities play a central role in regional innovation systems by generating knowledge, developing human capital, and facilitating technology transfer through collaboration with industry and government, thereby supporting regional competitiveness and development . Entrepreneurial universities with sustainability missions further promote green innovation, while university–industry collaboration and AI adoption enhance knowledge diffusion, resource optimization, and regional sustainability outcomes, contingent on organizational readiness and absorptive capacity [41]

10 Conclusion

This paper concludes that integrating Artificial Intelligence with Green Intellectual Capital provides a strategic pathway for universities to achieve sustainable development. AI technologies—such as big data analytics, decision support systems, and machine learning—enhance knowledge processing, strategic planning, and resource efficiency when supported by ethical frameworks and strong governance. At the same time, green human, structural, and relational capital form the foundation for sustainability through skilled people, supportive systems, and effective partnerships. The combined use of AI and GIC enables eco-innovation, smart campus initiatives, and data-driven decision-making, positioning universities—particularly in the MENA region—as leaders in sustainability, innovation, and the development of environmentally aware, AI-proficient graduates.

References

[1] A. Y. s. Sun et B. R. Scanlon, «How can Big Data and machine learning beneft environment and water management: a survey ofmethods, applications, and future directions,» *Environmental Research Letters,* vol. 14, n° %17, pp. 10.1088/1748-9326/ab1b7d, 2019.

[2] M. M. N. ·. P. Ngulube, « Enhancing environmental decision-making: a systematic review of data analytics applications in monitoring and management.,» *Discover Sustainability,* vol. 290, n° %15, pp. https://doi.org/10.1007/s43621-024-00510-0, 20241.

[3] G. A. Ahmed Alyahya, « Improving Corporate Environmental Performance Through Big Data Analytics Implementation: The Role of Industry Environment.,» *Sustainability,* vol. 17, n° %17, p. https://doi.org/10.3390/su17072928, 2025.

[4] P. I. E. I. N. D. &. W. N. D. Elemele Ogu, «Big data analytics in environmental impact predictions: Advancing predictive assessments in oil and gas operations for future sustainability.,» *International Journal of Multidisciplinary Research and Growth Evaluation.,* vol. 5, n° %11, pp. 1203-1208, 2024.

[5] S. S. S. A. R. R. P. M. S. S. K. K. B. B. Anjani Kumar Polinati, «Revolutionizing Information Management: AI-Driven Decision Support Systems for Dynamic Business Environments.,» *Journal of Information Systems Engineering and Management,* vol. 10, n° %135, p. https://doi.org/10.52783/jisem.v10i35s.6010, 2025.

[6] S. A. John Roni Coyanda, «Decision Support System for Strategic Planning in Educational Organization: A Survey. Journal of Computer Networks.,» *Journal of Computer Networks, Architecture and High Performance Computing,* vol. 6, n° %11, pp. 91-97, 2024.

[7] J. C. P. H. C. L. N. V. L. L. M. T. D. D. N. C. Thanh Tuan Le, «Harnessing artifcial intelligence for data-driven energy predictive analytics: A systematic survey towards enhancing sustainability.,» *International Journal of Renewable Energy Development.,* vol. 13, n° %102, pp. 270-293, 2024.

[8] E. E. ,. G. E. a. Z. A. Elda Cina, « The Role of AI in Predictive Modelling for Sustainable Urban Development: Challenges and Opportunities.,» *Sustainability,* vol. 17, n° %111, p. https://doi.org/10.3390/su17115148, 2025.

[9] A. &. M. A. Sarwar, «Analysing the impact of green intellectual capital on environmental performance: The mediating role of green training and development.,» *Technology Analysis & Strategic Management. ,* vol. 36, n° %111, pp. 3357-3370 https://doi.org/10.1080, 2024.

[10] L. L. V. S. A. P. A. F. B. F. F. D. L. B. L. Á. L. M. M. W. M. P. P. A. U. &. L. V. Filho, «University teaching staff and sustainable development: an assessment of competences.,» *Sustainability Science,* vol. 16, n° %18, pp. 101-116, 2020.

[11] H. E. Chunyan Zhou, « Triple Helix Twins: A Framework for Achieving Innovation and UN Sustainable Development Goals.,» *Sustainability,* vol. 13, n° %112, pp. 1-19, 2021.

[12] R. Plummer, S. Witkowski, A. Smits et G. Dale, « Higher Education Institution–Community Partnerships: Measuring thePerformance of Sustainability Science Initiatives.,» *Innovative Higher Education,* vol. 47, n° %11, pp. 135-153, 2021.

[13] Y. D. Y. X. Z. Z. Z. &. D. R. Shen, «Driving green digital innovation in higher education: the influence of leadership and dynamic capabilities on cultivating a green digital mindset and knowledge sharing for sustainable practices.,» . *BMC Psychology, ,* vol. 13, n° %101, pp. Doi https://doi.org/10.1186/s40359-025-02552-z, 2025.

[14] H. E. Chunyan Zhou, «Triple Helix Twins: A Framework for Achieving Innovation and UN Sustainable Development Goals.,» *Sustainability, ,* vol. 13, n° %112, pp. 1-19, 2021.

[15] N. T. T. G. T. &. V. A. Shmeleva, « Open Environmental Collaborations as an Innovation Tool for Sustainable Development: Evidence from Russian Pulp and Paper Industry.,» *Sustainability. ,* vol. 17, n° %13, pp. 1-27, 2025.

[16] A. &. G. Á. Gaspar, «Amaral, A., Rodrigues, E., A review of empirical data of sustainability initiatives in university campus operations.,» *Journal of Cleaner Production,* vol. 250, n° %11, 2020.

[17] R. H. W. M. R. &. O. B. Shawe, «. Mapping of sustainability policies and initiatives in higher education institutes,» .*Environmental Science & Policy.,* vol. 99, n° %1September 2019, pp. 80-88, 2019.

[18] C. T. M. B. I. &. K. M. Veres, «Sustainable Universities: A Bibliometric and Thematic Analysis in Higher Education.,» *Sustainability. ,* vol. 17, n° %15, pp. 1-19, 2025.

[19] M. Petković, «How Does Artifcial Intelligence Influence on Company’s Green Intellectual Capital?.,» *ECOLOGICA,* vol. 30, n° %1112, pp. 541-548, 2023.

[20] J. G. C. N. H. K. D. &. G. J. Schwaeke, «Artifcial intelligence (AI) for good? Enabling organizational change towards sustainability.,» *Review of Managerial Science,* vol. 19, n° %110, pp. 3013-3038, 2025.

[21] A. &. S. A. Al-Khatib, « Green Intellectual Capital and Green Supply Chain Performance: Does Big Data Analytics Capabilities Matter?,» *Sustainability,* vol. 14, n° %116, pp. 1054-1077, 2022.

[22] E. B. L. A. N. &. S. V. Crocco, « Green Innovation as Business Strategy in Small Manufacturing Businesses: Artifcial Intelligence and Blockchain Effects.,» *Business Strategy and the Environment. ,* vol. 34, n° %18, pp. 1207-1219, 2025.

[23] G. I. M. M. J. &. M. A. Biggi, «Green intelligence: the AI content of green technologies.,» *Eurasian Business Review,* vol. 15, n° %13, pp. 803-840, 2025.

[24] V. M.-F. L. C. B. &. A.-B. A. Bolón-Canedo, « A review of green artificial intelligence: Towards a more sustainable future.,» *Neurocomputing ,* vol. 599, n° %1128096, p. https://doi.org/10.1016/j.neucom.2024.128096, 2024.

[25] I. K. J. R. R. M. L. K. V. &. M. H. Kulkov, «Artifcial intelligence - driven sustainable development: Examining organizational, technical, and processing approaches to achieving global goals.,» *Sustainable Development,* vol. 32, n° %13, pp. 2253-2267, 2023.

[26] L. K. S. S. J. S. A. &. M. R. Waltersmann, « Artifcial Intelligence Applications for Increasing Resource Efciency in Manufacturing Companies—A Comprehensive Review.,» *Sustainability. ,* vol. 13, n° %112, pp. 1-26, 2021.

[27] I. M. D. M. A. M. M. B. T. &. T. K. Rojek, «Internet of Things Applications for Energy Management in Buildings Using Artificial Intelligence—A Case Study,» *Energies,* vol. 18, n° %17, pp. 1-28, 2025.

[28] Y. Zhao, «Advancing smart communities with a deep learning framework for sustainable resource,» *PLOS One,* p. https://doi.org/10.1371/journal.pone.0329492, 2025.

[29] S. Dash, «Green AI: Enhancing Sustainability and Energy Efciency in AI-Integrated Enterprise Systems.,» *IEEE Access,* vol. 13, p. https://doi.org/10.1109/access.2025.3532838, 2025.

[30] B. Y. J. C. Z. O. A. F. M. I. I. H. E. R. D. &. Y. P. Fang, « Artifcial intelligence for waste management in smart cities: a review.,» *Environmental Chemistry Letters,* vol. 1, n° %131, pp. doi: 10.1007/s10311-023-01604-3., 2026.

[31] R. Ranpara, «Energy-Efficient Green AI Architectures for Circular Economies Through Multi-Layered Sustainable Resource Optimization Framework,» *Ranpara Discover Sustainability,* vol. 1031, n° %16, pp. DOI:10.1007/s43621-025-01846-x, 2025.

[32] A. I. L. O. M. S. O. O. G. &. E. N. Taiwo, «Development of AI-Powered Optimization Frameworks for Enhancing Chemical Processes in Sustainable and Energy-Efficient Water Treatment,» *International Journal of Scientific Research in Science, Engineering and Technology,* vol. 12, n° %13, p. 663–673, 2025.

[33] P. P. M. &. M. A. Pariso, « AI integration in energy management: enhancing efciency in Italian hospitals.,» *Health Economics Review,* vol. 15, pp. https://doi.org/10.1186/s13561-025-00638-3, 2025.

[34] S. K. A. S. R. G. A. A. S. T. B. I. M. &. P. N. Mahariya, «Smart Campus 4.0: Digitalization of University Campus with Assimilation of Industry 4.0 for Innovation and Sustainability.,» *Journal of Advanced Research in Applied Sciences and Engineering Technology,* vol. 32, n° %11, pp. 120-138, 2023.

[35] A. Almusawy, « The role of sustainability strategies for climate adaptation in enhancing institutional,» *Edelweiss Applied Science and Technology,* vol. 9, n° %15, p. https://doi.org/10.55214/25768484.v9i5.6881, 2025.

[36] T. &. K. E. Shenkoya, « Sustainability in Higher Education: Digital Transformation of the Fourth Industrial Revolution and Its Impact on Open Knowledge.,» *Sustainability,* vol. 15, n° %13, pp. 1-16, 2023.

[37] N. H. S. &. G. H. Kling, «Towards a Data-Driven Organisation: Making Data a Strategic Knowledge Asset in SMEs,» *Journal of the Knowledge Economy,* vol. 16, n° %16, pp. 18424-18442, 2025.

[38] A. &. G. S. Intezari, «Information and reformation in KM systems: big data and strategic decisionmaking. J. Knowl. Manag.,» *Journal of Knowledge Management,* vol. 21, n° %11, pp. 71-91, 2017.

[39] D. S.-H. P. L. P. W. M. T. M. L. W. D. M. J. M. &. C. D. Krewski, «Principles of risk decision-making.,» *Journal of Toxicology and Environmental Health,* vol. 25, n° %11, pp. 250-278, 2022.

[40] L. F. W. B. L. M. C. M.-H. P. Ö. P. &. M. R. Ávila, «Barriers to innovation and sustainability at universities around the world,» *Journal of Cleaner Production,* vol. 164, n° %11, pp. 1268-1278, 2017.

[41] S. Z. Y. W. Z. H. Q. &. P. G. Xia, «Enhancing green innovation through university–industry collaboration and artifcial intelligence: insights from regional innovation systems in China.,» *The Journal of Technology Transfer.,* pp. DOI:10.1007/s10961-025-10232-8 , 2025.