



REVAMPING CLOTHING TECHNOLOGY AND VOCATIONAL EDUCATION THROUGH ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE DEVELOPMENT

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Journal of Research in Vocational and Technical Education (JORVTED), 2026, 5(1), 133–142

Publication history: Received on 23 January 2026; revised on 07 March 2025; accepted on 10 May 2026

Article DOI: <https://doi.org/10.5281/zenodo.20370000>

Abstract

The rapid advancement of Artificial Intelligence (AI) presents significant opportunities for transforming clothing technology and vocational education in ways that support sustainable development. The clothing and textile sector faces persistent challenges related to inefficiency, waste generation, and environmental degradation, while vocational education systems often struggle to keep pace with evolving industry demands and technological innovation. This paper examines the role of AI in revamping clothing technology through intelligent design systems, automated production processes, predictive analytics, and sustainable supply chain management. It also explores how AI-driven tools can enhance vocational education by enabling personalized learning, improving curriculum relevance, and equipping learners with future-ready skills. By integrating AI into both industrial practices and vocational training, a synergistic framework for sustainable development is established—one that promotes resource efficiency, innovation, employability, and green entrepreneurship. The paper concludes that strategic adoption of AI can strengthen the alignment between clothing technology and vocational education, contributing meaningfully to economic growth, environmental sustainability, and social inclusion.

Introduction

Clothing technology and vocational education are both undergoing significant transformation due to advancements in artificial intelligence (AI). Clothing technology has traditionally focused on manual design, pattern making, and linear production systems. Vocational education has often been constrained by static curricula and limited industry alignment. Integrating AI offers a pathway to sustainable development, linking improved industry productivity with quality, accessible education (UN SDG 4, 8, 9). AI's potential spans from intelligent design systems to adaptive learning that prepares learners for real-world challenges. The global drive toward sustainable development has intensified the need for innovation across both industrial and educational sectors. Clothing technology, a key component of the fashion and textile industry, plays a significant role in economic growth but is also one of the largest contributors to environmental degradation due to excessive resource consumption, waste generation, and inefficient production processes (Niinimäki et al., 2020). At the same time, vocational education systems—responsible for developing skilled manpower for industries—often struggle to keep pace with rapid technological advancements and changing labor market demands (UNESCO, 2022). These parallel challenges highlight the need for transformative solutions that can simultaneously enhance industrial efficiency and educational relevance. Artificial Intelligence (AI) has emerged as a powerful tool capable of driving such transformation. AI technologies, including machine learning, computer vision, data analytics, and intelligent automation, are increasingly being applied in clothing technology to improve design accuracy, optimize material usage, streamline manufacturing processes, and support sustainable supply chain management (Kumar et al., 2021). Through predictive analytics and intelligent systems, AI

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enables the fashion and apparel industry to reduce waste, minimize environmental impact, and adopt circular economy practices aligned with the Sustainable Development Goals (SDGs), particularly SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Consumption and Production). In parallel, AI is reshaping vocational education by introducing adaptive learning systems, intelligent tutoring platforms, and data-driven curriculum design. These innovations allow for personalized learning experiences, improved skill acquisition, and better alignment between training outcomes and industry needs (Holmes et al., 2019). For vocational education in clothing technology, AI integration offers opportunities to enhance practical training, foster creativity, and promote sustainable and digital competencies essential for the modern workforce. This aligns strongly with SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth). The convergence of AI, clothing technology, and vocational education presents a strategic pathway for sustainable development. By revamping clothing technology through AI-enabled innovation and strengthening vocational education through intelligent learning systems, societies can develop a skilled workforce capable of driving sustainable industrial practices. This paper therefore explores how artificial intelligence can be effectively harnessed to transform clothing technology and vocational education, emphasizing its role in promoting environmental sustainability, economic resilience, and social inclusion.

Sustainable Development and Artificial Intelligence

Sustainable development focuses on balancing economic growth, environmental stewardship, and social inclusion. In the contexts of clothing technology and vocational education, sustainability requires reducing waste and inefficiencies in industry while equipping learners with relevant skills. AI technologies such as machine learning and computer vision can optimize processes, reduce environmental impacts, and personalize educational experiences. Sustainable development is broadly defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development [WCED], 1987). It is anchored on three interdependent pillars: economic growth, environmental protection, and social inclusion. The United Nations' 2030 Agenda for Sustainable Development further articulates these principles through 17 Sustainable Development Goals (SDGs), emphasizing quality education, decent work, innovation, and responsible production and consumption (United Nations, 2015). Artificial Intelligence (AI) has emerged as a transformative technology with significant potential to accelerate progress toward sustainable development. AI refers to computational systems capable of performing tasks that typically require human intelligence, such as learning, reasoning, problem-solving, and decision-making (Russell & Norvig, 2021). Through machine learning, data analytics, computer vision, and automation, AI enables more efficient use of resources, improved productivity, and evidence-based decision-making across sectors. In the environmental dimension, AI contributes to sustainability by optimizing resource use, reducing waste, and supporting climate action. AI-driven systems are increasingly applied to energy management, waste reduction, supply chain optimization, and circular economy practices, particularly in manufacturing and production industries (Vinueza et al., 2020). By enabling predictive modeling and real-time monitoring, AI helps organizations minimize environmental impacts and improve sustainability performance. From an economic perspective, AI supports sustainable development by enhancing productivity, fostering innovation, and creating new forms of employment. While concerns exist about job displacement, research indicates that AI can also generate demand for new skills and occupations, particularly in technology-driven and green industries (Bughin et al., 2018).

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When integrated into education and training systems, AI can help prepare the workforce for these emerging opportunities, supporting inclusive and resilient economic growth. Socially, AI has the potential to promote inclusion through improved access to education, healthcare, and skills development. In education, AI-powered adaptive learning systems enable personalized instruction, helping learners acquire relevant competencies regardless of background or learning pace (Holmes et al., 2019). However, scholars also caution that ethical considerations—such as data privacy, algorithmic bias, and unequal access to technology—must be addressed to ensure that AI supports, rather than undermines, sustainable development goals (Floridi et al., 2018). Overall, AI represents a powerful enabler of sustainable development when deployed responsibly. Its integration into sectors such as clothing technology and vocational education offers opportunities to reduce environmental impact, strengthen human capital development, and promote innovation-driven sustainability. Strategic governance, ethical frameworks, and capacity building are essential to ensure that AI contributes positively to long-term sustainable development outcomes.

Enhancing Design and Creativity

Design and creativity are central to clothing technology, influencing aesthetics, functionality, market relevance, and sustainability. Traditionally, clothing design has relied heavily on manual sketching, experiential knowledge, and iterative prototyping, which can be time-consuming and resource-intensive. With the integration of Artificial Intelligence (AI), design processes are being redefined through data-driven creativity, generative design tools, and intelligent decision-making systems, enabling more innovative and sustainable outcomes (McCormick, Cagan, & Vogel, 2014). AI enhances creativity in clothing design through tools such as generative algorithms, computer-aided design (CAD), virtual prototyping, and trend forecasting systems. Machine learning models can analyze vast datasets—such as fashion trends, consumer preferences, color palettes, and fabric performance—to generate design suggestions that support designers' creative thinking rather than replacing it (Sun & Zhao, 2018). These AI-assisted systems allow designers and students to explore a wider range of design possibilities while reducing trial-and-error processes and material waste. In vocational education, AI-powered design tools play a crucial role in developing creative competencies among learners. Intelligent design platforms and simulation software enable students to experiment with styles, patterns, and materials in virtual environments, fostering creativity, problem-solving skills, and confidence (Holmes et al., 2019). Research indicates that integrating AI into fashion and clothing design education improves students' digital literacy, design ideation, and innovation capacity, preparing them for technology-driven industries (Jung & Suh, 2024). Moreover, AI contributes to sustainable creativity by optimizing material usage and supporting eco-friendly design decisions. Through predictive modeling and material efficiency analysis, AI systems can suggest designs that minimize fabric waste and encourage the use of sustainable materials, aligning creative outcomes with environmental responsibility (Niinimäki et al., 2020). This approach supports sustainable development by merging creativity with responsible production practices. Overall, AI enhances design and creativity by expanding creative possibilities, supporting skill development in vocational education, and promoting sustainability in clothing technology. When effectively integrated, AI acts as a collaborative creative partner—augmenting human imagination while ensuring efficiency, innovation, and sustainability.



Improving Manufacturing and Sustainability

Manufacturing processes in the clothing and textile industry are among the most resource-intensive and environmentally impactful industrial activities, characterized by high energy consumption, excessive water usage, and significant material waste. Traditional manufacturing systems often rely on linear production models that contribute to overproduction and environmental degradation. The integration of Artificial Intelligence (AI) into clothing manufacturing presents transformative opportunities to improve operational efficiency while advancing sustainable development objectives (Niinimäki et al., 2020). AI enhances manufacturing efficiency through automation, predictive analytics, and intelligent process control. Machine learning algorithms can monitor production lines in real time, detect defects, predict equipment maintenance needs, and optimize workflow scheduling, thereby reducing downtime and material loss (Kumar et al., 2021). In garment manufacturing, AI-driven cutting and pattern-nesting systems improve fabric utilization, minimizing off-cuts and reducing textile waste, which is a critical sustainability concern. From a sustainability perspective, AI supports responsible resource management and circular economy practices. AI-enabled demand forecasting helps manufacturers align production volumes with actual market demand, reducing overproduction and unsold inventory—one of the major contributors to waste in the fashion industry (Bhardwaj & Fairhurst, 2010). Additionally, computer vision and machine learning technologies are increasingly used for automated textile waste sorting and quality assessment, enabling recycling and reuse of garments and materials (Nisa et al., 2025). AI also contributes to energy and water efficiency in textile manufacturing. Intelligent systems can optimize dyeing, finishing, and washing processes by monitoring parameters such as temperature, chemical usage, and water flow, resulting in reduced environmental impact and compliance with sustainability standards (Vinuesa et al., 2020). These innovations align with Sustainable Development Goal 12, which emphasizes responsible consumption and production. Overall, AI-driven manufacturing systems represent a critical pathway for improving sustainability in clothing technology. By enhancing efficiency, reducing waste, and enabling circular production models, AI supports environmentally responsible manufacturing while maintaining competitiveness and economic viability. When integrated with vocational education and workforce training, these technologies further strengthen the industry's capacity to achieve long-term sustainable development.

AI in Vocational Education: Personalized and Adaptive Learning

Vocational education plays a critical role in preparing learners with practical and industry-relevant skills required for employment and sustainable economic development. However, traditional vocational education models often rely on standardized curricula and uniform instructional approaches that may not adequately address individual learners' abilities, learning speeds, or career aspirations. The integration of Artificial Intelligence (AI) into vocational education offers a transformative pathway through personalized and adaptive learning, enabling more responsive, inclusive, and effective training systems (UNESCO, 2022). AI-driven personalized learning systems utilize technologies such as machine learning, learning analytics, and intelligent tutoring systems to collect and analyze learner data, including performance, behavior, and progress. Based on this analysis, learning content, instructional strategies, and assessment methods are dynamically adjusted to meet individual learner needs (Holmes, Bialik, & Fadel, 2019). In vocational education, this approach supports competency-based learning by allowing students to progress at their own pace while mastering specific occupational skills. Adaptive

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learning is particularly valuable in vocational fields where learners possess diverse educational backgrounds and varying levels of technical proficiency. AI-enabled platforms can identify skill gaps and recommend targeted learning activities, simulations, or practical exercises that strengthen learners' competencies (Zawacki-Richter et al., 2019). For example, in vocational programs related to clothing technology, AI systems can personalize instruction in areas such as pattern making, garment construction, digital design, and production planning, thereby enhancing both technical skills and creative capacity. From a sustainable development perspective, AI-supported personalized learning contributes to equitable access to quality education, aligning with Sustainable Development Goal 4. By accommodating different learning needs and reducing dropout rates, adaptive learning systems promote social inclusion and lifelong learning opportunities (Pane et al., 2017). Furthermore, AI-driven upskilling and reskilling initiatives help vocational institutions respond to evolving labor market demands, supporting decent work and economic growth (SDG 8). Despite its potential benefits, the implementation of AI-based personalized and adaptive learning in vocational education is not without challenges. Issues related to data privacy, algorithmic bias, digital infrastructure, and teacher readiness must be carefully addressed to ensure ethical and effective use of AI technologies (Floridi et al., 2018). Capacity building for educators and the development of clear governance frameworks are essential for sustainable adoption. Overall, AI-enabled personalized and adaptive learning represents a powerful innovation in vocational education. By tailoring learning experiences to individual needs and aligning training with industry requirements, AI enhances skill acquisition, learner engagement, and employability, thereby contributing to sustainable development in education and the workforce.

Curriculum Alignment and Skill Development

Vocational education aims to equip learners with practical skills and competencies that meet industry standards and labor market demands. However, curricula in many vocational institutions often lag behind technological advancements, resulting in skill gaps and misalignment with employer requirements (UNESCO, 2022). Artificial Intelligence (AI) offers a transformative approach to curriculum alignment and skill development by enabling data-driven decision-making, predictive analysis, and real-time adaptation of training programs to evolving industry needs. AI can analyze labor market trends, job postings, and industry requirements to inform curriculum design. By identifying emerging skills, AI systems help educational institutions adjust learning modules, integrate new technologies, and prioritize competencies that are in high demand (Holmes, Bialik, & Fadel, 2019). In the context of clothing technology, AI tools can guide vocational institutions to include modules on digital textile design, AI-assisted pattern making, sustainable material use, and smart manufacturing processes, ensuring that graduates possess relevant and up-to-date skills. In addition to curriculum design, AI enhances skill development through personalized and adaptive learning pathways, intelligent simulations, and performance analytics. Learners can practice technical tasks in virtual environments, receive immediate feedback, and monitor their progress in real time. Such AI-driven platforms not only support mastery of foundational skills but also cultivate advanced competencies, such as problem-solving, innovation, and sustainable practice (Zawacki-Richter et al., 2019). This ensures that vocational education produces a workforce capable of meeting both current and future industry requirements. Furthermore, AI-enabled skill development supports green and sustainable practices by embedding environmental awareness into technical training. For example, AI simulations can demonstrate how design choices affect material waste, energy consumption, or production efficiency, allowing students to develop eco-conscious



competencies that align with Sustainable Development Goals 4 (Quality Education) and 8 (Decent Work and Economic Growth) (Vinuesa et al., 2020). Despite these benefits, successful AI integration into curriculum alignment and skill development requires careful planning, teacher training, and investment in digital infrastructure. Ethical considerations, such as data privacy and inclusivity, must also be addressed to ensure equitable access to AI-enhanced learning (Floridi et al., 2018). Overall, AI provides vocational education institutions with the tools to continuously adapt curricula, enhance skill development, and produce graduates who are industry-ready, technologically competent, and sustainability-conscious.

Intersection: Clothing Technology and Vocational Education – AI as a Catalyst for Sustainable Entrepreneurship

The convergence of clothing technology and vocational education presents a unique opportunity to harness Artificial Intelligence (AI) as a driver of sustainable entrepreneurship. Clothing technology encompasses the design, production, and distribution of garments, while vocational education equips learners with practical skills for employment and innovation. Integrating AI into this intersection enables learners and entrepreneurs to develop sustainable, resource-efficient, and market-relevant clothing solutions (Niinimäki et al., 2020). AI supports sustainable entrepreneurship in clothing technology by enhancing innovation, efficiency, and environmental responsibility. Intelligent design tools, generative algorithms, and virtual prototyping systems allow entrepreneurs and learners to explore novel design concepts, optimize material usage, and reduce waste during production (Sun & Zhao, 2018). Predictive analytics and market intelligence powered by AI help identify consumer preferences, emerging trends, and potential business opportunities, enabling informed decision-making and competitive advantage (Kumar et al., 2021). This aligns with the principles of circular economy by promoting responsible production and consumption, reducing overproduction, and minimizing environmental impact (Vinuesa et al., 2020). In vocational education, AI fosters entrepreneurial competencies by providing personalized learning experiences, adaptive skill development, and hands-on simulations of real-world business scenarios. For instance, learners in clothing technology programs can engage in AI-assisted production planning, sustainable sourcing, and digital marketing exercises, preparing them to launch eco-conscious start-ups or small enterprises (Holmes et al., 2019; Zawacki-Richter et al., 2019). By integrating AI into practical training, vocational institutions cultivate innovation, problem-solving, and decision-making skills essential for sustainable entrepreneurship. Furthermore, AI facilitates scalable and inclusive entrepreneurship by lowering entry barriers for resource-constrained learners and communities. Cloud-based AI platforms, virtual prototyping tools, and online marketplaces allow small-scale entrepreneurs to design, produce, and distribute sustainable garments without heavy upfront investment (Nisa et al., 2025). This not only promotes economic empowerment but also contributes to social inclusion and sustainable livelihoods, supporting Sustainable Development Goals 4 (Quality Education), 8 (Decent Work and Economic Growth), and 12 (Responsible Consumption and Production) (United Nations, 2015). In conclusion, AI serves as a catalyst at the intersection of clothing technology and vocational education, fostering sustainable entrepreneurship by combining technical innovation, practical skill development, and environmental responsibility. When integrated thoughtfully, AI empowers learners and entrepreneurs to create economically viable, socially inclusive, and environmentally sustainable ventures in the fashion and textile industry.



Opportunities: AI Integration in Clothing Technology and Vocational Education

The integration of Artificial Intelligence (AI) into clothing technology and vocational education offers a multitude of opportunities to advance sustainability, innovation, and skill development. AI serves as a transformative tool that not only enhances learning and production processes but also contributes to the broader goals of sustainable development (Vinueza et al., 2020).

1. Innovation in Design and Creativity

AI empowers designers and learners to explore new creative possibilities. Generative design algorithms, virtual prototyping, and intelligent design tools allow the rapid development of innovative garment designs while minimizing trial-and-error processes (Sun & Zhao, 2018). In vocational education, learners can engage with AI-assisted design platforms to experiment with styles, patterns, and materials, fostering creativity, problem-solving, and design thinking skills (Holmes, Bialik, & Fadel, 2019).

2. Enhanced Skill Development and Personalized Learning

AI enables personalized and adaptive learning, tailoring vocational training to individual learners' abilities, pace, and learning preferences. Intelligent tutoring systems and adaptive modules allow learners to acquire both foundational and advanced technical skills in clothing technology efficiently (Zawacki-Richter et al., 2019). Personalized learning ensures learners can progress based on competency rather than fixed schedules, promoting mastery of practical skills and improving employability.

3. Sustainable and Efficient Manufacturing

AI facilitates sustainable clothing production through predictive analytics, optimized resource allocation, and waste reduction. Smart production planning, AI-driven pattern nesting, and automated quality control improve efficiency while minimizing material waste and energy consumption (Niinimäki et al., 2020; Kumar et al., 2021). This supports environmentally responsible practices in the fashion industry, aligning with Sustainable Development Goal 12 (Responsible Consumption and Production).

4. Data-Driven Curriculum and Industry Alignment

AI systems can analyze labor market trends, consumer preferences, and industry requirements to inform curriculum design and vocational training priorities. By integrating AI insights into curriculum planning, institutions can ensure graduates acquire skills that are relevant, industry-ready, and sustainable (UNESCO, 2022). This creates a direct link between education, entrepreneurship, and employment opportunities.

5. Promotion of Sustainable Entrepreneurship

AI enables learners and graduates to launch eco-conscious ventures by providing tools for digital design, market analytics, and virtual prototyping. Small-scale entrepreneurs can design and produce garments sustainably, reaching global markets without heavy upfront costs (Nisa et al., 2025). AI thus supports inclusive economic growth, skill-based entrepreneurship, and environmentally responsible business practices.

6. Policy Development and Strategic Planning

For educators and policymakers, AI provides actionable insights for governance, resource allocation, and ethical deployment in vocational institutions. By leveraging AI analytics, policies can be designed to enhance access, equity, and quality of education while integrating sustainability principles into both teaching and production practices (Floridi et al., 2018; Vinueza et al., 2020).



In summary, AI integration offers unprecedented opportunities to revamp clothing technology and vocational education, fostering creativity, personalized skill development, sustainable production, entrepreneurship, and policy innovation. By strategically leveraging these opportunities, educational institutions and industry stakeholders can contribute to sustainable development, economic growth, and inclusive education.

Challenges in Revamping Clothing Technology and Vocational Education through AI for Sustainable Development

While the integration of Artificial Intelligence (AI) into clothing technology and vocational education offers significant opportunities, several challenges must be addressed to ensure effective, equitable, and sustainable implementation. Understanding these challenges is critical for policymakers, educators, and industry stakeholders aiming to harness AI for skill development, innovation, and sustainable practices (Floridi et al., 2018).

1. Digital Infrastructure and Resource Limitations

Many vocational institutions, especially in developing regions, lack the digital infrastructure required for AI integration. Limitations include insufficient internet connectivity, outdated hardware, and lack of AI-enabled software platforms. Without reliable infrastructure, learners cannot access AI-based tools for design, production simulation, or personalized learning (UNESCO, 2022). Additionally, small-scale institutions may struggle to afford high-cost AI technologies, creating inequities in access to AI-enhanced vocational training.

2. Educator Preparedness and Training

Effective AI integration requires educators to possess digital literacy, data analysis skills, and the ability to facilitate AI-driven learning. Many vocational educators have limited exposure to AI tools and lack confidence in integrating them into teaching and assessment (Holmes, Bialik, & Fadel, 2019). Continuous professional development and training programs are necessary, but they often face budgetary, logistical, and time-related constraints.

3. Data Privacy, Security, and Ethical Concerns

AI systems rely on collecting and analyzing learner data to provide personalized learning and adaptive assessments. This raises concerns about data privacy, cybersecurity, and ethical use of sensitive information. Inappropriate data handling or biased algorithms may compromise student trust, reinforce inequalities, and lead to unethical decision-making (Floridi et al., 2018; Zawacki-Richter et al., 2019).

4. Curriculum and Industry Alignment

Although AI can support dynamic curriculum adaptation, many vocational programs still struggle to align their curricula with industry needs and emerging technologies. In clothing technology, this may lead to skill gaps where graduates are unprepared for modern, AI-enhanced production methods, smart textiles, or sustainable manufacturing practices (Kumar et al., 2021). Continuous monitoring of labor market trends and updating curricula remains a significant challenge.

5. Resistance to Change

Introducing AI into established vocational programs often faces resistance from educators, administrators, and even learners. Concerns about technology replacing human roles, disrupting traditional pedagogical methods, or increasing workload can impede adoption (Holmes et al., 2019).



Overcoming resistance requires careful change management, awareness campaigns, and demonstration of AI's value in improving learning and sustainable outcomes.

6. Sustainability and Ethical Implementation

While AI can support sustainable practices in clothing technology, its own energy consumption and carbon footprint may undermine environmental benefits if not managed properly (Vinuesa et al., 2020). Institutions must consider the environmental impact of running AI systems and promote energy-efficient technologies to ensure that AI contributes positively to sustainable development goals.

In summary, the successful integration of AI into clothing technology and vocational education requires addressing infrastructure, educator readiness, ethical concerns, curriculum relevance, and resistance to change. Tackling these challenges is essential for creating inclusive, sustainable, and future-ready vocational education systems that support innovation, skill development, and responsible entrepreneurship.

Conclusion

The integration of Artificial Intelligence (AI) into clothing technology and vocational education represents a transformative approach to advancing sustainable development. AI has demonstrated significant potential to enhance design innovation, manufacturing efficiency, personalized learning, curriculum alignment, skill development, and entrepreneurship. By enabling data-driven decision-making, adaptive instruction, and intelligent production planning, AI empowers learners, educators, and entrepreneurs to meet contemporary industry demands while promoting environmental and social responsibility (Holmes, Bialik, & Fadel, 2019; Vinuesa et al., 2020). However, the full potential of AI is contingent upon addressing critical challenges, including digital infrastructure gaps, educator readiness, data privacy, ethical concerns, curriculum misalignment, and resistance to change (Floridi et al., 2018; UNESCO, 2022). Without strategic planning and supportive policies, AI adoption may exacerbate inequalities and fail to achieve sustainable outcomes. Overall, when implemented thoughtfully, AI acts as a catalyst for sustainable transformation in clothing technology and vocational education. It supports inclusive and innovative learning, sustainable production practices, and entrepreneurial skill development, all of which are essential for meeting the Sustainable Development Goals (SDGs) related to quality education, decent work, innovation, and responsible consumption (United Nations, 2015).

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