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APPLICATION OF HUMAN-CENTERED APPROACH IN INDUSTRY 5.0 – THE ROLE OF SMART LEARNING FOR SUSTAINABLE ECONOMIC GROWTH

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Abstract. This paper examines how the human-centered vision of Industry 5.0 can be implemented through smart learning that combines Artificial Intelligence (AI) personalization, interactivity, gamification and Virtual Reality (VR)/ Augmented Reality (AR) training to mitigate skill gaps. Enhanced learning methods strengthen critical thinking, creativity, ethical decision-making and human–machine collaboration skills. Case evidence from industry and academia confirm reduced training time, higher knowledge retention and improved workforce sustainability, linking human capital development to sustained economic growth. Digital transformation of training systems enables their effective and scalable adoption. These findings position smart learning as both a technological solution and a strategic investment.

Keywords: Industry 5.0, smart learning, human-centered manufacturing, artificial intelligence, immersive learning (VR/AR), gamification

JEL: L86, D83, J24

Introduction

The transition from Industry 4.0 to Industry 5.0 represents a fundamental rethinking of the industrial environment. While Industry 4.0 focuses on integrating automation, the Internet of Things, and AI to increase the efficiency of manufacturing processes, Industry 5.0 builds on this foundation by prioritizing human connection, sustainability, and resilience (Tóth et al., 2023). This change extends manufacturing automation beyond

mere efficiency, aligning it with worker well-being and environmental responsibility. Industry 5.0 is an overarching concept that aims to contribute to the prosperity of businesses and people while taking into account environmental aspects and placing special emphasis on the well-being of employees in the industry (Briken et al., 2023). This reorientation towards humans and the environment is a qualitative change that requires new approaches to industrial growth. If the definition of industrial progress already includes human well-being and sustainability, then the means to achieve this, namely the development of the human workforce, should be seen as a fundamental, fundamental element of industrial policy and economic development.

As a result of this transition, there is a significant skills gap among employees. Industry 5.0 is redefining the roles of the workforce, shifting responsibilities to managing complex, creative, or strategic decisions (Rikala et al., 2024). Classifying a large proportion of work tasks in manufacturing as unattractive, dirty, or dangerous, including linking them to accidents and injuries to employees, makes it difficult for companies to operate. stresses the critical need to automate these tasks, allowing people to upskill. Employees are expected to need higher skills in creative problem-solving, data analysis, and programming. Moreover, basic human skills such as empathy, active listening, emotional intelligence, collaborative problem-solving, ethical decision-making, and systems thinking are becoming leading skills in complex business environments. Traditional learning methods often fail to develop these new, higher skills. The lack of these skills in a human-centered industrial model directly affects productivity, innovation, and adaptability. If humans are central to value creation and collaboration with machines, then inadequately prepared workers become an obstacle. Qualification gaps not only pose a challenge for human resources but play the role of a serious economic vulnerability for businesses seeking industrial growth (Rikala et al., 2024). For this reason, investing in advanced training methodologies such as smart, interactive and gamified learning becomes an economic necessity to mitigate this vulnerability and ensure sustainable industrial growth and achieve competitiveness for firms. Similar learning models based on artificial intelligence and personalized interaction have proven effective in developing the skills and adaptability of human capital (Bhutoria, 2022).

This paper highlights intelligent interactive and gamified learning as a critical factor in achieving the human-centered goals of Industry 5.0 and broader economic development. These methodologies represent not just pedagogical tools, but strategic investments to sustain firms in a dynamic economic environment and maintain a competitive advantage (Tóth et al., 2023; Bhutoria, 2022).

Industry 5.0 as a paradigm based on human-machine cooperation

Industry 5.0 represents an evolutionary step that goes beyond the efficiency of Industry 4.0 to place an emphasis on human-machine interaction, worker well-being, and environmental sustainability (Ali et al., 2025).

Basic principles of Industry 5.0

Industry 5.0 builds on the technologies of Industry 4.0, but shifts the focus from automation alone to people, collaboration and long-term sustainability. The principles below outline how this new approach is taking shape in modern industry.

Human-machine cooperation

In contrast to Industry 4.0, which focused on replacing manual tasks with automation, Industry 5.0 emphasized collaboration between humans and machines (Roveda, 2024). This includes the emergence of "cobots" (collaborative robots) designed for human-robot interaction in a shared space. Cobots are a catalyst for the evolution of human skills (Zafar et al., 2024). Their introduction doesn't just free people from routine, dirty, or dangerous tasks. It requires a new set of human skills for effective collaboration. Humans need to understand how to interact with these intelligent machines, operate them, and use them (Roveda, 2024). This includes skills such as problem-solving when automation crashes, creative decision-making when cobots offer options, and even empathy for the machine's "needs" in a collaborative environment. This implies a higher cognitive load and the need for adaptive, contextually aware human responses. The introduction of cobots fundamentally changes the role of humans, making the development of these advanced collaboration skills and cognitive skills paramount to operational efficiency and safety, directly related to the need for advanced training methodologies.

Workers' welfare

The growing focus is on ergonomic work environments, mental health, and worker safety in production systems (Ali et al., 2025). This is a direct response to the fact of the large relative share of production tasks that are related to boring, dirty or dangerous, as well as a high proportion of employees have suffered injuries at work.

Environmental sustainability

Reducing the environmental impact is imperative, with a focus on energy-efficient machinery, waste reduction processes, and sustainable materials (Ali et al., 2025).

Changing the roles of the workforce and focusing on basic human skills

In the context of the transition to Industry 5.0, workers' responsibilities shift to making complex, creative, or strategic decisions as they collaborate with AI-driven systems (Ali et al., 2025). The most valuable workers combine technical knowledge with strong human qualities. So-called basic human skills include empathy and active listening, emotional intelligence, collaborative problem-solving, ethical decision-making, and systems thinking (Zafar et al., 2024). They are no longer "soft skills", but skills for survival in complex business environments. Employees

need higher skills in creative problem-solving, data analysis, and computer programming. Furthermore, as technology facilitates basic tasks, human differentiation must come from areas where machines cannot yet excel. These basic human skills are precisely those non-routine, complex, and context-specific abilities that lead to higher-order value creation: fostering customer loyalty through personal connections, increasing team productivity through trust and communication, accelerating innovation through safe experimentation, and ensuring success in change through employee engagement and consent. This elevates these skills from "soft" to "strategic" (Ali et al., 2025). Companies that invest in the development of these human capabilities will adapt faster and grow more sustainably, gaining a significant competitive advantage in the era of Industry 5.0. This provides a strong economic case for investing in training methods specifically designed to cultivate such skills.

The role of artificial intelligence and advanced technologies in supporting human capabilities

Artificial intelligence and advanced technologies in Industry 5.0 are not designed to replace humans, but to support them (Asad et al., 2023). AI systems can perform real-time risk assessments to ensure worker safety (Zafar et al., 2024). Intelligent systems are used to develop biocompatible materials and recycling processes. Connectivity is crucial for learning, teaching, and understanding between humans and machines.

The concept of human digital twins requires an understanding of human cognitive abilities, preferences, and the pursuit of optimized human-machine interaction (Wang et al., 2024; Armiyanova, 2025). If Industry 5.0 aims to optimize human-machine synergy at such a granular level, then training systems must also meet this goal. Traditional learning, which does not take into account the specificities of learners and is implemented in the same way for everyone, does not possess the necessary efficacy.

Smart learning, which includes personalization, is data-driven, and adaptive, represents a complement to the concept of the digital twin of the human as it allows learning pathways tailored to individual cognitive profiles, ensuring maximum efficiency and integration with advanced industrial systems (Asad et al., 2023). This connects the technological advancements of Industry 5.0 directly with the need for advanced training methodologies.

Digital transformation of workforce development – from e-learning to smart learning

The evolution related to education in Higher Education Institutions (HEIs), as well as corporate training, is essential to meet the needs of Industry 5.0. Traditional e-learning methods typically rely on lectures, presentations, and written materials, resulting in passive learning and lower engagement (Gligorea et al. 2023). The lack

of real-time feedback and personalized pathways can become an obstacle to the effective development of learners and the improvement of their skills (Wang et al., 2024). Often, traditional teaching methods are perceived as repetitive, and learners do not see a direct connection between what they learn and what they need to apply in their real work at a later stage. They lack practical application and relevance to their daily responsibilities.

Scope of smart learning – integration of artificial intelligence, data analytics and personalized pathways

Digital transformation of human resources (HR) is the complete integration of digital technologies into all aspects of HR operations. This approach fundamentally reimagines how HR departments deliver value to employees and to the organization as a whole. Intelligent learning goes beyond simply digitizing existing processes; it fundamentally reimagines how HR delivers value through the use of AI and data-driven platforms (Wang et al., 2024). It includes modernizing legacy systems, implementing data-driven HR platforms, using AI, and creating seamless digital experiences for employees.

Smart learning, as a component of HR's digital transformation, uses artificial intelligence to quickly create learning content and track learning performance, enabling personalized learning experiences (Gligorea et al., 2023; Dimcheva & Hristova, 2025). Data-driven insights provide real-time metrics of workforce competencies and performance trends, allowing for more informed decisions related to the talent discovery strategy that firms typically create and execute. This allows for tailored training programs to meet individual employee needs, providing the most applicable and productive training opportunities.

Digital transformation is fundamental for both HEIs training (Milev & Dimitrov, 2025) and HR training. It provides the basic technological and strategic framework needed to scale up smart learning. It's not just about automating HR tasks, it's about building the ecosystem that supports advanced, data-driven learning. Without this broader digital transformation of human resources, smart learning initiatives may remain isolated or lack the necessary data integration and strategic alignment to be truly effective. It transforms human resources into a strategic partner in workforce development.

The role of interactivity – increasing engagement, critical thinking, and application in the real world

Interactive learner assessment places employees in realistic scenarios, assessing not only knowledge but also their critical thinking, problem-solving, and social skills abilities. Interactivity methods include role-playing, simulations, and gamified components (Capatina et al., 2024). Interactivity is critical to cultivating the complex core human skills that are necessary to survive in complex business envi-

ronments, such as collaborative problem-solving, ethical decision-making, and systems thinking. As Industry 5.0 requires humans to manage increasingly complex, creative, or strategic decisions while machines engage in routine tasks, learning must provide real-world application and human connection, emphasizing experiential learning methods over traditional classroom learning.

Immersive environments such as VR and AR have the opportunities to significantly change learning and assessment (Dimitrov, 2025) by placing learners in realistic scenarios that enhance the learning experience, for example when interacting with cobots in a shared workspace (Wang et al., 2024). This type of simulation allows employees to implement decision-making under pressure and develop confidence in managing new technologies while minimizing the risk of real-world mistakes.

Interactive tests offer instant feedback that is critical to growth, allowing employees to identify areas for improvement and adjust their strategies. This fosters a growth mindset and stimulates taking responsibility for one's own learning. Fast feedback loops are particularly important in dynamic industrial environments, where adaptability and rapid error correction are essential for operational resilience.

They are designed to be fun and engaging, engaging staff and encouraging active participation, making learning a motivating activity. They also encourage collaboration between employees and promote social interaction and teamwork through group challenges and competitive elements. Platforms like Kahoot! 360 offers interactive questions, brainstorms, and polls to make learning dynamic and impactful during live sessions, as well as small-volume self-study materials for flexible learning. This embedding of learning in daily work creates an integrated learning ecosystem that supports continuous development and organizational adaptability.

A practical application of interactive learning technologies confirms that these approaches are not only theoretical constructions but are already implemented in industrial practice. A corporate case study published by DiSTI demonstrates the use of a VR-based training system for gas turbine maintenance in the context of Siemens Power Generation Services. Technicians are trained in a virtual environment using digital twins of real equipment, where they can simulate malfunction scenarios, perform repairs, and make decisions in a risk-free setting. Siemens reports a significant reduction in training time (up to 30%) and improved retention of procedural knowledge compared to conventional instructional methods[1].

As a real-world example, Boeing implemented AR-based training and support systems for its aircraft wiring and assembly operations. Using smart glasses and line-of-sight instructions, technicians achieved first-pass accuracy of approximately 88% and reduced task time by around 20 %, while error rates dropped significantly (Boland, 2022).

In addition to corporate case studies, academic publications demonstrate tangible impacts of immersive training in industrial settings. In aviation maintenance, AR

has been shown to guide technicians through complex procedures and reduce human error during training and operations (De Crescenzio et al., 2011). In industrial assembly, controlled studies report that VR-supported training improves learning outcomes compared to traditional on-the-job methods (Wolfartsberger et al., 2023). These findings are reinforced by a recent systematic review synthesizing multiple VR training deployments in assembly/disassembly, which highlights gains in time-to-competence and error reduction (Di Pasquale et al., 2024).

Gamification in Learning – Psychological Principles and Benefits for Motivation and Retention

Gamification incorporates elements and principles of game design (points, badges, leaderboards, challenges, and rewards) into training programs to increase employee engagement, motivation, and knowledge retention (Gómez Niño et al., 2024). Psychological principles that work include:

Activating the reward system – it stimulates the release of dopamine associated with pleasure and motivation. This principle uses the knowledge of neuroscience to increase motivation in gamification. When a learner achieves a goal (e.g., earning a point or a badge), the brain immediately releases dopamine, a neurotransmitter associated with pleasure and anticipation. This dopamine spike creates a positive association between learning and feelings of satisfaction. In this way, the learner is stimulated to repeat the action, which leads to further engagement and effective assimilation of the material.

Goal-oriented behaviour – this principle is based on the fact that people are naturally motivated when they have a clear direction and a measurable goal. In gamification, goals (e.g., reaching the next level or earning a badge) should be concrete and realistically achievable, and necessarily in the short to medium term. This reduces the feeling of overload and creates a sense of progress and competence. that his efforts lead to visible results, this maintains engagement and encourages the continuation of learning.

Competitive spirit – the principle takes advantage of inherent competitiveness as a powerful external motivator. Through the introduction of leaderboards and scoring systems, learners are encouraged to compare and surpass the performance of their colleagues. This not only stimulates efforts to achieve high results but also adds a social element to the learning process. Ultimately, the desire to be at the forefront or improve one's own rank leads to higher engagement and faster absorption of the learning content.

Real-time feedback loops – this principle emphasizes the fact that in order to be effective, learning requires an immediate evaluation of actions. In the context of gamification, when a learner makes a decision or completes a task, the system must immediately provide information about whether it was right or wrong (Gligorea et al., 2023). This quick feedback allows the learner to immediately correct their

behavior and consolidate the right skills without making mistakes. In this way, the action-result-correction cycle is accelerated, which is essential for rapid and lasting skill development.

A sense of autonomy and control – the principle is that people are more motivated when they have control over their learning process. Through gamification, learners can progress at their own pace, choose the order of tasks themselves, or decide when to move on to the next level. Giving them choice and flexibility strengthens their sense of ownership and responsibility for learning. This inner sense of autonomy leads to deeper engagement and more success retention of acquired knowledge and skills.

Following these psychological principles are an important prerequisite for the successful implementation of gamification.

The benefits of using gamification include increasing engagement and productivity, fostering social interaction and teamwork, stimulating creativity and innovation, improving learning outcomes, and providing shorter feedback loops. It increases knowledge retention and speeds up the time to achieve competence. Gamification is especially appealing to tech-savvy employees, including millennials and Gen Z.

Interactive assessments and gamification provide 'immediate feedback' on learners' actions. In a dynamic environment and an ever-changing labour market, the ability to quickly identify learning gaps and adapt skills is crucial for organisational and individual resilience. Which is fundamentally linked to continuous learning and accepting new challenges. It's more than just knowledge retention; It's about fostering a flexible and responsive workforce. Thus, the feedback mechanisms inherent in intelligent interactive and gamified learning directly contribute to the growth of the workforce's capabilities for continuous adaptation, which is very essential for successful market positioning and crisis management (Gómez Niño et al., 2024).

In Table 1. the advantages of the proposed training methodologies over traditional approaches to basic indicators are outlined. The comparison shows the positive effects that the implementation of smart learning achieves in relation to the aspects indicated.

Table 1. Comparison between traditional e-learning and smart, interactive and gamified learning

Indicator	**Traditional e-learning**	**Intelligent interactive and gamified learning**
Commitment and motivation	Low, passive learning, relies on lectures and materials	High, uses game elements (points, badges, leaderboards) to motivate and engage
Knowledge retention	Limited due to passivity	Elevated through active participation and immediate feedback

Skills development	Basic knowledge transfer, less application of skills	Develops critical thinking, problem-solving, social skills through simulations and role-playing
Feedback mechanism	Deferred, often after completion of a module	Real-time, instantaneous, allows for instant adjustments
Personalization	Limited, does not adapt to individual needs	High, data-driven, adjusts to individual needs and pace
Adaptability to complex environments	Limited, does not imitate real circumstances	High, involves learners in realistic scenarios (with VR/AR tools)
Cultivating "human skills"	Does not support the development of empathy, cooperation, ethical decision-making	Encourages collaboration, creativity, ethical thinking through interactive challenges
Performance impact	Gradually, often difficult to measure	Directly, leads to increased productivity and efficiency

Strong emphasis should be placed on increased engagement and motivation through the application of gamified elements, the achievement of a higher level of knowledge retention, and especially the development of critical thinking. The results presented in the table support linking the impact of pedagogical advantages to the achievement of real business results.

Leveraging Intelligent Interactive and Gamified Learning to Develop Skills in Industry 5.0

Intelligent interactive and gamified learning offers powerful tools to develop the specific skills needed for Industry 5.0 that traditional methods cannot provide (Capatina et al., 2024; Rahiman et al., 2023). Intelligent learning through the tools of interactive and gamified approaches meets the specific skill requirements in Industry 5.0. They help solve **problems collaboratively** through interactive role-playing scenarios and group challenges in gamified environments, helping to develop this skill (Altomari et al., 2023). Trainings can include confidence-building exercises and systems thinking applied to real-world business challenges. Gamification, on the other hand, gamification can support ethical **decision-making** training. In this case, gamified scenarios may include asking ethical issues that allow for a solution to be sought in a safe environment and the possibility of quick feedback on the choice made. Interactive simulations can introduce employees to complex ethical cases, allowing them to see the direct consequences of their choices. This experience-based approach is key to developing ethical intelligence and decision-making that aligns with corporate values. The other effect is related to the **development of critical thinking and systems thinking** (Gómez Niño et al., 2024). Through immersive simulations and interactive assessments, it is critical and systems thinking that is effectively enriched. They expose learn-

ers to complex relationships between different business areas, fostering a deeper understanding of the overall picture.

Their impact on creative **problem-solving** training is important. Gamified learning encourages creativity and innovation through open-ended challenges and tasks. AI-powered tools can help identify skills gaps and create targeted development plans, aligning with the need for data analytics skills (Capatina et al., 2024).

The development in learners of the skills necessary to build Industry 5.0 is based on the following opportunities:

Improving human-machine collaboration skills – The emergence of cobots necessitates training for human-robot interaction in a shared space (Asad et al., 2023). Immersive environments such as VR and AR can revolutionize assessment and training by placing employees in realistic scenarios that enhance the learning experience with machines. creative or strategic decisions while machines deal with routine or dangerous tasks.

Accelerating upskilling and reskilling for new technologies and redefined roles – digital transformations of human resources accelerate the process of acquiring skills and professional development, fostering a culture of organizational adaptability. Gamification increases knowledge retention and accelerates all important measurements of time to achieve competence. content allow for the rapid development and implementation of learning materials. Customised learning pathways and self-learning options allow employees to acquire new skills effectively and at their own pace. Instant feedback loops accelerate skill acquisition and mastery. The emphasis on real-time feedback loops and instant feedback in gamified interactive learning is crucial for the rapid adaptation of skills and error correction in dynamic industrial environments (Baah et al., 2024). This is in stark contrast to traditional, delayed feedback mechanisms and directly supports the flexibility required for Industry 5.0.

Fostering a culture of continuous learning and adaptability – gamification and interactivity turn learning into enjoyable activities, fostering constant engagement. The desire for development and growth, cultivated by immediate feedback, encourages employees to take responsibility for their own learning process. This continuous development prepares the workforce for new challenges in an ever-changing job market. needs real-world application and human connection, advocating experiential learning methods over classroom learning.

Conclusion

Industry 5.0 marks the transition from technological automation to human-centered, intelligent cooperation between humans and machines. In this context, skills development through smart, interactive and gamified learning is becoming a key factor for the sustainable development of the workforce. These approaches integrate artificial intelligence, data and immersive technologies (VR/AR) to provide

personalized, motivating and effective learning that develops critical thinking, creativity and collaboration – skills on which success in Industry 5.0 depends.

The digital transformation of human resources creates the necessary infrastructure for the implementation of smart learning, turning training from an administrative process into a strategic tool for organizational development. Interactivity and gamification enhance engagement and knowledge retention, while AI personalization accelerates the acquisition of competencies and increases employee adaptability.

In summary, intelligent interactive and gamified learning is not just a pedagogical innovation, but a strategic necessity. It combines human potential with technological power, ensuring sustainability, productivity and competitiveness in the transition to Industry 5.0.

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NOTES

1. https://www.disti.com/case-study/siemens-digitalizes-maintenance-training-for-its-global-workforce

REFERENCES

Ali, I., Nguyen, K. & Oh, I. (2025). Systematic literature review on Industry 5.0: current status and future research directions with insights for the Asia Pacific countries. *Asia Pacific Business Review*, 1 – 28. https://doi.org/10.1080/13602381.2025.2452877.

Altomari, L., Altomari, N. & Iazzolino, G. (2023). Gamification and soft skills assessment in the development of a serious game: design and feasibility pilot study. *JMIR serious games*, *11*(1), e45436. https://doi.org/10.2196/45436.

Armiyanova, M. (2025). Features, challenges andIssues of digital twins. *The Law and the Business in the Contemporary Society: Conference Proceedings of the 7-th National Scientific Conference, 18 October 2024 г.*, 316 – 325.

Asad, U., Khan, M., Khalid, A. & Lughmani, W. A. (2023). Human-centric digital twins in industry: A comprehensive review of enabling technologies and implementation strategies. *Sensors*, *23*(8), 3938. https://doi.org/10.3390/s23083938.

Baah, C., Govender, I., & Subramaniam, P. R. (2024). Enhancing learning engagement: A study on gamification's influence on motivation and cognitive load. *Education Sciences*, *14*(10), 1115. https://doi.org/10.3390/educsci14101115.

Boland, M. (2022, August 23). Case study: Boeing streamlines aircraft assembly with AR. *AR Insider*. https://arinsider.co/2022/08/23/case-study-boeing-streamlines-aircraft-assembly-with-ar/.

Briken, K., Moore, J., Scholarios, D., Rose, E. & Sherlock, A. (2023). Industry 5 and the human in human-centric manufacturing. *Sensors*, *23*(14), 6416. https://doi.org/10.3390/s23146416.

Bhutoria, A. (2022) Personalized education and artificial intelligence in the United States, China, and India: A systematic review using a human-in-the-loop model. *Computers and Education: Artificial Intelligence, 3*, 100068. https://doi.org/10.1016/j.caeai.2022.100068.

Capatina, A., Juarez-Varon, D., Micu, A. & Micu, A. E. (2024). Leveling up in corporate training: Unveiling the power of gamification to enhance knowledge retention, knowledge sharing, and job performance. *Journal of Innovation & Knowledge*, *9*(3), 100530. https://doi.org/10.1016/j.jik.2024.100530.

De Crescenzio, F., Fantini, M., Persiani, F., Di Stefano, L., Azzari, P. & Salti, S. (2011). Augmented reality for aircraft maintenance training and operations support. *IEEE Computer Graphics and Applications*, *31*(1), 96 - 101. https://doi.org/10.1109/MCG.2011.4.

Di Pasquale, V., Cutolo, P., Esposito, C., Franco, B., Iannone, R., & Miranda, S. (2024). Virtual reality for training in assembly and disassembly tasks: A systematic literature review. *Machines*, *12*(8), 528. https://doi.org/10.3390/machines12080528.

Dimcheva, G. & Hristova, S. (2025). Advantages and disadvantages of artificial intelligence in Bulgarian education. *Industrial Growth Conference 2024*, 269 – 280. https://doi.org/10.53656/igc-2024.25.

Dimitrov, K. (2025). Enhancing higher education with virtual and augmented reality: Unleashing the power of digital educational technology. *Industrial Growth Conference 2024*, 281 – 289. https://doi.org/10.53656/igc-2024.29.

Gligorea, I., Cioca, M., Oancea, R., Gorski, A. T., Gorski, H. & Tudorache, P. (2023). Adaptive learning using artificial intelligence in e-learning: A literature review. *Education Sciences*, *13*(12), 1216. https://doi.org/10.3390/educsci13121216.

Gómez Niño, J. R., Árias Delgado, L. P., Chiappe, A. & Ortega González, E. (2025). Gamifying learning with AI: A pathway to 21st-century skills. *Journal of Research in Childhood Education*, *39*(4), 735 – 750. https://doi.org/10.1080/02568543.2024.2421974.

Milev, P. & Dimitrov, K. (2025). A new fontier: The convergence of emerging digital technology and higher education. *Industrial Growth Conference 2024*, 357 – 365. https://doi.org/10.53656/igc-2024.36.

Rahiman, H. U., Kodikal, R. & Suresh, S. (2023). Game on: Can gamification enhance productivity? *F1000Research*, *12*, 818. https://doi.org/10.12688/f1000research.131579.2.

Rikala, P., Braun, G., Järvinen, M., Stahre, J. & Hämäläinen, R. (2024). Understanding and measuring skill gaps in Industry 4.0-A review. *Technological Forecasting and Social Change*, *201*, 123206. DOI: 10.1016/j.techfore.2024.123206.

Roveda, L. (2024). Human-robot collaboration in Industry 5.0: a human-centric AI-based approach. *Frontiers in Robotics and AI*, *11*, 1511126. https://doi.org/10.3389/frobt.2024.1511126.

Tóth, A., Nagy, L., Kennedy, R., Bohuš, B., Abonyi, J. & Ruppert, T. (2023). The human-centric Industry 5.0 collaboration architecture. *MethodsX*, *11*, 102260. https://doi.org/10.1016/j.mex.2023.102260.

Wang, B. Zhou, H., Li, X., Yang, G., Zheng, P., Song, C., Yuan, Y., Wuest, T., Yang, H., & Wang, L. (2024a). Human digital twin in the context of Industry 5.0. *Robotics and Computer-Integrated Manufacturing*, *85*, 102626. https://doi.org/10.1016/j.rcim.2023.102626.

Wang, S., Wang, F., Zhu, Z., Wang, J., Tran, T. & Du, Z. (2024b). Artificial intelligence in education: A systematic literature review. *Expert Systems with Applications*, *252*, 124167. https://doi.org/10.1016/j.eswa.2024.124167.

Wolfartsberger, J., Zimmermann, R., Obermeier, G. & Niedermayr, D. (2023). Analyzing the potential of virtual reality-supported training for industrial assembly tasks. *Computers in Industry*, *147*, 103838. https://doi.org/10.1016/j.compind.2022.103838.

Zafar, M. H., Langås, E. F. & Sanfilippo, F. (2024). Exploring the synergies between collaborative robotics, digital twins, augmentation, and industry 5.0 for smart manufacturing: A state-of-the-art review. *Robotics and Computer-Integrated Manufacturing*, *89*, 102769. https://doi.org/10.1016/j.rcim.2024.102769.

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