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## Engineering Education in the Age of Industry 5.0: Mapping the Inner Development Goals to the Graduate Attributes and Professional Competencies Framework

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### ABSTRACT

#### BACKGROUND & CONTEXT

Engineering education is undergoing a significant transformation to meet the demands of Industry 5.0, which emphasizes a human-centric, sustainable, and resilient approach to innovation. Traditionally, curricula have focused on technical competencies, but there is growing recognition of the need to integrate personal and interpersonal skills to address complex global challenges, as outlined in the UN Sustainable Development Goals (SDGs).

#### PURPOSE OR GOAL

This paper is part of a broader research project that explores the role of the Inner Development Goals (IDGs) for transformative engineering education, and as a framework for developing personal capacities needed to navigate complex sustainability challenges.

#### APPROACH OR METHODOLOGY

In this preliminary exploratory study, we examine the alignment between the Graduate Attributes and Professional Competencies (GAPC) and the IDGs framework. The research employs a qualitative, deductive methodology, systematically mapping GAPC attributes to the five IDG dimensions to identify areas of convergence and gaps.

#### OUTCOMES

The GAPC dimensions primarily align with the IDG pillars of Thinking, Collaborating, and Being, while the Relating and Acting pillars receive insufficient attention despite their importance. Elements of human-centricity are also insufficiently addressed.

#### CONCLUSIONS

To effectively support Industry 5.0, education must prioritize developing mindsets and skills for sustaining cross-boundary partnerships and interdisciplinary co-creation—competencies currently missing from tertiary education curricula.

#### KEYWORDS

Inner Development Goals (IDGs), Industry 5.0, Graduate attributes.

## Introduction

Engineering education has historically placed insufficient emphasis on non-technical skills in their curricula. However, the complexities of the 21st century highlight the need to redefine the role of engineering education to address broader societal challenges, including those outlined in the UN Sustainable Development Goals (SDGs), and the transition to Industry 5.0, which is a “more transformative view of growth that is focused on human progress and well-being” (European Commission, 2021).

In 2021, the International Engineering Alliances (IEA), in collaboration with UNESCO and the World Federation of Engineering Organizations (WFEO), revised the Graduate Attributes and Professional Competencies (GAPC) to emphasize “sustainable development, diversity and inclusion and ethics” (IEA, 2021, p.1). Around the same time, a new initiative focused on transformative change for sustainable development was developed by an international group of interdisciplinary scholars – the Inner Development Goals (IDGs), a framework focused on cultivating personal and collective capacities that enable individuals to navigate complex global challenges.

### The Graduate Attributes and Professional Competencies (GAPC)

The GAPC (IEA, 2021) outline the skills, knowledge, and abilities expected of engineers, technologists, and technicians. This international benchmark ensures that engineering education and professional competence meet consistent global standards, facilitating accreditation and professional recognition across different countries. In 2021, the GAPC was reviewed by a joint working group of the International Engineering Alliance (IEA) and the World Federation of Engineering Organisations (WFEO), with the support of the UNESCO (United Nations Educational, Scientific and Cultural Organizations). The underlying motivation for reviewing the GAPC was to address the needs of emerging technologies and engineering fields, incorporate new teaching methods, and emphasise values such as sustainable development, diversity, inclusion, and ethics. This updated international benchmark was approved by Accords (Washington Accord, Dublin Accord, Sydney Accord) and Agreements (International Professional Engineers Agreement, International Engineering Technologists Agreement, APEC Engineer Agreement, Agreement for International Engineering Technicians).

The benchmark defines graduate attributes as “a set of individually assessable outcomes that are the components indicative of the graduate’s potential to acquire competence to practice at the appropriate level” (IEA, 2021, p.3). These attributes “are stated generically and are applicable to all engineering disciplines” (IEA, 2021, p.5). On the other hand, the professional competencies profiles describe “the elements of competence necessary for performance that the professional is expected to be able to demonstrate in a holistic way at the stage of attaining registration” (IEA, 2021, p.6).

Both graduate attributes and professional competence profiles are differentiated for three types of roles (engineers, technologists and technicians) in eleven dimensions: 1. engineering knowledge, 2. problem analysis, 3. design/development of solutions, 4. investigation, 5. tool usage, 6. the engineer and the world, 7. ethics, 8. Individual and collaborative teamwork, 9. communication, 10. project management and finance, and 11. lifelong learning. The scope of this paper is the role of the engineer.

### What is Industry 5.0 and what skills are required from engineers

Industry 5.0 represents the next evolution in industrial systems, building on the technological foundations of Industry 4.0 (automation, IoT, AI, and robotics) but shifting focus toward three interconnected core values: human-centricity, sustainability, and resilience (European Commission, 2021a; Rame et al., 2024). Unlike its predecessor, this approach envisions an industry that transcends efficiency and productivity as primary goals emphasizing its role and contribution to society (Onyemelukwe et al., 2023; Xu et al., 2021). This concept originates

from the European Commission's initiative to integrate social and environmental priorities into technological innovation, transitioning from a technology-centric approach to a holistic, system-oriented framework (Xu et al., 2021).

Industry 5.0's focus on human-centricity, resilience, and sustainability necessitates a transformation in engineering education. It extends beyond traditional training to integrate multidisciplinary skills, lifelong learning, and advanced digital tools, equipping engineers for the evolving industrial landscape (Suganya et al., 2024; Trstenjak et al., 2025). For instance, human centricity in Industry 5.0 requires engineers with skills such as empathetic design thinking, human-machine interface design, user-centered design, empathy and emotional intelligence, ethical decision-making, and proficiency in collaboration tools and technologies. Achieving resilience in Industry 5.0 will require engineers with expertise in adaptive problem-solving, risk management, predictive analytics, agile systems design, cybersecurity, crisis management, and supply chain resilience. Sustainability skills for driving eco-efficiency and circularity in Industry 5.0, require proficiency in sustainable design thinking, expertise in green engineering, the circular economy, and competence in environmental impact assessment. However, competencies that cut across the three interconnected core values of Industry 5.0 include systems thinking, digital fluency & technical adaptability, continuous learning, interdisciplinary collaboration and leadership & advocacy.

In Industry 5.0, engineers need to blend technological expertise with a strong emphasis on human values, resilience, and sustainability, empowering workers while addressing the evolving skills and training needs of employees. This is essential for the European Commission's foresight exercise system, which seeks to predict environmental risks, identify opportunities, and enhance the quality of policy development (European Commission, 2021b).

### The Inner Development Goals

The Inner Development Goals (IDGs) were publicly launched in May 2021 as framework to address the slow progress in achieving SDGs by 2030. While the SDGs provide a comprehensive framework for tackling global sustainability issues, the IDGs recognize that achieving these goals requires not only technical and policy solutions but also a shift in mindset, leadership, and human capability. This framework emphasizes that holistic human development requires a balance between inner growth - through the development of transversal skills - and external progress. This way, the IDGs complement the SDGs by ensuring that individuals possess the necessary attitudes, values, and skills to lead change effectively.

The IDGs framework includes five dimensions (IDG, 2021):

1. **Being.** Relationship to Self: Inner compass, Integrity and Authenticity, Openness and Learning Mindset, Self-awareness, Presence.
2. **Thinking.** Cognitive Skills: Critical thinking, Complexity awareness, Perspective skills, Sense-making, Long-term orientation and visioning.
3. **Relating.** Caring for Others and the World: Appreciation, Connectedness, Humility, Empathy and Compassion.
4. **Collaborating.** Social Skills: Communication skills, Co-creation skills, Inclusive mindset and intercultural competence, Trust, Mobilization skills.
5. **Acting.** Driving change: Courage, Creativity, Optimism, Resilience.

Recent research underscores the importance of integrating IDGs into engineering education, suggesting that they offer a novel conceptualization of the skills and attitudes needed to address complex and socially relevant issues in engineering (Polmear, 2024). By incorporating IDGs into engineering education, institutions can better prepare students to become well-rounded professionals capable of addressing real-world challenges and driving positive social change.

Scientific, social, and industry-driven paradigm shifts have profoundly altered mindsets, skills, and capabilities across generations. The Industrial Revolution is an example of such a shift, transforming education, apprenticeships, research, innovation practices, and the nature of work. The Inner Development Goals (IDGs) and Industry 5.0 share a common focus on human-centric approaches. Both emphasize the importance of developing inner skills and well-being to address sustainable development challenges. IDGs aim to cultivate personal growth and transformative education, while Industry 5.0 prioritizes worker well-being and integrating technology in a way that enhances human capabilities. Together, they advocate for a holistic approach to progress that values both technological advancements and human development. This exploratory study is guided by the following research question: How does the GAPC address the skills required for Industry 5.0 in relation to the IDGs?

## Methodology

This exploratory study investigates potential enhancements to existing benchmarks in engineering education by examining the alignment between two conceptual frameworks: the Graduate Attributes and Professional Competencies (GAPC) and the Inner Development Goals (IDGs). Adopting a qualitative, deductive methodology, the research systematically analyzes how engineering graduate attributes correspond with broader developmental goals and emerging industrial paradigms.

The analysis began with the extraction of engineering competencies from the GAPC framework (Table 1, Columns 1 and 2). These attributes were then examined through the lens of the IDGs, which encompass five core dimensions: Being, Thinking, Relating, Collaborating, and Acting. A deductive coding strategy was employed, using these predefined IDG categories to guide the mapping process.

Each GAPC attribute was assessed for its relevance and alignment with the IDG dimensions and the thematic priorities of Industry 5.0—namely, human-centricity, resilience, and sustainability (Table 1, Columns 3 and 4). This comparative framework enabled the identification of areas where current engineering education benchmarks align with or diverge from the competencies emphasized by the IDGs and Industry 5.0.

## Preliminary Results

### Alignment with the IDGs

The engineering graduate attribute profile is mostly focused on the cognitive skills of (*Thinking*), social skills (*Collaborating*) and relationship to self (*Being*) of the IDGs (Table 1).

**Table 1: Mapping Industry 5.0 and IDG's in the GAPC**

| Dimension                                                                                             | Engineering Graduate                                                                                                                                                                                                                | IDGs Pillar(s) and exemplar skills                                                | Industry 5.0 and exemplar notes |
|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|---------------------------------|
| <b>Engineering Knowledge:</b><br>Breadth, depth and type of knowledge, both theoretical and practical | <b>WA1:</b> Apply knowledge of mathematics, natural science, computing and engineering fundamentals, and an engineering specialization as specified in WK1 to WK4 respectively to develop solutions to complex engineering problems |                                                                                   |                                 |
| <b>Problem Analysis:</b>                                                                              | <b>WA2:</b> Identity, formulate, research literature and analyze <i>complex</i>                                                                                                                                                     | <b>IDG Thinking –</b><br><i>Critical thinking:</i> Skills in critically reviewing | Sustainability.                 |

|                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                     |
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| Complexity of analysis                                                                                                                                                                                            | engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences with holistic considerations for sustainable development (WK1 to WK4)                                                                                                                         | the validity of views, evidence and plans (IDG, 2021, p.15); <i>Complexity awareness</i> : Understanding of and skills in working with complex and systemic conditions and casualties (IDG, 2021, p.16)                                                                                                                                               |                                                                                                                                                                                                                                                                     |
| <b>Design/development of solutions:</b><br>Breadth and uniqueness of engineering problems i.e., the extent to which problems are original and to which solutions have not previously been identified and codified | <b>WA3:</b> Design creative solutions for complex engineering problems and design systems, components or processes to meet identified needs with appropriate considerations for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations as required (WK5) | <b>IDG Acting –</b><br><i>Creativity</i> : Ability to generate and develop original ideas, innovate and being willing to disrupt conventional patterns (IDG, 2021, p.23)<br><b>IDG Thinking –</b><br><i>Perspective skills</i> : Skills in seeking, understanding and actively making use of insights from contrasting perspectives (IDG, 2021, p.16) | Sustainability.                                                                                                                                                                                                                                                     |
| <b>Investigation:</b><br>Breadth and depth of investigation and experimentation                                                                                                                                   | <b>WA4:</b> Conduct investigations of complex engineering problems using research methods including research-based knowledge, design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions (WK8)                                                                              | <b>IDG Thinking –</b><br><i>Critical thinking</i> : Skills in critically reviewing the validity of views, evidence and plans (IDG, 2021, p.15); <i>Sense-making</i> : Skills in seeing patterns, structuring the unknown and being able to consciously create stories (IDG, 2021, p.17)                                                               |                                                                                                                                                                                                                                                                     |
| <b>Tool Usage:</b><br>Level of understanding of the appropriateness of technologies and tools                                                                                                                     | <b>WA5:</b> Create, select and apply, and recognize limitations of appropriate techniques, resources, and modern engineering and IT tools, including predictions and modelling, to complex engineering problems (WK2 and WK6).                                                                                                         | <b>IDG Thinking –</b><br><i>Critical thinking</i> : Skills in critically reviewing the validity of views, evidence and plans (IDG, 2021, p.15)                                                                                                                                                                                                        | <b>Human-Centricity:</b><br>appropriate usage of technology – “as a means to empower and (ethically) enhance workers, thus generating greater productivity and well-being on the workplace through meaningful interactions of humans and machines.” (EC, 2023, p.7) |

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|-------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>The Engineer and the World:</b> Level of knowledge and responsibility for sustainable development</p> | <p><b>WA6:</b> When solving complex engineering problems, analyze and evaluate sustainable development impacts to: society, the economy, sustainability, health and safety, legal frameworks and the environment (WK1, WK5, and WK7).</p>           | <p><b>IDG Being – Inner Compass:</b> Having a broad scope of awareness that also leads to a motivation to care for and contribute to the welfare or something much larger than oneself. This larger whole can be constructed in different ways: humanity, the global ecosystem, or particular large-scale issues, such as climate change, environmental problems, public health, human rights, etc. (IDG, 2021, p.13)</p>                              | <p><b>Sustainability:</b> focus on economic and social dimensions of sustainability, in addition to the environment (EC, 2023, p.8).</p> |
| <p><b>Ethics:</b> Understanding and level of practice</p>                                                   | <p><b>WA7:</b> Apply ethical principles and commit to professional ethics and norms of engineering practice and adhere to relevant national and international laws. Demonstrate an understanding of the need for diversity and inclusion (WK9).</p> | <p><b>IDG Being – Inner Compass:</b> Having a deeply felt sense of responsibility and commitment to values and purposes relating to the good of the whole; <i>Integrity and Authenticity:</i> A commitment and ability to act with sincerity, honesty and integrity . (IDG, 2021, p.13)</p>                                                                                                                                                            | <p><b>Human-centricity:</b> “respect for human agency and self-determination, transparency” ((EC, 2023, p.7)</p>                         |
| <p><b>Individual and Collaborative Team Work:</b> Role in and diversity of team</p>                         | <p><b>WA8:</b> Function effectively as an individual, and as a member or leader in diverse and inclusive teams an in multi-disciplinary, face-to-face, remote and distributed settings (WK9).</p>                                                   | <p><b>IDG Collaborating – Inclusive mindset and Intercultural competence:</b> Willingness and competence to embrace diversity and include people and collectives with different views and backgrounds (IDG, 2021, p.21); <i>Co-creation skills:</i> Skills and motivation to build, develop and facilitate collaborative relationships with diverse stakeholders, characterized by psychological safety and genuine co-creation (IDG, 2021, p.20).</p> | <p>Human-centricity.</p>                                                                                                                 |

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| <b>Communication:</b><br>Level of communication according to type of activities performed                | <b>WA9:</b> Communicate effectively and inclusively on complex engineering activities with the engineering community and with society and large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, taking into account cultural, language, and learning differences. | <b>IDG Collaborating – Communication skills:</b> Ability to really listen to others, to foster genuine dialogue, to advocate own views skilfully, to manage conflicts constructively and to adapt communication to diverse groups (IDG, 2021, p.20); <i>Inclusive mindset and Intercultural competence:</i> Willingness and competence to embrace diversity and include people and collectives with different views and backgrounds (IDG, 2021, p.21) |                                                                                                                                                                                                   |
| <b>Project Management and Finance:</b><br>Level of management required for differing types of activities | <b>WA10:</b> Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.                                                                                         | <b>IDG Collaborating – Mobilization skills:</b> Skills in inspiring and mobilizing others to engage in shared purposes (IDG, 2021, p.22)                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                   |
| <b>Lifelong learning:</b><br>Duration and manner                                                         | <b>WA11:</b> Recognize the need for, and have preparation and ability for 1) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change (WK8).                                                                                     | <b>IDG Being – Openness and Learning mindset:</b> A capacity to be open to learning, reevaluation and be curious about alternative ways of perceiving and interpreting various issues (IDG, 2021, p.14)<br><br><b>IDG Thinking – Critical thinking:</b> Skills in critically reviewing the validity of views, evidence and plans (IDG, 2021, p.15)                                                                                                    | <b>Resilience:</b> “the prioritisation of versatile skills, which could be applied to new uses in case of a sudden need to adapt; the constant re-training of workers on the job” (EC, 2023, p.8) |

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WA = Washington Accord Attribute; WK = Washington Accord Knowledge and Attitude Profile (IEA, 2021, p.11-12)

## Alignment with Industry 5.0

Several aspects of the GAPC align with the concepts of resilience, sustainability, and human-centricity that are central to Industry 5.0. Thus, exploratory analysis focused mostly on

elements of human-centricity and resilience, as the GAPC was updated with the skills required from engineers for sustainable development and sustainability values.

**Sustainability.** The preamble explicitly states that the revised GAPC reflects the value of sustainable development. For example, when solving complex engineering problems, engineer graduates are expected to analyse and evaluate sustainable development impacts to society, the economy, sustainability, health and safety, legal frameworks, and the environment (WA6).

**Human-Centricity.** The revised GAPC emphasizes ethics, diversity and inclusion. Engineering graduates are expected to act ethically with understanding of the need for diversity and inclusion (WA7). The acknowledgement that the deployment of new technologies should be analysed critically and used ethically is implicit in the Tool Usage (WA5). Communication is another key human-centric aspect.

**Resilience.** The GAPC highlights the importance of lifelong learning and adaptability. Engineer graduates are expected to recognise the need for and have the ability for independent and life-long learning, adaptability to new and emerging technologies, and critical thinking in the broadest context of technological change (WA11).

## Discussion and Conclusions

This exploratory study analysed how the GAPC attributes reflect the key requirements of Industry 5.0 and the transformative skills in the Inner Development Goals. Considering that these attributes are generically stated, the analysis should be interpreted with caution and not generalized beyond the scope of this exploratory exercise. Most dimensions in the GAPC relate to IDGs pillars on *Thinking*, *Collaborating*, and *Being* – the latter closely aligned with ethics. Skills related to the *Relating* and *Acting* pillars are insufficiently addressed. However, there are several opportunities to further explore other pillars. For example, in 'The Engineer and the World' (GAPC), in the pillar *Relating*, 'Connectedness' is defined as "Having a keen sense of being connected with and/or being a part of a larger whole, such as a community, humanity or global ecosystem" (IDG, 2021, p.18). This deserves further exploration as it suggests that engineers are not separate entities from the world they act upon. It suggests a more holistic approach to the role of engineers, their identity and belonging to the environments they impact with their engineering solutions. In addition, 'Empathy and Compassion' are essential foundations for human-centricity in engineering education, enabling students to design solutions that address human needs rather than merely solving technical problems, and inform professional ethics by helping them recognize their responsibility to communities and the environment.

The Policy Brief "Industry 5.0: A transformative vision for Europe" (European Commission, 2021b) does not mention 'engineer(ing)' in any form, but the implications of Industry 5.0 describe what an engineering mindset is and the role of engineers towards a more sustainable, resilient and human-centric industry, "Industry 5.0 implies mind-sets, skills and capabilities, from entry level employees to boards of directors, trained to understand complexity, think in systems, using complexity friendly tools and methodologies, design principles, experiential learning, action and reflection cycles and iterations. Curiosity, adaptability, empathy and responsibility for interdependence and for long-term outcomes will need to become foundational objectives for qualification and for employment." (p.21)

Industry 5.0 presents significant challenges for new educational and re-skilling approaches. It requires a transformation of educational institutions, "a comprehensive overhaul of existing academic programmes to focus on the development of future business and policy leaders with a solid understanding of complex systems and decision-making" (p.21). In the same way engineering accreditation agencies are updating accreditation standards to ensure graduates have the attributes and competencies to address the SDGs, a similar approach could be followed for the integration of the IDGs. Whereas engineering education values skills in the

curricula (such as communication, problem solving, and ethical reasoning), more needs to be done in regard to the holistic development of engineering students. A holistic education approach – essential for professional and personal growth – will ensure that sustainable development is not only about policies and infrastructure but also about cultivating the inner capacities necessary for lasting transformation in engineering education and practice.

## References

- European Commission: Directorate-General for Research and Innovation, Dixson-Declève, S., Dunlop, K., Renda, A., Charveriat, C., Christophilopoulos, E., Balland, P.-A., Isaksson, D., Martins, F., Mir Roca, M., Pedersen, G., Schwaag Serger, S., Soete, L., Stres, Š., Gołębiowska-Tataj, D., Walz, R., & Huang, A. (2023). *Industry 5.0 and the future of work: making Europe the centre of gravity for future good-quality jobs*, Publications Office of the European Union. <https://data.europa.eu/doi/10.2777/685878>
- European Commission: Directorate-General for Research and Innovation, Breque, M., De Nul, L., & Petridis, A. (2021a). *Industry 5.0: towards a sustainable, human-centric and resilient European industry*, Publications Office of the European Union. <https://data.europa.eu/doi/10.2777/308407>
- European Commission: Directorate-General for Research and Innovation, Renda, A., Schwaag Serger, S., Tataj, D., Morlet, A., Isaksson, D., Martins, F., Mir Roca, M., Hidalgo, C., Huang, A., Dixson-Declève, S., Balland, P.-A., Bria, F., Charveriat, C., Dunlop, K., & Giovannini, E. (2021b). *Industry 5.0, a transformative vision for Europe : governing systemic transformations towards a sustainable industry*, Publications Office of the European Union. <https://data.europa.eu/doi/10.2777/17322>
- Inner Development Goals (IDG) (2021). *Inner Development Goals: Background, Method and the IDG Framework* <https://drive.google.com/file/d/13fcf9xmYrX9wrsh3PC3aeRDs0rWsWCpA/edit>
- International Engineering Alliance (2021). *Graduate Attributes & Professional Competencies* <https://www.ieagrements.org/assets/Uploads/IEA-Graduate-Attributes-and-Professional-Competencies-2021.1-Sept-2021.pdf>
- Onyemelukwe, I. C., Ferreira, J. A. V., & Ramos, A. L. (2023). Human energy management in industry: A systematic review of organizational strategies to reinforce workforce energy. *Sustainability*, 15(17), Article 17. <https://doi.org/10.3390/su151713202>
- Polmear, M. (2024, June). Engineering Identity Development Among International Students in UK Foundation Year. In *Proceedings of the 2024 ASEE Annual Conference and Exposition*, doi: 10.18260/1-2—47285
- Rame, R., Purwanto, P., & Sudarno, S. (2024). Industry 5.0 and sustainability: An overview of emerging trends and challenges for a green future. *Innovation and Green Development*, 3(4), 100173. <https://doi.org/10.1016/j.igd.2024.100173>
- Suganya, G., Joshua Selvakumar, J., Varadharajan, P., & Pachiyappan, S. (2024). Skill Sets Required to Meet a Human-Centered Industry 5.0: A Systematic Literature Review and Bibliometric Analysis. In M. Khan, R. Khan, P. Praveen, A. Verma, & M. Panda (Eds.), *Infrastructure Possibilities and Human-Centered Approaches With Industry 5.0* (pp. 231-252). IGI Global Scientific Publishing. <https://doi.org/10.4018/979-8-3693-0782-3.ch014>
- Trstenjak, M., Benešova, A., Opetuk, T., & Cajner, H. (2025). Human factors and ergonomics in Industry 5.0—A systematic literature review. *Applied Sciences*, 15(4), Article 4. <https://doi.org/10.3390/app15042123>
- Xu, X., Lu, Y., Vogel-Heuser, B., & Wang, L. (2021). Industry 4.0 and Industry 5.0—Inception, conception and perception. *Journal of Manufacturing Systems*, 61, 530–535. <https://doi.org/10.1016/j.jmsy.2021.10.006>

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