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Engineering Skills for Intelligent Manufacturing

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Abstract: *The terms ''digital manufacturing'', ''Industry 4.0'', ''smart factory'', ''intelligent/smart manufacturing'', or ''factory of the future'' represent the same concept today. This means that individually automated machines and separate processes have experienced the full integration of all of its elements into a single digital system. This paper presents the elements of the engineering skills for model of Industry 4.0.*

Keywords: *Industry 4.0, Skills, Engineering.*

1. Introduction

Global trends that have a great influence on the development of a new generation of technological systems, based on the concept of Industry 4.0, are: (i) population aging, (ii) minority populations and their inclusion in manufacturing flows, (iii) reduction of natural resources, (iv) imagination and mobility of young talents, (v) digitization of manufacturing and supply and sales chains, their connection and cyber threats, and (vi) progressive global warming. All these facts have a greater or lesser impact on the development of technological systems, including the development and application of Industry 4.0 model [3,4].

At present, the main components of intelligent manufacturing are: (1) semantic multimodality - presentation of different information in the factory - attributes with a hierarchical structure, relations, tables, graphs and entities; (2) multidimensionality - information in several dimensions must be presented and recorded - description of business processes and technological operations performed at different levels of the digital manufacturing structure; (3) multi-granularity - access to sensor and equipment data contributes to the assessment of the technological process, and if necessary, provides the possibility of its regulation and control; (4) transparency and integration. Distribution of information between units - manufacturing automation, quality control, enterprise resource planning system, etc. - should be integrated while maintaining the systemic nature of records [1,2,4].

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Digital manufacturing is causing changes in various areas, both within the industry itself and outside it, i.e., all stakeholders. One of the most important segments of the development and application of this concept in industry is education for digital manufacturing, and within this segment is engineering education. Research shown in [1, 2] indicates that, from the point of view of digitalization, educational systems in developed countries have serious shortcomings, which are reflected in the following: (i) untimely monitoring of trends related to digital manufacturing in terms of required skills and, on the other hand, (ii) clearly defined requirements for advanced jobs by the industry. If we analyze the changes in the knowledge required for digital manufacturing in the last decade, in relation to the workplace and the manufacturing function itself, we come to the conclusion that the requirements for new skills in the workplace have increased more than four times. This is due to the fact that machine tools have become Cyber-Physical Systems (CPS), with completely new features.

On the other hand, research presented in [2] shows global trends in the USA and the EU in changing the character of skills for digital manufacturing, in the period 2016-2030. The mentioned changes relate to a significant reduction in the need for manual and basic cognitive skills, compared to, for example, technological skills, which will increase by more than 50%. This means that the structure of knowledge in this field is changing, from classical engineering to integrated knowledge of mechanical engineering, electrical engineering and computer science.

2. Skills for the Technological Systems of the Future

New generations of technological systems require new knowledge and skills, because new paradigms and models are being introduced into manufacturing: (i) zero-waste manufacturing, (ii) global agile supply chain networks, (iii) energy and resource efficiency, (iv) mass personalization, (v) integration - horizontal and vertical, and (vi) data security and accuracy [5-8].

Our research shows that the basic skills for intelligent manufacturing are defined as[6-8]:

- digital literacy as a holistic skill to interact, understand, apply and even develop digital technological systems, technologies used for the systems, and applications and tools used in the systems
- effective communication skills with people, IT and AI systems, through different platforms and technologies,
- ability to use and design new solutions for AI /ML and data analysis with critical interpretation of results,

- creative problem solving by analyzing big data sets and technological possibilities in smart manufacturing systems,
- cyber security, privacy and data/information protection, reflect the rapidly growing digital model of the manufacturing value chain,
- strong entrepreneurial mindset, including proactivity and the ability to think outside the box,
- physical and psychological ability to work safely and efficiently with new technologies,
- the ability to deal with the increasing complexity of multiple demands and simultaneous tasks,
- an intercultural and interdisciplinary, inclusive diversity orientation, in order to respond to new challenges arising from a diverse manufacturing workforce, and
- openness to constant change and transformational skills that constantly question the status quo and initiate the transfer of knowledge from other domains.

As the previous analysis shows, all skills for intelligent manufacturing can be grouped into two units: (i) technical-technological (first five groups), and (ii) socio-economic (second five groups).

When we have defined the characteristics of the required skills, the following questions are asked and relate to everything that needs to be solved in the context of application in industry, namely[5-8]:

- openness to constant changes and transformational skills that constantly question the status quo and initiate the transfer of knowledge from other domains,
- increased investments in employee education in order to reach the full potential of new technologies,
- support policies to promote education and training of employees in the organization,
- provide a person who will deal with career development for manufacturing,
- develop new profiles with technical expertise complemented by general knowledge,
- use digital technologies for innovative delivery of education and training,
- support social mobility in manufacturing,
- ensure that relevant skills are trained,
- increase the importance of professional technical education and training with work in the organization, and
- encourage collaboration to address skills development needs.

In this way, we connect and integrate the knowledge and methods that form the framework for intelligent manufacturing.

3. Jobs in Intelligent Manufacturing

Already today, in technologically advanced companies, which represent examples of intelligent manufacturing, we have workplaces that support these manufacturing models, and in the following text, we list some of them [9-12].

They are responsible for implementing digital twin technology that enables predictive maintenance, which helps to identify potential failures in equipment before they occur. **Digital twin engineers** must actively collaborate with multiple departments and stakeholders, such as product design teams, operations teams, data scientists, and software engineers, to ensure the digital twin is aligned with the physical product and its context.
Digital twin engineers must have a deep understanding of physical systems, IoT devices, programming languages, and data analysis tools. They must also be able to reverse engineer complicated systems and evaluate how to engineer digital twins for them.
Overall, digital twin engineers play a critical role in bridging the gap between the physical and digital worlds, helping companies optimize their operations, reduce costs, and improve customer experience.
Additionally, digital twin engineers should have strong communication skills, the ability to work in a team, and the capacity to adapt to changing technologies and processes. They must be able to prioritize tasks and manage time effectively to ensure efficient product development and implementation. They must also stay up-to-date with the latest industry trends and technologies related to digital twin engineering.

Data analysis and modeling skills for **predictive supply chain analysts (PALs)** should also include a deep understanding of supply chain management, logistics, and industry trends. They must have strong communication and collaboration skills, as they often work with various stakeholders across different departments to ensure seamless supply chain operations. PALs must also be able to adapt to new technologies and processes, be proficient in project management, and have a good understanding of regulatory requirements and compliance. Furthermore, PALs should be able to identify and mitigate risks in the supply chain, including disruptions caused by unforeseen events such as natural disasters or geopolitical events. They should also be able to optimize inventory management and warehouse operations, as well as analyze supplier performance to ensure the timely delivery of goods.PALs need to be able to develop and implement strategies to reduce waste, lower costs, and improve overall efficiency in the supply chain. Overall, PALs play a crucial role in enabling organizations to leverage the power of digital tools to transform their supply chain operations, helping them gain a competitive advantage in the marketplace.PAL helps companies achieve optimal inventory and supply chain management under current and anticipated demand scenarios.

Some of the important skills for PALs should include:

- Data analytics and statistical modeling
- Forecasting techniques and demand planning
- Knowledge of transportation modes and freight management
- Supplier relationship management
- Understanding of financial forecasting and budgeting
- Familiarity with e-commerce platforms and omnichannel logistics
- Effective communication and collaboration skills
- Adaptability and agility in dealing with change and uncertainty
- Ethical decision-making and compliance with regulations.

PALs should also continuously update their skills and knowledge to keep up with the evolving technology landscape and changing business needs. They should be proactive in seeking out opportunities to learn, network, and build their professional development.

Robots team coordinators (RTCs) also work closely with programmers and engineers to develop robot control systems and ensure that robotic equipment is properly maintained. They are responsible for identifying areas where robotics can be integrated into the manufacturing process to improve efficiency, reduce costs and enhance product quality. Another critical aspect of an RTCs' role is to ensure that human workers are trained in the safe and effective operation of robots. They develop training programs and help workers become comfortable with new technologies, so that they can effectively work alongside robots. People skills are imperative for RTCs to possess, since these professionals must be able to manage and motivate teams composed of human workers and robots. They must be able to communicate effectively and work collaboratively with individuals from different departments, including engineering, operations, and human resources. As automation and robotics increasingly become a critical part of the manufacturing industry, the demand for RTCs is likely to grow. This new generation of manufacturing professionals must be able to adapt to this rapidly-evolving landscape while making sure that human skills are complemented by the technology they create.

Some important skills for RTCs should include:

- Strong analytical and problem-solving skills to identify areas where robotics can be integrated for maximum benefit
- Strategic thinking and planning skills to develop long-term plans for implementing robotics in manufacturing or assembly environment
- Technical expertise in robotics, automation, and machine learning
- Familiarity with programming languages such as C++, Python, or Java
- Excellent communication and interpersonal skills to work collaboratively with cross-functional teams and effectively communicate complex technical concepts to non-technical stakeholders
- Knowledge of industry regulations and safety standards for working with robots
- Ability to manage multiple tasks and prioritize competing demands to meet project deadlines.

Overall, RTCs must be able to balance the needs and capabilities of robots and humans in order to effectively integrate robotics into the manufacturing process. They must have a deep understanding of how robots operate, and how they can be programmed and trained to work alongside humans. Additionally, they should be able to identify opportunities for automation and use data analysis to optimize the performance of robotic systems.

With a wealth of customer data at their disposal, companies have started using it to create customized customer groups, leading to a demand for professionals known as Digital Sales Managers (MDPs).
MDPs evolved from the product manager career.
Their key responsibilities are to identify and create new product offerings for clients, which are fully digitally rounded - the so-called smart products, and virtually available to the client, making them completely different from the physical products that a traditional company produces.
MDP is responsible for contributing to the expansion of new digital offerings in the company's portfolio of smart products.

Digital Sales Managers (DSMs) have become increasingly important in today’s digital age, where companies are using customer data to create personalized marketing and sales strategies. They are responsible for identifying new opportunities for digital products and services that can be developed and marketed to customers. In addition to identifying new product opportunities, DSMs also work closely with cross-functional teams to develop and launch new digital products. This involves collaborating with designers, developers, and

product marketers to create products that meet customer needs and align with the company's overall business strategy. DSMs must have a strong background in digital sales and marketing, as well as experience in product management. They should be familiar with the latest digital technologies and trends, and have a deep understanding of customer behavior and needs. Strong analytical and problem-solving skills are also critical, as DSMs must be able to analyze complex data sets to identify opportunities and develop effective sales strategies. DSMs play a critical role in driving the growth of digital products and services in today's market. They must be able to adapt to the rapidly-changing world of digital sales and marketing, and have a deep understanding of how to leverage customer data to increase sales and growth.
The key skills required for DSMs include:

- Sales and marketing: DSMs must be able to identify new opportunities for digital products and services and develop effective sales and marketing strategies to promote them to customers.
- Analysis of customer behavior and experiences: DSMs must have a deep understanding of customer needs and behavior in order to develop products that align with customer preferences and thus increase sales.
- Communication: Effective communication skills are critical for DSMs to collaborate with cross-functional teams, communicate project updates, and engage with customers.
- Networking: DSMs must be able to build and maintain professional networks to identify new business opportunities and partnerships.
- Cooperation: DSMs must be able to work effectively with cross-functional teams, including designers, developers, and product marketers, to develop and launch new digital products and services.
- Client management: DSMs must be able to build and maintain strong relationships with clients to ensure customer satisfaction and increase sales.
- Social skills: DSMs must be able to work effectively with individuals from diverse backgrounds and cultures and build strong professional relationships.
- Change management: DSMs must be able to navigate and drive change within a company, including shifts in business strategy or product offerings, to enhance growth and remain competitive.
- Project management: DSMs must be able to oversee the implementation of new digital products and services, including managing timelines, budgets, and ensuring successful launches.

As automation technology advances and more companies begin to adopt drones and other automated equipment, new roles will emerge to manage and coordinate the data generated by these technologies. One such role is that of a

drone data coordinator (DDC), who will be responsible for overseeing the use of drone fleets and managing the data that they capture. The DDC role will require a combination of technical and managerial skills, including:

- Proficiency in project management: DDCs will be responsible for overseeing the use of drones on construction sites and ensuring that they are used safely and effectively to achieve project goals.
- Resource and equipment management: DDCs must be able to manage fleets of drones and other automated equipment, ensuring that they are properly maintained and utilized to maximize efficiency.
- Knowledge of data management: DDCs will be responsible for managing the data collected by drone fleets, including organizing, analyzing, and reporting on the data.
- Networking with service providers: DDCs may be responsible for sourcing unmanned drone service providers, negotiating contracts, and managing ongoing relationships with service providers.
- Executive responsibility: In some companies, the DDCs role may involve executive-level responsibilities, such as developing and implementing strategies to expand the use of drones in the company's lifecycle data management model.
- Overall, the DDCs role highlights the growing importance of data management and automation in the construction industry, and underscores the need for skilled professionals who can manage and coordinate these technologies effectively.

The key skills required for a DDC role include:

- Data lifecycle management: DDCs must have a deep understanding of data management principles and be able to manage all aspects of the data lifecycle, including collection, storage, analysis, and reporting.
- Optimization of resources: DDCs must be able to optimize the use of drone fleets and other automated equipment to maximize efficiency and productivity on construction sites.
- Analytics and communication: DDCs must be able to analyze and interpret data from drone fleets and communicate insights effectively to stakeholders.
- Networking and automation: DDCs must be skilled at building and maintaining professional networks, as well as leveraging automation technologies to improve data collection and analysis.
- Client management: DDCs must be able to build and maintain strong relationships with clients, ensuring that their needs are met and that they are satisfied with the services provided.
- Coordination and cooperation: DDCs must be able to coordinate with cross-functional teams, including drone service providers and other stakeholders,

to ensure that data collection and analysis is integrated effectively into overall project planning and execution.

- Change management: DDCs must be able to navigate change in the industry, including shifts in technology or strategic priorities, and adapt their strategies accordingly.
- Project management: DDCsmust be able to oversee the implementation of drone fleets and other automation technologies on construction sites, including managing timelines, budgets, and stakeholder relationships.

4. Conclusion

The application of Industry 4.0 model includes forty-five elements, whereas SMEs model in the field of manufacturingincludes eighteen elements.
The application of this model requires detailed knowledge and skills, which is specifically presented in the work.
Therefore, organizations that realize the elements of Industry 4.0 must also have specific workplaces, some of which are analyzed in this paper.
Our research in this area in the future will be related to defining the curriculum for intelligent manufacturing, based on our research in this area so far [3,4].

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