MetaTech Exchange

BRIDGING INDUSTRY 4.0 IN WESTERN BALKANS

TRAINING CONTENT

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1. Introduction

The following information is a guideline for the development of the e-learning platform. Based on present content, the e-learning platform materials should be elaborated, however it is not required to keep only the content provided in this document. It is possible to expand the content with local VET and metal industry requirements and omit certain parts if they are less important.

Due to the ongoing industrial revolution 4.0 and the changes resulting from it, the modern manufacturing industry needs to adapt to the new environment in which it will operate. The changes taking place include not only the workplaces and the tools used but also, above all, a new philosophy of design, manufacturing, management, work and, most importantly, employee training.

Modern industry faces wide range of challenges related to, among other things:

– digitalization of practically every aspect regarding the company's performance;

– challenges of cyber security;

– application of artificial intelligence in the manufacturing process;

– increasing competitiveness especially during the implementation of the production process and prototyping;

– implementation of tools of the so-called Internet of Things;

– reduction of the use of materials (raw materials) and electricity;

– reduction of emissions of harmful substances;

– introduction of the LEAN manufacturing process;

– working conditions including remote working and working in the cloud;

– changes in the approach to vocational training;

– increased production automation and robotisation;

– big data analysis.

Such many necessary changes require the involvement of both large financial resources and human capital, which is not easy. Key to understanding why it is important to introduce the above is to know the current industrial revolution as well as the previous three.

1.1. Industry Transformation from 1.0 to 3.0

All previous industrial transformations have always involved the introduction of a disruptive tool in the production process as well as partly including the implementation of a new energy source.

In the case of the first industrial revolution, dating from the turn of the 18th century, we are talking about the large-scale use of mechanisation in the production process and a source of energy in the form of steam (steam engines). This combination allowed to increase the production significantly and to reduce the physical strain on workers doing the hardest physical types of work. One of the most famous inventions of this era certainly included the steam engine but also the weaving loom. The Industrial Revolution obviously involved the invention of new machines that increased, to some extent, the repeatability of production and the accuracy of manufacturing, but its most important driving force was the initiation of mechanisation through the steam engine.

The second industrial revolution, dating from the turn of the 20th century, was characterised by advances in the automation of production and the invention of the assembly line in this area. Henry Ford is recognised as the pioneer of the first car factory in the United States to use the assembly line method of production. The second industrial revolution also saw the invention and mass application of electricity. The combination of many modern tools, assembly lines and electricity accelerated the production process considerably, as well as allowing for more repeatable production. The worker on the assembly line had specific tasks and tools, which, by improving, minimised errors in the production process. In addition, such solution allowed for mass corrections and changes to the currently produced models.

The third industrial revolution, also known as the scientific and technological revolution, dates from after the Second World War until around 2015, when the term Fourth Industrial Revolution came into use. In the case of the Third Industrial Revolution, the key innovations certainly include the implementation of computer control in the manufacturing process, as well as the beginning of large-scale implementation of automation and robotisation in production. In the case of computer control, the best examples of this revolution are numerically controlled machine tools - CNC, welding equipment, waterjet cutting, computer control in quality control, etc. A principal issue of the industrial revolution is another aspect related to the working conditions of workers and thus concerning the use of robots to assist the process of transportation and any other production work.

Analysing the industrial revolution from the point of view of a new energy source, the start of electricity production using nuclear power plants on a massive scale is certainly noteworthy. This source of power has allowed to significantly reduce the use of fossil fuels as the power source used to produce electricity.

A key point about Industrial Revolution 3.0 is that the measurable effects of it are currently being analysed and there is a great deal of information about its impact. In the case of Industrial Revolution 3.0, it is evident that in Europe the progress and implementation of 3.0 tools vary. There are countries where the implementation level is extremely high and some where it is still ongoing.

1.2. Industry 4.0

The current Industrial Revolution 4.0 is unique in many aspects, where the most important is the level of complexity. The industrial revolutions described above usually distinguished between one or two revolutionary tools and a power source, in the case of Industry 4.0 the list of tools is extremely long. Below, the figure shows a list of some selected tools included in Industry 4.0.

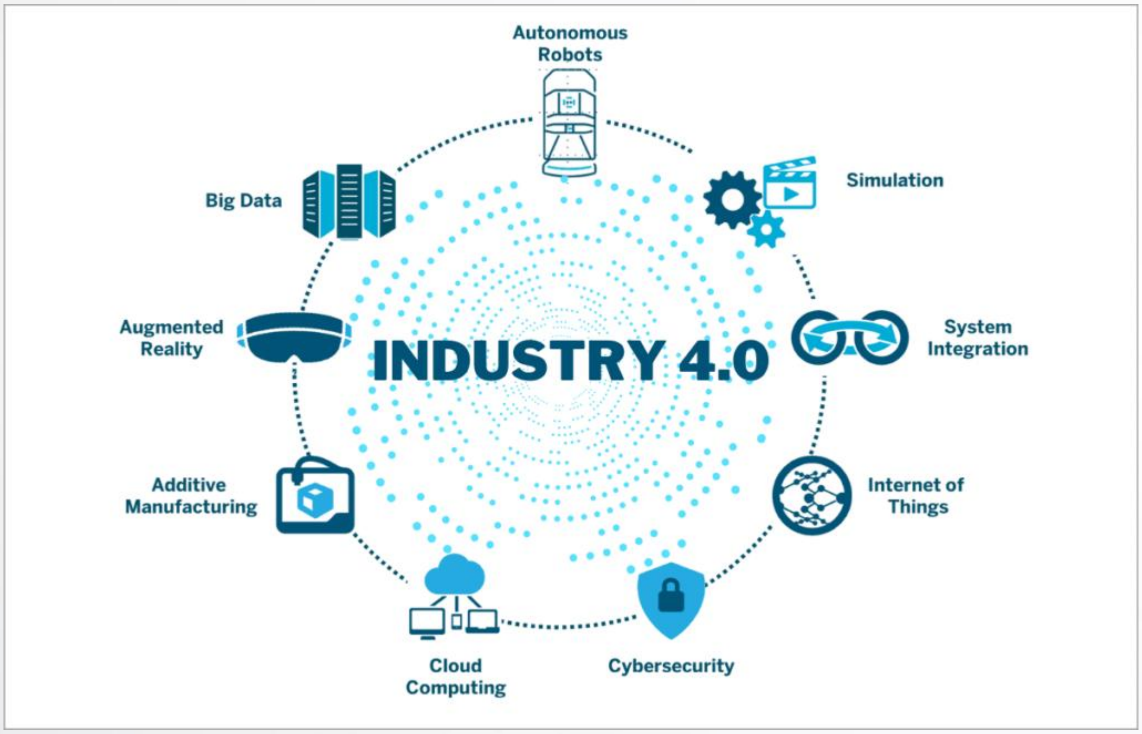


Figure 1. List of selected tools of Industry 4.0 [1]

Knowledge of the ongoing industrial transformation is crucial, both in terms of industrial production and issues related to the training of future and current employees. As Figure 1 shows, the number of tools is enormous. We can say that industrial transformation/revolution 4.0 is not about one or two tools, we can certainly say that the current transformation requires the use of a wide variety of production tools, which only when combined form a powerful tool for industrial transformation 4.0.

The philosophy regarding Industry 4.0 is extremely important. The implementation of Industry 4.0 tools should start with digitisation issues, which offers a high-level of efficiency. The key tools used are the Internet of Things, 3D printing, 3D scanning, cloud computing, robotics, etc. depending strongly on the characteristics of the company in question, but very often we are currently dealing with the implementation of at least several of them simultaneously. There are cases where almost all the aforementioned tools are implemented, which is undoubtedly a competitive advantage for such a company but at the same time a huge challenge for the company's employees at all levels.

The industrial revolution currently underway certainly also concerns ecology. The aspect related to the use of ecological materials and their recycling is an extremely principal issue raised during the implementation of Industry 4.0 tools. Not only materials, but also technological processes have a significant impact on the ecological aspect, in terms of reducing unnecessary technological processes or the consumption of consumables during production.

As with previous industrial revolutions, Industry 4.0 also represents a new energy source, which, however, is not as obvious as it was before. In the case of the ongoing industrial revolution, we delt with the tools of Industry 4.0 and not about one single tool; and the same applies to the question of the energy source. There is no single energy source, as there are many and they can be categorised as so-called renewable energy sources, which generally are:

– solar;
– wind;
– hydro;
– geothermal;
– other ecological/renewable sources of heat such as heat pumps.

Recommendations

I recommend the development of an introductory film to the modern systems of Industry 1.0-4.0 showing the major developments in technology and improvements in working conditions over the successive ongoing industrial revolutions. This film could be interesting for young workers/students in vocational training, as well as for those already employed who improve their competences by participating in training courses. I recommend that the video presents the content of Chapter 1 with an emphasis on a graphic interpretation of the positive changes resulting from industrial transformations.

2. Training Modules

The guidelines presented in the second part concern exemplary proposals for the implementation of Industry 4.0 solutions in enterprises mainly in the metal sector and related to vocational training which needs to be adapted to the new industrial solutions being implemented. The information in this chapter will be used to develop training materials to raise awareness among metal workers and trainees of the need for continuous skills improvement and professional development. The developed training material should come as e-learning platforms. Such developed materials can be prepared in any form, for example:

- e-learning videos;
- presentations for example in PowerPoint or PDF format;
- digital tests;
- telephone applications;
- knowledge exchange forums for people from a particular industry and VET.

This chapter focuses on both Industry 4.0 tools, digitalization, artificial intelligence, smart manufacturing, smart factory, lean manufacturing, and the process of vocational training VET.

2.1. VET in Modern Manufacturing

Vocational training has been a pillar of industrial development worldwide for many years. Properly tailored vocational training makes it possible to bring highly skilled workers into the labour market, thereby increasing the productivity of companies, thus enabling their growth. Vocational training properly matched to the conditions of the country and its region eliminates unemployment problems and enables economic development. Due to the ongoing industrial revolution 4.0, the labour market has changed, and new jobs have been created requiring different skills from those of currently present on the labour market or those trained according to educational curricula that are not up to date and do not match reality. This problem can be solved by introducing both recent changes to the curricula of vocational education at school and university level, adapted to the current needs of the labour market. In addition, the problem can be addressed through on-the-job training of employees or through self-development using, for example, e-learning platforms such as the one just developed within the project MetaTech Exchange - Bridging Industry 4.0 in Western Balkans. E-learning platforms are an excellent complement to the knowledge currently acquired during traditional learning in vocational schools, technical schools, engineering studies, etc. The undoubted advantage of such platforms is the easy access to knowledge using a mobile phone or tablet, which is certainly an advantage in the current reality of digital development.

Throughout history, the development of the professional industry has never been so digitally driven, and this applies not only to the new tools of Industry 4.0, which are undoubtedly almost always strongly digital. Nowadays, many machines that used to be controlled manually by the operator are equipped with digital controls. This means that learning to operate, for example, machine tools must be preceded by an in-depth knowledge of computer operation, cloud work, software supporting the design and manufacturing process and many other digital tools with which workplaces are now equipped.

The problem of vocational training adapted to the needs of the labour market concerns several fundamental groups and issues. It is advisable to develop the materials of an online e-learning platform considering the needs of all professional groups listed below and the necessary areas. This will increase the awareness of each group involved in issues focused on modern vocational training. An appropriate tab can be prepared for each of these groups to better adapt the content prepared on the platform for them.

1. The first group of people whose awareness needs to be raised are young persons currently in vocational training schools and courses. This group also includes people who are still in the process of choosing their career path and should also be addressed by the e-learning platform to support them in the choice of an appropriate training profile. In this group, it is extremely important to present forecasts for the development of the metalworking industry, the growing shortage of employees with training aimed at specialised occupations requiring digital competences and Industry 4.0, as well as the combination of already existing industries/occupations with modern tools and the direction of their development in terms of job prospects in a stable growing industry. It is worthwhile to present data on the e-learning platform related to the financial aspect of working in the metal industry and the development prospects of dynamic employees.

2. The second group of platform users are certainly people who are already employed in metal sector and want to improve their skills. Upgrading skills can be due to several reasons such as a change of

profession, the development of the current job or the desire for professional development. For those currently working, the content of the e-learning platform certainly does not have to include basic information related to the labour market within the metal sector but should be related to specific developing specialisations or tools, such as cloud work, Artificial Intelligence, metrology, 3D printing, 3D scanning, robotisation, automation, lean manufacturing, smart factory, etc. It is worth noting that employees in the metalworking industry often work shifts and irregular hours, which means that they are not as available as pupils or students. For such an audience, it is worthwhile to present on an e-learning platform information related to specific solutions and the possible implementation of online courses, online or hybrid training, which is often used recently. The hybrid form makes it possible to complete the theoretical part of the training in a convenient way, i.e. by familiarising oneself with the online platforms and taking a test at a convenient time and then proceeding to the practical part after having familiarised oneself with the materials of the online platform.

3. Another audience is certainly one of the most important groups to which the content of the online platform should be directed, namely vocational education teachers/trainers. The quality of learning and development of metalworking employees depends not only on the curriculum and curricular content but mainly on the content-related preparation of trainers, and the implementation of Industry 4.0 solutions should start from it. In the case of developed materials, the e-learning platform should include a place with materials intended for this group of recipients. Certainly, such materials should include presentations or videos that will help trainers and VET teachers find information on courses and training intended for them, and possibly funding sources. It also seems reasonable to address in digital materials to the issue of increasing the awareness of VET teachers about the changes taking place and the need to implement several digital solutions such as simulators, apps, Internet of Things tools etc. in the teaching process.

4. Another audience that should find its place in e-learning platforms are employers. Increasing employers' awareness of not only the characteristics of the Industry 4.0 revolution, but also the need to improve employees' competencies is one of the pillars of implementing positive change. In the case of employers and the e-learning platform, it is worth citing data on the implementation of automation, robotization, digitization in various industrial areas of developed countries and analyses of the benefits of this. In addition, it is worth noting that the introduction of relevant changes in the process of vocational training should be preceded precisely by an analysis of employers' needs. As the experience of European

countries such as Poland shows, the introduction of opportunities for consultation and greater involvement of industry representatives in the vocational training process brings great mutual benefits. An example of such cooperation can be found in the Center for Vocational and Continuing Education (Centrum Kształcenia Zawodowego i Ustawicznego) in Kielce, Poland, where local industrial companies play the role of patrons of given classes/training groups with given specializations that fit into the industries of the regional industry. For the company, this is undoubtedly an opportunity through sponsorship of laboratory equipment and influence on the methodology of equipment use, which makes it possible to attract employees who, thanks to work on equipment already used in the company, can immediately take up employment in the company that is just a patron of the class. Such an example Canter for Vocational and Continuing Education in Kielce from the metal industry is the patronage of the company Aebi Schmidt Poland, which took patronage of the laboratory of modern metal cutting, and the company Fronius, which took patronage of the laboratory of joining and welding of metals and preparation of test joints. The website [2] provides information about the laboratory and photos of the signing of such an agreement. In the era of digital transformation of ubiquitous website, text and photos translators, the translation of this website is one click away. It would be worthwhile to develop, within the framework of the e-learning platform, just an analysis of several such cases of good practice related to cooperation between the vocational education community and the industrial community. The fact that classes are patronized by the industrial environment also greatly benefits the other groups mentioned above: students/trainees use real industrial equipment and thus gain very strong practical competencies, employers systematically acquire qualified staff, and VET teachers/trainers maintain knowledge of modern technologies used in the industrial environment. It can be said that vocational training in connection with rapid digital development should not be as a component/element of work [3] and highly accounted for as an employee's contribution to the enterprise, which is already the case in a great many enterprises. In addition, entrepreneurs engaging in supporting vocational training have, as it were, the opportunity to learn from other entrepreneurs also engaged in precisely this type of activity. The changing job market and evolving technology require us to be much more knowledgeable in almost all jobs. Manufacturers strive to increase reliability, productivity very often by investing in technology, which requires training of employees, and very often throughout working life. This creates a learning community which is worth emphasizing when developing an e-learning base.

Summary

A crucial factor affecting the development of vocational training of the metal industry as well as any other industry is the creation of the right climate on the part of all the groups/communities mentioned. It would be worthwhile to develop a bookmark on the e-learning platform, for example, called "Metal VET we create the cooperation", where information would be included regarding precisely the creation of space for the implementation of Industry 4.0 solutions in the aspect of vocational education with emphasis on cooperation with the industrial environment. It is the appropriate cooperation of all the groups mentioned above that will allow for the proper development of education/training programs and valuable guidance from local companies will allow to refine the needs posed by the industrial environment.

The quality of the workforce, which guarantees the achievement of the goals set for implementation, is significant for building modern teams in enterprises. When it comes to the implementation of Industry 4.0 tools, it is not possible to achieve the desired goals without an adequate number of skilled workers and without ensuring the continuity of their training in the future.

The impact of a well-functioning vocational training industry on the entire local/national community is significant, which thrives due to a well-qualified workforce and entrepreneurs who keep up with the changing tools of Industry 4.0. An adequate number of skilled workers influences low unemployment and contributes to the growth of the industry and economic development of both the region and the country, hence such a serious approach to the vocational training process should become the foundation of the entire community.

Recommendations

Given the presented Chapter II, it is recommended that material or videos be developed for the various groups involved in shaping VET. Such a video will primarily play an awareness-raising role and allow informed decisions to be made in acting for vocational education. In the digital material, I recommend including good practices drawn from the cooperation of VET and industry and addressing the topic of a stable form of professional development through the process of continuing education.

2.2. Industry 4.0 Tools

This chapter is devoted to the basics of Industry 4.0 tools and is mainly dedicated to those who want to increase their awareness of the opportunities presented by Industry 4.0 without targeting specific groups. Such a detailed description is presented in the sections/chapters 2.3-2.9, which, after consultations with representatives of the communities involved in the project implementation, directed the development of these guidelines and, as a further consequence, the e-learning platform to these selected issues. As outlined in the previous Figure 1, there are a wide variety of Industry 4.0 tools. Depending on the type of enterprise/company and the nature of its operations, not all tools are implemented, but there are some common features. Below I have divided the tools of Industry 4.0 into two groups, one of which is general and can be implemented in almost all companies and institutions, and the second group is aimed at the development of the metal industry and vocational training in this area.

The first group of general Industry 4.0 tools includes:

- cybersecurity;
- increased digitalization;
- transformation of the nature of work - remote and hybrid work;
- Internet of Things.

The second group oriented to the metal industry and VET education includes:

- digitalization;
- rapid prototyping technologies (additive manufacturing - 3D printing and reverse engineering);
- artificial intelligence;
- Internet of things;
- automation and robotization of production.

In further chapters 2.3-2.9 (digitalization and cloud work, new design philosophy: smart manufacturing and ecology, 3D printing, 3D scanning and metrology, artificial intelligence, production automation and robotics, LEAN in metal production), the possible solutions of the second group of Industry 4.0 tools are presented in an extended way, with their extension to some issues related to ecology and LEAN in design and manufacturing. The content has been developed in such a way that it is possible to prepare separate digital material for each of them for the e-learning platform and conduct a short test for self-solving, for example, in the form of a multiple-choice test so-called A, B, C). At the same time, for the content presented in chapters 2.3-2.9, I recommend developing separate questions for those who participate in training (vocational schools, high schools, students, employed industrial workers upgrading competencies and changing industries) and for teachers/trainers of the vocational training industry - VET.

Recommendations

From the chapter presented, I recommend the development of digital material for the e-learning platform presenting two groups of Industry 4.0 tools, which are general and apply to enterprises overall, and a second group of tools dedicated specifically to the metal industry. Such material can be short with reference to further materials of the e-learning platform, where much more detailed information from chapters 2.3-2.9 is included. I recommend on the video referring to the other chapters and other sources such as reports on the implementation of Industry 4.0 tools in selected countries of the European Union and the world. It is important that the following questions or others included at the end of the chapter have a reference to the content of the digital materials to which they refer.

2.3. Digitalization and Cloud Work

Nowadays, digitalization is one of the foundations of development. Digitalization not only applies to industrial and service industries but also extends to public service, government offices, health care, tourism, hospitality, and almost every other area of daily life. We can certainly consider convenience through easy access to digital devices, fast time associated with verification, processing and exchange of information, increased competitiveness, opening to new customers and markets as the driver of digital transformation. It is the issue related to processing and verification that is now considered the most important. Digitization is contained in several key areas, and here we can talk about digitization in the social (general) area but also digitization geared towards the marketing model and the industrial - production model. We can certainly say that digitization increases market efficiency and contributes to increased competitiveness. In the area of digitization, there are many tools that can be distinguished for development, however, in the materials for the e-learning platform it is most relevant to focus only on selected areas that can be implemented in the metal industry and the VET sector. Therefore, issues related to Internet access and its benefits, as well as issues related to platforms used in daily operations, will not be discussed here but issues that can be implemented in the aspect of the metal industry and the VET industry will be discussed.

In the area of digitization, following the example of the European Union on the e-learning platform, it is possible to point out some systemic measures implemented over the past few years [4].

Such measures include several conclusions and directives on, for example:

- 5G networks of 3 December 2019;
- Cybersecurity Act of 9 April 2020;
- Council conclusions: shaping Europe's digital future of 9 June 2020;
- conclusions on digitization of justice of 13 October 2020;
- resolution on encryption of 13 December 2020;
- conclusions on digitization for the environment of 17 December 2020;

- conclusions on exploring the potential of a joint cyber unit of 19 October 2021;
- Data Governance Act of 16 May 2021;
- European Chips Act of 1 December 2022;
- Council and Parliament agree on legislation on liability for defective products of 14 December 2023;
- Digital transformation in companies: Council adopts position on updating digital tools in company law of 14 February 2023;
- Council adopts directive to adapt company law to the digital era of 16 December 2024.

The following are some tools related to digitization in companies that are necessary to implement both in terms of the operation of the company and the need to learn how to work in digital environment. I recommend choosing several of the following digital tools and presenting them in the e-learning platform materials in a video or presentation manner.

Inter-enterprise communication

One of the basic digital tools that can be implemented in almost any company is internal communication based on a digital model. This type of communication also known as Intranet - “non-public telecommunication network” requires proper implementation but also training for employees. Due to the different forms of Intranet in companies, training related to its functioning depends on the complexity and capabilities, but it seems that in the aspect of vocational training - VET it is advisable to include in the working material the company environment based on digital communications. Nowadays, only this form makes it possible to quickly transfer files, and work on documents by several people. In addition, intranet eliminates the possibility of losing files, gives the opportunity to archive them, allows you to leave a so-called digital footprint, which in the case of the production process is extremely important. Importantly, an intranet is not a closed work environment limited to an office in a company, but a network that allows the realization of remote work extremely popular since 2022, when the COVID-19 pandemic began. We can say that this form of digitization is basic for the implementation of further solutions. Digitization of communications also affects an especially important aspect of the cost of storing materials in paper form and reduces the risk of their destruction or damage. In addition, the process of working with files is faster.

Cybersecurity

Another tool that is essential to implement and intricately linked to the company's Internal Communication described above is cybersecurity. A good example of an agency working on cybersecurity is *the European Union Agency for Cybersecurity (ENISA)* [5], which is an agency tasked with ensuring an equal level of cybersecurity throughout Europe. This concept is very often associated only with computer software, and this should change dynamically in the coming years due to the increasing awareness of employees and society. Based on the data presented in international reports, it is worthwhile presenting statistical data related to the issue in a related module on the e-learning platform. Based on the data of publicly available reports related to cybersecurity [6] and the data published by antivirus software manufacturers [7], it is possible to single out typical problems related to its provision, which should also be the subject of training:

- 60-70% of companies have a cybersecurity incident at least once a year;
- problems related to ensuring cybersecurity are influenced by the problem of recruiting and retaining qualified employees;
- still phishing is the biggest challenge on the road to ensuring cybersecurity;
- lack of awareness of good practices related to cybersecurity and data theft through, for example, connecting unauthorized devices.

The aspect related to good practices and employee recruitment is where vocational training has great application potential. The developed e-learning platform should pay special attention to this point when developing training materials. On the platform, it is worth highlighting the predicted trends of threats in cybersecurity as shown in Figure 2.

Figure 2. List of selected threats projected for 2030 in cybersecurity - data from ENISA's 2024 report [6]

Based on the sample threats shown in Figure 2, certain areas should be included in the currently developed training materials, VET curricula and e-learning platform, where the data from the report is a valuable source of knowledge about the development directions.

Working in the Cloud

Another important solution, the content of which should be included on e-learning platforms, is cloud work. An extension of the Intranet or “non-public telecommunications network” is the “cloud.” Cloud work is considered one of the basic tools of Industry 4.0. Nowadays many companies, enterprises or public institutions cannot see the possibility of working at the current level of productivity without the use of the cloud by the entire cooperating team, and now as never before teamwork is the basis for the functioning of almost every enterprise and public institutions. A graphical interpretation of cloud work as a combination of multiple smart solutions is shown in Figure 3.

Figure 3: Graphical interpretation of cloud work as a combination of multiple smart solutions [8]

In the figure above, we can observe that cloud working like most Industry 4.0 solutions, consists of many interconnected tools, which only as a whole are a huge advantage. Cloud work seems being an excellent steppingstone from an Intranet with limited capabilities. For many companies, and most importantly for VET, the perfect tools within which to start working in the cloud are either free or subscribed software. Basic cloud work systems include Google Workspace or Microsoft SharePoint, for example.

In the case of Microsoft SharePoint, we can say that it is relatively easy to implement both in companies and vocational education. Starting the adventure with the cloud in this case will be quite simple and will not carry a large financial outlay. Access to work in the cloud at current prices is as low as 10-15 euros/month per user, and in such a package we immediately have at our disposal the ability to work with many tools without having to install them on our own computer. It is this feature - not having to install software - that is one of the more interesting advantages of working on the cloud. In the case of professional training and the use of compute-intensive software, students/trainees may not have a powerful computer at their disposal both in class during training and at home completing courses on their own. This is when cloud work is an excellent solution. Such tools are recommended to be included in the e-learning platform under development, which will certainly contribute to the development in digitization in the broadest sense. Working in the cloud is not only the possibility to learn technical software available in the cloud, but also to use such tools as word processing programs, computational calculators, a large amount of storage space for projects, digital files, company chat, instant messaging for conversations, email inbox, shared calendars of employees, better organization of work, control over projects.

Cloud work in the metal industry can be related to the organization of work, concern production files, quality control, projects, analysis, reports, training issues, audits, and all other areas of its activities. An important aspect is the proper training of employees in working in the cloud, especially in its skills which are already enormous in the case of Microsoft SharePoint - and therefore the e-learning platform cannot miss the presentation of basic information on the subject, and perhaps even the development of either a short guide to cloud work or the provision of sites of existing videos, which just refer to work in the cloud. A principal issue determining cloud work is increasingly the need for skilled workers/experts who can carry out remote or hybrid work due to access to a large amount of information. In Europe, there is a noticeable upward trend, especially in skilled workers who, thanks to the cloud, can work with companies from anywhere on earth in a much more flexible manner. These advantages should also find their way into the e-learning platform under development.

Advanced software in the cloud

Working in the cloud is not only about online meetings, or working with text files, posting files, or setting meetings, but also specialized software available from any place where the only condition is an Internet connection and access to a browser. An example of such a solution is the software used to support the design, manufacturing, and simulation process - Solidworks, classified mainly in the CAD (computer aided design) group. This type of software and its capabilities will be described in a later part of the work, but now it is worth mentioning that it is one of the basic tools of an engineer engaged in design, manufacturing using, for example, 3D printing. When it comes to 3D printing, too, many companies have now made it possible to work in the cloud with digital files. The undoubted advantage of such work is that there is no need to install a lot of advanced software on company/private computers very often with too little computing power. Working in the cloud means that every time, every year, our software “does not slow down” due to increasing hardware requirements, as it uses the computing power of the cloud and not our increasingly older computer hardware. In our case, we execute processes through the window of our own web browser hence internet speed is extremely important. The metal industry can also benefit from advanced measurement software, which can certainly be found in the cloud. In many cases, an employee carrying out remote/hybrid work at home from a browser panel can carry out the work on its own - which is worth emphasizing in the e-learning platform materials under development. An example of a video which, in English and with Polish subtitles, explains the issues of working in the cloud using Solidworks software is presented at the link and can be used on the platform under development by appropriate reference [9].

Vocational training thanks to cloud work can immediately almost overnight acquire the latest tools (rent them) and conduct training in hybrid mode, where the student trainee or company employee uses a home or company computer sometimes with too little computing power. In addition, installing advanced software on a company computer would require the purchase of an expensive license, which is not always cost-effective for training.

The cloud in international cooperation currently plays a key role. When it comes to implementing international projects, hiring experts, and expanding a company's reach, its high flexibility and computing power is an invaluable tool. When it comes to implementing VET in workplaces, relying on the Microsoft SharePoint cloud will not only allow better training, classes, and activities, but will also enable trainees to acquire digital competences in cloud working, which is worth implementing nowadays in vocational training.

Computer simulations - virtual reality

Virtual reality is one of the digital tools with great implementation potential both in companies and in vocational training. Its good example is the possibility of training employees using goggles and virtual reality tools that make it possible to almost ‘move’ to another factory and implement remote training but using virtual reality. This training format makes it unnecessary to make a long-term trip to another facility and, in addition, the employee has the possibility to use such tools when, for example, performing maintenance activities and repairing equipment.

In the case of vocational training in the metal industry, the virtual reality tool for simulating the welding process, as shown in Figure 4, is ideal for this process.

Figure 4. Simulation of a welding process using Virtual Reality tools [10]

As part of this project and the training materials being developed, it is worthwhile to familiarise students and VET trainers with virtual reality issues in, for example, the process of welding metals. The metal industry very often uses welding as a method of joining and repairing manufactured components. An example of the operation of such a welding simulator is presented in the video from link [11], which I recommend including in the e-learning platform under development. It seems worth gathering on the platform a library of videos developed by suppliers of simulators supporting the learning of technological processes - not only welding. At the same time, it recommends purchasing simulators according to needs and including training based on the use of virtual reality in the didactic process. It is also worthwhile, in this area, establishing cooperation with local centers dealing with welding or the metal industry in the broadest sense, to tailor specific tools to make the most of the knowledge gained in this way in industrial practice.

Digital CAD documentation

Currently, technological documentation is created using digital CAD (computer aided design) software. There are other types of digital tools to support the design process, such as CAM (computer aided manufacturing) or CAE (computer aided engineering), but CAD is one of the most widely used.

In industrial practice, the use of CAD software is unquestionable, but it is worth introducing this type of digitisation into vocational training. At present, graduates of technical colleges, i.e. engineers and master's degree holders, have adequate knowledge of the software but vocational schools and their graduates and vocational courses already often overlook these issues. It seems that nowadays the teaching process in the VET sector, thanks to working in the cloud and easier access to such solutions, can implement these tools more and more cheaply and, importantly, also thanks to the cloud, implement part of the classes in a hybrid/online form, without need to install the software. For each of the above-mentioned software, it is extremely important to adapt and select the appropriate programme according to the needs of the local industrial market, which is already using these types of tools. In the case of CAD software and working in cloud in both industrial practice and the vocational training sector, it is possible to share work and collaborate on the creation of documentation on the same file, which significantly speeds up work, while at the same time allowing control over changes made.

CAD software eliminates in many cases the need for manual calculations of, for example, sheet bending lines by creating this almost automatically for the planned sheet. This eliminates unnecessary waste of material and contributes to the environmental aspect of production.

I recommend that within the framework of this project and the e-learning platform under development, information should be provided on the possibilities of designing with any CAD software, perhaps after consulting with the local audience to tailor the programme to their needs.

Recommendations

From this chapter, I recommend developing digital material for the e-learning platform, presenting both digitisation and its selected areas, such as cloud work and virtual reality. Undoubtedly, the issue of cyber security should also be included in the material, as well as cloud work and its possibilities. In addition, I recommend developing some questions for self-answering or in the form of a multiple-choice test. It is important that the following questions or others included at the end of the chapter are relevant to the content of the digital materials they refer to.

2.4. New Design Philosophy: Smart Manufacturing and Ecology

The process of designing and training those responsible for manufacturing is one of the many challenges facing us in Industrial Transformation 4.0. In this area, I encourage you to present material on both smart manufacturing and ecological aspects on the e-learning platform.

Smart manufacturing: “fully integrated collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs” - definition from NIST (National Institute of Standards and Technology).

We can say that the above definition fits the reality of SMART FACTORY, i.e. a place where digitisation enables the integration of manufacturing systems to reduce downtime and failures, increase productivity and quality, avoid accidents related to the health and lives of employees and, most importantly, increase the competitiveness of the company. An example of a smart manufacturing project and a smart factory are shown in Figures 5 and 6, respectively.

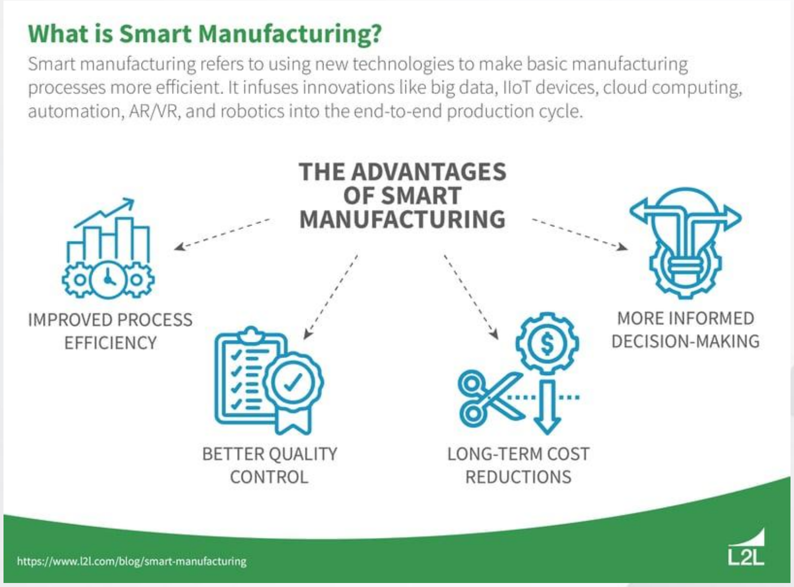


Figure 5. Integration of systems in smart manufacturing and the advantages of this in the transformation of Industry 4.0 [12]

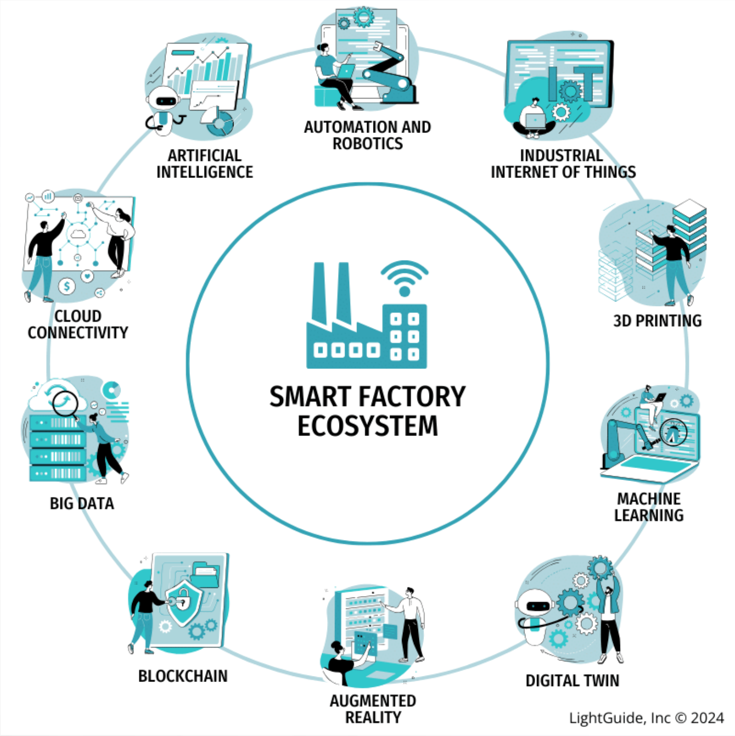


Figure 6. Integration of systems in smart factory and the advantages of this in the transformation of Industry 4.0 [13]

The integration of all systems and the advantages this brings are presented in many literature items, for example [14] and online sources. As part of the work on e-learning, the platform recommends the inclusion of graphics and the development of a video or references on the platform to videos showing how smart factories implementing smart manufacturing function, as this knowledge highlights the importance of the various tools of Industry 4.0 and can in some way positively influence the learning of subjects containing knowledge in this area. This knowledge of the smart factory and smart manufacturing should also include training trainers in implementing modern training tools. In the platform materials being developed, references can be made to specific companies that have implemented smart factory tools and concepts such as smart city.

Ecology in the Area of Smart Manufacturing

The aspect of ecology in new design philosophy concerns mainly the departure from the current model, based very often on modular construction of mechanisms in favour of fragmentation of the construction in a way that enables its repair at low financial cost but also at low ecological cost, which consists not only of the energy aspect but also of the aspect related to the harmful production process. Rather than a single integrated module containing components that cannot be repaired as separate components and require the entire module to be replaced, the development should move towards a design where individual mechanisms can be replaced separately, thus limiting the negative ecological aspect associated with the unnecessary production of properly functioning mechanisms. This aspect of ecology is emphasised not only in the automotive sector or metal production, but in the field of everyday components, which concerns us all as users.

In the aspect of the metal industry and the implementation of smart manufacturing solutions, it seems justified to perform a kind of analysis of the current production technology and to take measures aimed at minimising the consumption of both materials from which products are manufactured and materials supporting the technological process. In this area, there are real opportunities to reduce the consumption of electricity, water, chemicals, and unnecessary transport, which in a measurable way we can present as the implementation of environmental good practices within smart manufacturing. The key to the implementation of any smart manufacturing and smart factory solutions is to make measurable changes in the era of regulations being introduced that determine actions within the framework of the energy transition and the European Green Deal.

In smart manufacturing, I recommend that certain process-related issues determining ecological changes in the functioning of the company be developed in the information material of the e-learning platform. These changes may be both product design and the technological process. At the same time, the e-learning platform could have a database of links to currently existing publicly available materials in the field of smart design in ecological aspect and smart manufacturing.

Recommendations

From the presented chapter, I recommend the development of digital material for the e-learning platform presenting both smart manufacturing and smart factory as a holistic fulfilment of the industrial transformation of Industry 4.0. Moreover, I recommend the development of several questions for self-answering or in the form of a multiple-choice test. It is important that the following questions, or others included at the end of the chapter, are relevant to the content of the referenced digital materials.

2.5. 3D Printing

3D printing technologies, also known as additive manufacturing, have become a permanent feature of the manufacturing world. Depending on the company and the branch of vocational training, the role of 3D printing is different.

What is 3D Printing?

3D printing technologies have been known since the 1980s, when the first 3D printing systems were developed. This period is mainly marked by two 3D printing technologies: fused deposition modelling (FDM) and photo-curing of liquid polymer resins - stereolithography (SLA). Since then, 3D printing technology has developed rapidly in terms of both new technologies and materials.

3D printing involves building a model layer by layer based on digital 3D file models. The digitalisation of 3D printing is advanced and developments in this area are strongly visible. Currently, 3D printing allows models to be produced from plastic, metal, and ceramic-based materials. The most common materials used in 3D printing include ABS, polamid, PLA, tool steels, titanium-based steels, stainless steels such as 316L, materials based on quartz sand and ceramics, etc. Such a wide range of materials makes 3D printing very applicable.

Principle of Operation

The e-learning platform under development should include information on the basics of 3D printing illustrating how advanced the process is, and therefore a brief model of manufacturing prototypes using 3D printing technology and information on the stage of 3D printing is presented below in Figure 7.

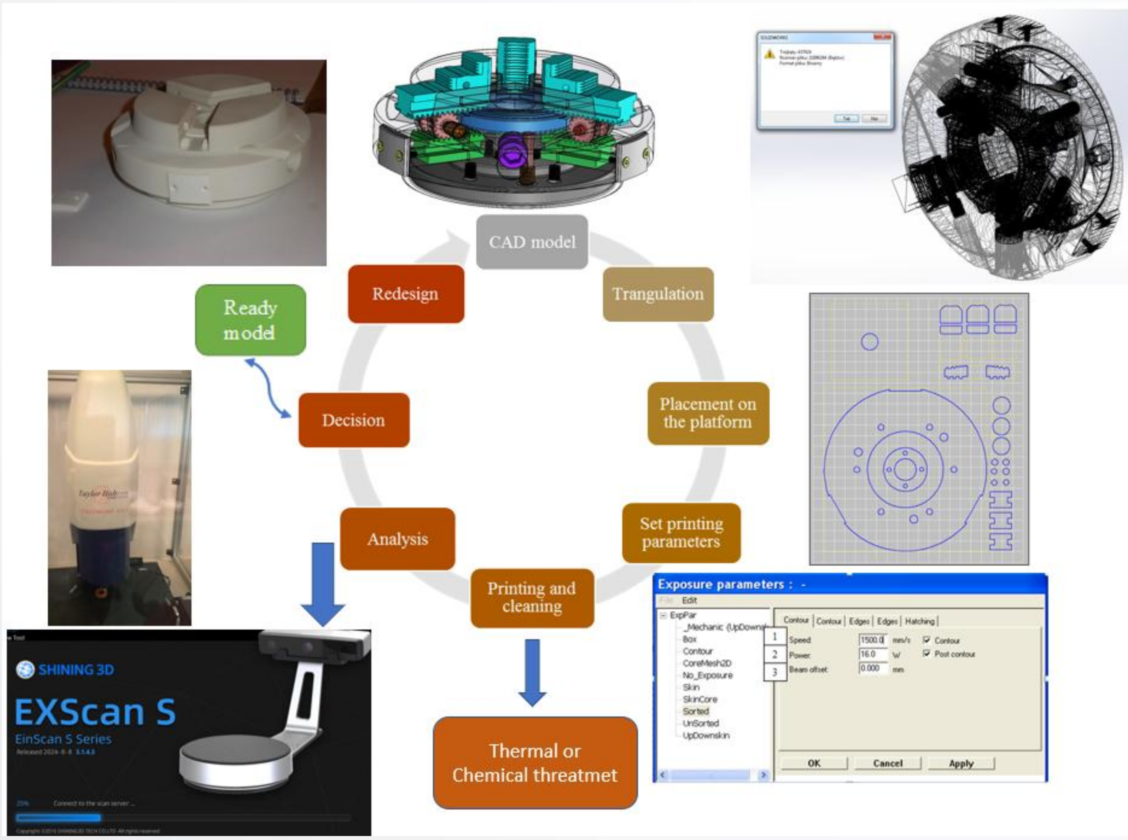


Figure 7. Methodology of manufacturing models by using 3D printing technology and analysis tools

As can be seen, 3D printing technologies are not easy to use and require a great deal of knowledge at each stage of manufacturing, shown in Figure 7. It is worth noting that the implementation of 3D printing requires an employee with a great deal of technological and digital knowledge. Work with 3D printing begins with the development or obtaining by other methods of 3D models - CAD, then we proceed to the process of saving the file as a triangle mesh (e.g. STL), the next step is the appropriate location of the model on the working platform of the 3D printer in a digital form and the selection of an appropriate 3D printing strategy through the selection of technological parameters and, in many cases, the selection of appropriate supports supporting selected fragments of the model. The next stage is already followed by the production process, which, however, also requires cleaning operations, removal of supports, heat or chemical treatment and proceeding to the analysis process. This is followed by the manufacturing process, which, however, also requires cleaning operations, removal of supports, heat or chemical treatment and the transition to the analysis process. The analysis process of 3D printing in terms of prototype manufacturing covers a wide spectrum of tests, but the key is the use of 3D scanning, for example, which will be described in detail in the next chapter. The analysis is followed by the decision stage, if the model meets the quality expectations the manufacturing process can be completed, however, in the case of defects, inaccuracies error the technological process must be repeated, and errors occur at any stage shown in the pie chart in Figure 7.

In the aspect of the e-learning platform, I recommend presenting information about the complexity of the prototyping process to make employers, employees, trainees aware that 3D printing requires a qualified employee after appropriate training.

3D Printing in Metal Factory

The implementation process of 3D printing in the industrial aspect is now at a very advanced stage. Almost every manufacturing industry uses 3D printing to some extent, and very often other non-manufacturing industries use 3D printing to increase competitiveness in the market.

In the area of the metalworking industry, 3D printing mainly comes down to the production of prototypes or short production runs. In this area, a combination of a low-cost 3D printer implementing plastic FDM technology in the new ISO/ASTM 52900 standard known as MEX (Material Extrusion) and a technology from the metal powder 3D printing group, Powder Bed Fusion (FBF), is ideal. 3D printing in metal companies allows several prototypes to be developed in a brief time. Initially using 3D printing in plastic with a low material cost of around €25-30/kg, followed by metal-based 3D printing. It is worth mentioning this role of 3D printing on the e-learning platform - the elimination of costs and the brief time it takes to put products into mass production by speeding up the prototyping process. An example of a model made by 3D printing from metal powder-based material is shown in Figure 8. It is worth noting the need to design support structures and the problematic nature of their subsequent removal. 3D printing, due to the flexibility of production, the lack of the need for tools in the technological process, the possibility of producing models with complex shapes and the wide range of available materials in the era of industrial transformation 4.0, is an essential tool for the competitive advantage of metal/manufacturing companies.

Figure 8. Metal 3D printing - manufactured example [15]

3D Printing in VET

In the case of 3D printing technology and the vocational training industry, two issues are worth noting:

– an introduction to the general methodology of 3D printing.

– training in printer operation.

For the first issue, the general methodology should certainly be included in the developed training programmes of the VET industry. The e-learning platform should introduce such issues but also introduce the possibility of implementing the second part, i.e. training in the use of such systems. The e-learning platform, thanks to its cloud-based capabilities, fits perfectly into the realities of industrial transformation. An example of such a solution, which can be included in the platform under development, is the free **MakerBot CloudPrint** software, which, from any web browser, makes it possible to simulate the 3D printing process and analyse the impact of technological parameters on selected quality features of manufactured models. In addition, there are possible tasks to be implemented on the e-learning platform, for example to assess the influence of technological parameters on the manufacturing process:

– analysis of digital files.

– influence of the thickness of the layer being built.

– analysis of the 3D printing angle.

– filling density.

Support for the implementation of such exercises can be provided by access to materials on an e-learning platform, for example as a PDF book with exercises. An example of such a book is **“Fundamentals of Rapid Prototyping 3D Printing FDM/FFF Technology”**, by Kozior and Bochnia. A book with exercises precisely for the cloud-based software and 3D printer makerbot sketch is available for purchase online as a paperback version and as a PDF [16]. This book has just been developed by the authors for training purposes of the VET sector.

In the area of qualification of 3D printer operators, international ISO/ASTM standards are emerging that refer to the training and certification process in operation of 3D printing of metal powders in particular - ISO/ASTM 52926-2:2023 **Additive manufacturing of metals - Qualification principles - Part 2: Qualification of operators for PBF-LB** [17]. It is worth emphasising that 3D printing as a specialised industry in terms of vocational training is of great value to the employee in terms of job search. A major challenge in 3D printing, especially for metals, is the area of safety, which I recommend highlighting in the e-learning platform materials.

In VET training in 3D printing, it is worth considering the possibility of delivering classes in a hybrid form, for example, the theoretical part as cloud work and the practical part with purchased 3D printers, which for teaching purposes are not expensive and their prices start from as little as EUR 1,000 per printer. Nowadays, vocational training centers are increasingly using 3D printers for training purposes which they have purchased or use the base of, for example, technical colleges.

Recommendations

From this chapter I recommend the development of digital material for an e-learning platform presenting both 3D printing as an innovative tool for Industry 4.0, but one that is extremely advanced, requires training and has a high growing potential for implementation in the metalworking industry. It is important that the following questions or others included at the end of the chapter are relevant to the content of the digital materials they refer to.

2.6. 3D Scanning and Metrology

The 3D scanning is undoubtedly one of the most relevant in terms of the implementation of Industry 4.0 tools, implementable in the manufacturing and metal sector and the vocational training sector. 3D scanning of physical models is, in terms of working with digital files, just as complex as 3D printing and, in many applications, even more so. In the case of the implemented e-learning platform, it is worth paying attention to issues related to the degree of complexity and key areas related to the subsequent analysis of the results obtained from scanning.

3D Scanning Procedure

3D scanning begins with the appropriate setup of the scanner and the selection of its scanning parameters. An excellent example of scanners that are widely used in industrial practice in the metal sector and in VET is the rotary table scanner. In terms of real-life use in the metal industry, such a scanner allows objects as small as several meters to be scanned and dimensionally inspected using dedicated software. 3D scanning skills in this aspect can also be acquired using didactic 3D scanners equipped with a rotary table but characterised by a compact design and dimensions that allow the scanners to be placed in teaching rooms.

Once the scanning parameters have been selected, the process begins, and the so-called point cloud is collected. For a simple object, the point cloud can be as large as several million points, and the process itself can take many minutes. The point collection process is followed by data processing consisting of:

- combining individual scans.
- removing erroneously collected points.
- filling in areas that could not be measured.
- creating the final mesh and generating an output file such as ASC or STL.

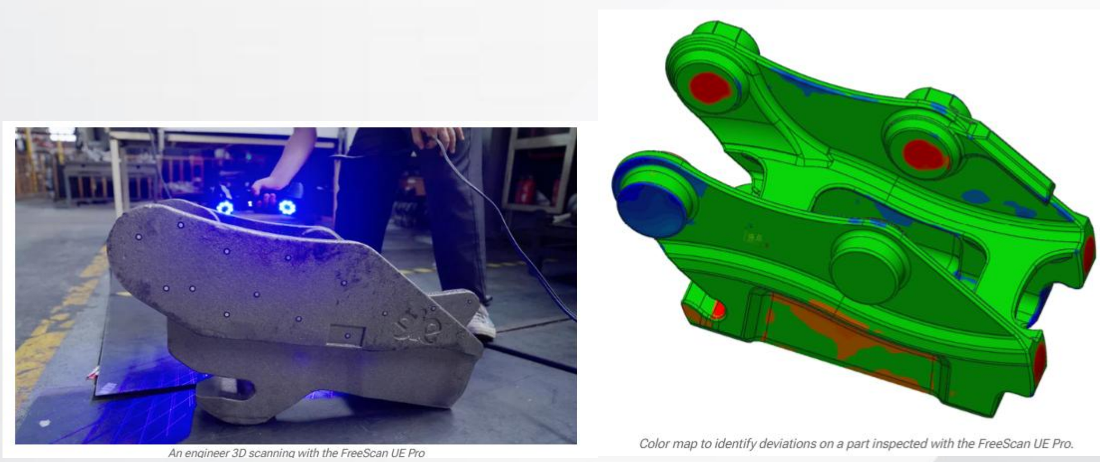
All the above-mentioned points require the acquisition of the relevant knowledge, which can certainly be obtained by carrying out, for example, exercises at the vocational training center while working with didactic scanners. An example of the integration of the 3D printing process and 3D scanning is shown in the example of the didactic training room for vocational education located in the Laboratory of

Unconventional Manufacturing Technologies at Kielce University of Technology, Poland, shown in Figure 9. A link to the laboratory's website can be found in the literature [18].

Figure 9. Integration of 3D printing and 3D scanning for didactic purposes of vocational education implemented at Kielce University of Technology, Kielce, Poland

The continuous development of digital scanning-related technologies means that industrial systems increasingly resemble metrological measuring instruments like coordinate measuring machines or measuring arms, although their role is similar. An example of such a scanner is shown in Figure 10. An important aspect of 3D scanning is the possibility of dimensional inspection and, above all, rapid error detection, which is ideally suited to the realities of smart manufacturing and smart factory. 3D scanning, as a rapid metrological system for assessing dimensional accuracy, can perform almost real-time inspection of dimensionally large metal manufactured components and, importantly, such 3D scanning systems can very often be mobile metrological inspection systems.

Figure 10: 3D scanning using 3D scanner [19]



An engineer 3D scanning with the FreeScan UE Pro

Color map to identify deviations on a part inspected with the FreeScan UE Pro.

Figure 11: Dimensional inspection of a model after 3D scanning in terms of deviations between the expected model and the received model [20]

Recommendations

From the presented chapter I recommend developing digital material for an e-learning platform presenting 3D scanning as an innovative tool of Industry 4.0, however, extremely advanced, requiring training and with a high growing potential for implementation in the metal industry, especially in manufacturing process metrology. It is important that the following questions or others included at the end of the chapter are relevant to the content of the digital material to which they refer.

2.7. Artificial Intelligence

Artificial intelligence in industrial applications has a wide range of uses, where one of the key areas is precisely the manufacturing process and its aspect related to automation and LEAN Manufacturing. Machine systems that operate using artificial intelligence can autonomously (autonomously) control the operation of machines and equipment, optimising their operation as in the LEAN process, but in an autonomous manner. The advantages of such a solution are mainly the issues described below such as [21]:

- increased productivity.
- reduced downtime resulting from, for example, breakdowns and material shortages.
- improved quality.
- time savings.
- increased competitiveness of the company.

An excellent example of the application of artificial intelligence in large industrial plants in the metal sector is the use of machines, equipment, and software based on artificial intelligence (AI) in aspects of maintenance and prediction of events in this area such as breakdowns, material shortages, wearing and tear. An application of AI is also an all-important area of quality control. All these activities are carried out using many sensors and high computing power, allowing preventive action to be taken and costly downtime and repairs to be avoided.

However, such use of artificial intelligence requires training of employees in the functioning of AI tools and the need to provide access to process data, which can occur when properly servicing a company's machinery and equipment. Awareness of employees at every level about the relevance of such a complex process and the impact of the operation of a single sensor on the correctness of the prediction is crucial.

Examples of artificial intelligence solutions include, for example, optimising the supply chain in the metal industry and customising products. Both examples are based on the principle of set analysis operating under the name of big data and therefore a widely discussed tool of Industry 4.0. An example of the integration of widely understood tools within Biga data is shown in Figure 12. It is worth including information on this topic in a graphical form in the e-learning platform under development.

Figure 12. Visualisation of so-called big data for the manufacturing sector [22]

The e-learning platform under development should certainly include both basic information about the advantages of using artificial intelligence in the manufacturing process, but also more detailed information about practical types of software already in industrial use today.

Examples of software that currently are based on artificial intelligence and can be implemented in the metal industry are the following.

Welding process

In the welding process, a good example of the application of artificial intelligence is software such as COGNEX VisionPro, which uses artificial intelligence to analyse the images and data received from the welding process, consequently allowing automatic and autonomous adjustment of welding parameters in real time. The speed of the process and the ability to develop the AI base results in a product with higher weld quality and fewer defects.

Metrology - Quality Control

Using image analysis acquired from cameras and image recognition technology in visual inspection in the production process, we get much more precise and faster detection of defects and flaws in almost real time and elimination of defective models of further production processes.

Production Management Systems

An example of the implementation of tools supporting the process of planning and optimising production plans using artificial intelligence algorithms is Siemens Opcenter software. The software reduces the time associated with machine changeovers and downtime between operations.

Simulation and Modelling

Software such as Altair HyperWorks (Design and Simulation Platform) uses artificial intelligence tools in physics, design, engineering work, allowing faster and more efficient design of new components for the metal industry, for example. A whole scope of dedicated software to support the engineer's work is available on the platform www.altair.com (2025).

Vocational Education

It seems that, based on the many systems available on the market implementing support for the production process both in industrial implementation and vocational education, there is a real possibility of choosing a particular software and implementing it in the teaching process. In the e-learning platform currently under development, it is worth mentioning the already well-known applications of artificial intelligence, which we naturally encounter on a daily basis, such as chat GPT, and chatbots that help to clarify our queries, orders and support the process of contacting customers, but at the same time a great deal of emphasis should be placed on issues of production support, quality control analysis by a fast vision system using artificial intelligence or welding process control.

Recommendations

From the chapter presented, I recommend the development of digital material for an e-learning platform presenting artificial intelligence as both a tool used daily and to support the work of the engineer and metalworkers in manufacturing/quality control/maintenance/planning, etc. It is worth highlighting big data. It is important that the following questions or others included at the end of the chapter are relevant to the content of the digital material to which they relate.

2.8. Production Automation and Robotics

The modern manufacturing process uses an increasing number of robots in many areas of manufacturing. A process in which machines perform more and more of the tasks carried out by humans minimizes accidents and speeds up production, in many cases, reduces the downtime, what results in increasing productivity. The industrial transformation, robotisation through the integration of multiple devices with the Internet and cyber-physical systems is speeding up work and fits into the smart factory framework. The introduction of robotisation into the production process allows to carry out often the hardest operations from a human perspective and, as in previous Industrial Revolutions 1-3, improves working conditions.

The introduction of machines to streamline the production process and thereby increase the automation of a company in the age of the ongoing industrial revolution cannot take place without the use of robots. Robots within companies are used for:

- transport;
- inspection;
- assembly;
- welding;
- painting;
- packaging and sorting;
- cleaning;
- prototyping (3D printing).

Nowadays, the development of control systems, the use of artificial intelligence and advances in technology are making the cost of implementing robots in industrial applications ever lower and their implementation simpler. Until recently, robots used a simple control and guidance system, and now AMR (Autonomous Mobile Robots) use artificial intelligence and machine learning.

In the e-learning platform under development, it is worthwhile to include general information about robotisation and automation in metal sector enterprises, but at the same time it is worthwhile to orient some applications to the example of AMR robots in terms of their practical use and programming.

Recommendations

From the chapter presented, I recommend the development of digital material for an e-learning platform presenting automation and robotisation as interlocking tools of Industry 4.0. It is worth noting the use of artificial intelligence in this area and the decreasing costs associated with it. It is important that the following questions, or others included at the end of the chapter, are relevant to the content of the digital materials they refer to.

2.9. LEAN in metal production

Lean design (LEAN) fits perfectly with the smart manufacturing and smart factory. Lean in manufacturing is the perfect idea for Industrial Transformation 4.0 as it requires the implementation of changes in many areas, as is the case with many of the tools of Industry 4.0. In the area of the manufacturing process and factory operation, LEAN is about designing the technological process in an appropriate way to reduce costs/operations, implementation time, prototyping time, complaint time, procedure management issues, etc.

Several of these issues can certainly be implemented in the aspect of the technological process for which the technological staff of a company in the metal sector is responsible. In this area, we enter the issues of training these employees already at the vocational training stage.

In terms of training, however, it is important to consider LEAN issues for the newly implemented tools of Industry 4.0, for example cloud work, which reduces precisely the time needed for production, complaints, implementation of new technologies, documentation workflow. In addition, LEAN manufacturing can be implemented in prototype manufacturing using 3D printing and making rapid prototypes themselves for rapid verification with a 3D scanner. The system integration also allows lean design of used material and optimisation to meet quality requirements while ensuring low weight and low energy consumption in production.

The LEAN manufacturing, we also touch Closed Circuit Economy, i.e. the design of the technological process to reduce energy consumption, the design of the technological sequence or manufacturing operations to reduce the negative impact on the environment despite the profitability of certain process procedures. In the case of manufacturing technology, improvement of the technological process, for example, minimising the number of press movements, the number of necessary heavy model transports, the number of necessary fixtures, etc. [3], or standardising certain tools can bring significant benefits not only in terms of production costs but also in terms of time, which creates space for new orders and gives more capacity.

In the process of training and developing the online platform, it is worthwhile including information that the LEAN philosophy in the company should not as become the wheel of all areas of the company. The training area for VET employees should include LEAN manufacturing as a core knowledge related to each technological process: producing more with less.

In addition, the implementation of LEAN manufacturing contributes to a reduction in the number of complaints and thus an increase in the quality of the models produced. The current employee is required to be involved in the company's activities and his or her LEAN activities, even on the smallest scale, increase the potential of the production company.

Recommendations

From this chapter, I recommend developing digital material for an e-learning platform presenting LEAN as a design and manufacturing philosophy focused on smart manufacturing and smart factory. It is important that the following questions or others included at the end of the chapter are relevant to the content of the referenced digital material.

3. Conclusions

In summary, the e-learning platform to be developed may be based on the guidelines presented but may exclude certain issues to suit the current needs of the metal industry in the region. In addition, the scope of the e-learning platform may go beyond the areas discussed in the presented document to tailor the platform's programme to the needs of VET in the country and region.

Modern industrial tools, which are part of Industry 4.0 transformation, need to be implemented both in industrial practice and in vocational training. Great emphasis should also be placed on the ecology of the production process and the safety of using modern tools such as 3D printers, robots, etc.

The form of the e-learning platform can consist of content presented in any way, for example: videos, presentations, a library of links to websites/platforms, or training materials such as PDFs with exercises.

The questions in the table at the end of each chapter can be grouped together and prepared as one or two tests at the end, rather than separately for each issue presented in this document.

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