Basic Technologies and Models for Implementation of Industry 4.0

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Industry I4.0, Education E4.0, Web 4.0 and Knowledge Needs

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Abstract: *Industry I4.0 is a term we always come across when talking about today's advanced technologies, especially in manufacturing plants. At the same time, we usually forget that the latest development, stage I4.0, was achieved mutually through the acquisition of the necessary knowledge, which was becoming more and more diverse, and had to be obtained in an ever-shorter time. From the point of view of education, similarly to industrial development, we can also talk about today's level of education, i.e., Education E4.0. An important contribution in the development of technology, both in terms of I4.0 and E4.0, undoubtedly enabled the development of web technologies. Web technologies also developed gradually, but much more intensively and in a shorter time, until the current state of Web4.0.*

The paper summarizes, in a transparent manner, the characteristics of the individual development stages of the state of the industry from I1.0 to I4.0, education from E1.0 to E4.0as well as the impact of web technologies from Web1.0 to Web4.0. At the forefront of the discussion is the interactive influence and development of all three mentioned key players, which, mutually, have led to the current state, which could be called Technology Society 4.0. In this case, the individual necessary knowledge, skills, as well as the methods of imparting and acquiring knowledge, are given according to individual development periods.

Keywords: *Industry I4,0, Education E4.0, Web4.0, milestones, interaction, knowledge*

1. Introduction

Industry I4.0 is an extremely common term these days denoting the current state of technology and ‘’spirit’’ connected to every pore of our daily life. The fourth industrial revolution, Industry I4.0, emerged with the introduction and use of control over various production processes, using data-driven scientific methods and intelligent production structures. Ever since the first industrial revolution, our view of the world has been changing constantly, and for each period the view is different, aligned with the state of technology and the necessary knowledge and skills. Thus, considering the turning events and related time milestones, today we can talk about the development stages of industrial development, from the initial Industry I1.0 to the current Industry I4.0.

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Similarly, we can discuss educational revolutions (or evolutions) in terms of the necessary learning content, knowledge and skills in education. These are also time-defined in some way, according to the method of implementation and approach to the states from Education E1.0 to Education E4.0 (or also referred to as Classroom C1.0 to Classroom C4.0), except that these stages of educational development are less known to the general public.

The latest, modern approaches to education have certainly been made possible by the extremely fast development of the Internet and web technologies. From this point of view, the development stages could also be divided into time periods from Web1.0 to Web4.0. Unlike the development phases of education or the development stages of industry, the development of web technologies took place extremely quickly and in a much shorter period.

For a better understanding of the temporal correlation, mutual content connection and mutual influence between the individual stages of the development of industry, education, and the development of the World Wide Web, we will first summarize the basic characteristics of all three, that is I, E and Web development stages briefly.

2. Industry Development Stages from I1.0 to I4.0 – Necessary Knowledge and Skills

The period of *Industry I1.0* (beginning around 1760) was characterized by using water and steam-powered hardware and a suitable way of transferring the motive power to individual workplaces. This period was characterized by use of transmission of mechanical energy transfers and the arrangement of machines according to the available power.
Before the invention of the steam engine the sequence of (manual) machining and production processes was managed (and determined) by one person. During the period of manufactory, the benefits of the division of work were used. The first work groups that performed only one operation appeared and the flow of material was organized and regulated. The situation changed when an independent source of energy appeared in the form of a steam engine. From the central power supply, the transmission of power to mechanized processing devices was carried out via transmission drives. The flow of energy was dominant, determining the layout of the machines, and, thus, the design and appearance, as well as the dimensions of the factory. The arrangement of the machines was carried out according to their type or type of processing (e. g. turning, milling), or according to their size (large, small machines).

The necessary knowledge and skills in this period could be said to have required knowledge in the field of energy production (mainly steam), the construction of machines operating on this energy, knowledge of energy transmission and transmitters, and knowledge of basic manufacturing technologies.

The next era, *Industry 2.0* (beginning around 1870), was based on the division of labour and mass production using electricity. In the second half of the 19th century, the discovery of the electrodynamic principle by Werner Siemens led to the use of the electric drive as an alternative source of power. In the following years, this replaced the central energy supply. The first independent, autonomous drives appeared on transfer lines at Ford (1912), and in Europe in the 1920s. The predominance of the flow of energy was replaced by the predominance of the flow of material or of the product. The Second Industrial Revolution was a period of great economic growth, with increased productivity and the replacement of workers using machines.

Based on the required knowledge, there was a need for additional knowledge related to the structure, properties and possibilities of using electric drives and electricity transmission. In addition, due to higher production speeds, there was a need for knowledge about new cutting tools and materials, as well as knowledge in the field of production organization – assembly lines and mass production.

Industry 3.0, also known as the digital revolution, began around the 1970s, with the partial automation of machinery and equipment using microprocessor programmable controllers and computers. It was based on the use of electronic and information technologies for further automation of production.
This era was characterized by the mass production and widespread use of semiconductor digital logic, MOS transistors and integrated circuit chips, and technologies derived from them, including computers, microprocessors, digital mobile phones, and even the Internet. These technological innovations have changed traditional production and business methods. In essence, we can say that the digital revolution has changed technology, from analogue to digital – the era of digitization.

During this period, there was a need to master completely new skills, not only analogue electrical engineering, but also digital engineering. Extraordinary progress in the field of electronics dictated a whole range of special skills and related learning content in the field of electrical engineering and automation, which had to work in symbiosis with various drive concepts (mechanics, hydraulics, pneumatics). This led to a new look at the machine or device, to new, advanced conceptual solutions – Mechatronics.

Industry 4.0 (today's characteristic state) is based on the use of cyber-physical systems where the real world is connected to the virtual (and vice versa). Industry 4.0 is somehow the gateway to the modern world, which includes Cybernetics, Robotics, Big Data, Nanotechnology, Artificial Intelligence, Automation, global citizenship, the digital age, and many other concepts in our lives. (e.g. [1], [2], [3])

In any case, this period has a radical impact not only on the set of necessary modern knowledge and learning skills, but also on the ways of imparting knowledge. The recent Covid-19 pandemic has additionally contributed to the use of new, innovative approaches to acquiring knowledge.

Figure 1 shows a timeline of the mentioned industrial revolutions with their basic characteristics.

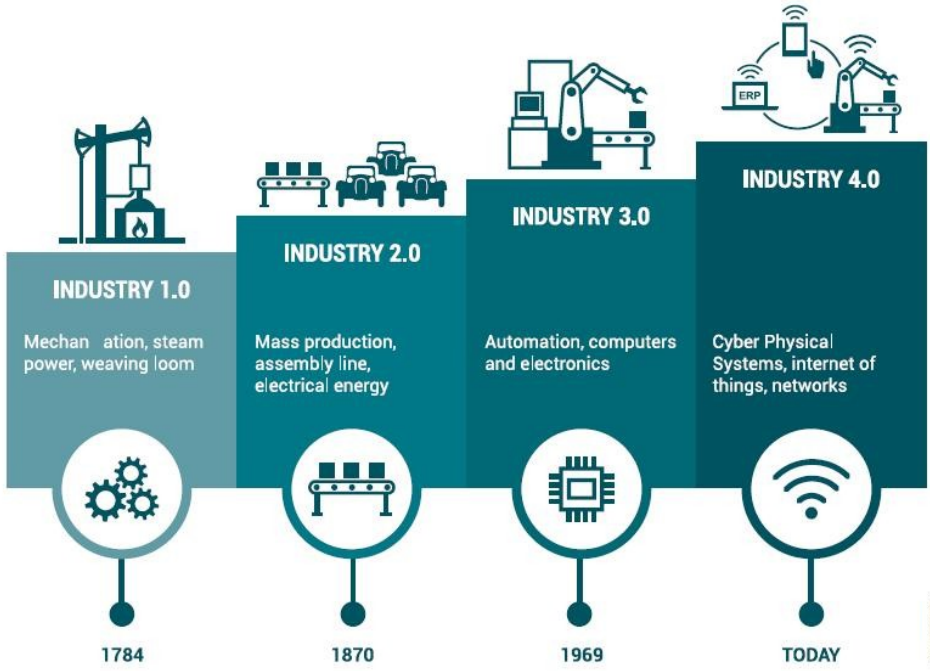

Figure 1. Industrial revolutions through time – from I1.0 to I4.0 [1]

It is absolutely necessary to know the characteristics of the development period of technology, as educational content and the process of imparting knowledge are closely related to them. Users and designers of machines and devices must have knowledge of what industry needs in a certain period.

3. Education Development Stages from E1.0 to E4.0 and Pedagogical Approach

Similar to the development stages of industry and technologies, the methods of education can also be divided into characteristic stages of development, both in terms of time and content as well as in terms of implementation and approach.

Rapid technological development, especially in the last fifty years, has not only influenced changes in the industrial field, but also in education. Similar to the given milestones and stages of industrial development Jacke Gerstein [4]has written down the tentative and approaches in the field of Education, Development Stages of Education, as Education E1.0, E2.0 and E3.0. Nowadays, due to new possibilities and major changes in this field, we have moved to a new, higher level of educational approaches. We also added the stage Education E4.0. The current state E4.0 has been influenced greatly by the development of the Internet and web technologies.

The beginnings of the individual phases of educational development, E1.0 to E4.0, did not coincide in time with the initial periods of the industrial revolutions from I1.0 to I4.0, and they did not last for the same length of time either. All major changes in the way knowledge are delivered have occurred in the last 50 years (before that there were no major, noteworthy changes). By comparison, changes in industry took place over a much longer period of about 250 years. Therefore, there is more divergence regarding the milestones of the development of education than with the milestones of industrial revolutions, where these milestones are defined much more clearly, as they are based on major discoveries and the implementation of achievements in the industry that they changed drastically.

According to some reports, the milestones of (modern) education have been shifted to the present time, as they are limited to the use of the Internet and modern ways of imparting/assimilating knowledge (e.g. [5]), while other sources cover a much wider period (e.g. [6]). Considering the longer time distribution of the levels of educational ‘’revolutions’’, we can list the most important characteristics of each level from E1.0 to today’s E4.0. The focus here is on providing knowledge at higher education institutions.

Education E1.0 is the manner and method of imparting instructions during the ancient and Middle Ages. The process of teaching within that time was personalized and in close contact with the teacher. *This ancient way of education was limited to only a few students, usually selected from the elite class, and it was an informal education and not a structured curriculum. The teacher*

sharedhis knowledge with the students according to his choice, depending on his will and desire, and his mood and current inspiration. This informal education system existed in India, where the teacher was called a guru, and the method of imparting knowledge was the Guru-Shishya Parampara' method, similar to Teacher-Student relationship. Apart from India, such a way of imparting knowledge was also typical of China, Israel, Rome and Greece, and also in tribal societies (this is still the case in some places today).

Although there was no formal curriculum at this time, E1.0 education changed gradually from basic non-formal education to the beginning of higher education, resulting in the establishment of a few universities, such as Nalanda, Takshashila, Ujjain, Viramshila in India and Heian-Kyo in Japan in the 9th century. Religious and spiritual education were also important during this time.

Education E2.0 emerged when, *during the mid-15th century, the invention of the printing press changed the dynamics of knowledge reproduction & sharing the system of knowledge. During this time, books became crucial to the spread of knowledge. In the era of Higher Education 2.0, the process of knowledge transfer changed, and the one-to-one concept (from teacher to student) became one-to-many (from teacher to several students in a class).*

During this period there was only a partial revolution in the pedagogical process, renaissance, reforms and the establishment of universities as centers of higher education. Between the 14th and 18thcenturies, universities were already established in Europe and many other countries, which also opened the door to higher education to common people. *It was a path from the education only of individuals who belonged to the elite to the mass education, including the education of women. Informal education became formal and individual disciplines appeared, so-called subject-oriented knowledge.*

The period *Education E3.0* can also be called the period of democratization of all levels of education, including higher education, which increased the accessibility of all levels of education greatly. *In this state, the state of the 20th century, the blackboard has been replaced using Information and Communication Technology (ICT),* which is often referred to as boring ICT education, in other words: just showing slides, ''slide-show'', ''sliding''. This was the beginning of the digital age, which consists of technology, the use of computers, improved administration and (assumed) better learning, research and development in all disciplines dominated by science and technology.

ICT can have a compelling impact on student learning or the appropriate acquisition of knowledge only if teachers are also digitally ''literate'' and

understand how to integrate these approaches into the curriculum. Different schools in different settings use a diverse range of ICT tools to communicate, create, disseminate, store and manage information. The ICT method also includes education through radio and television broadcasts as well as information already available on the Internet.

The further development of ICT, especially in the field of higher education, has led to a higher level than E3.0 (which is still level used extremely frequently today), i.e., to the *new era Education E4.0. The E4.0 education approach puts the learner at the center, and enables him/her to choose the method of education by structuring an individual path to achieve individual goals* (the latter applies mainly to higher education). It is the so-called collaborative and personalized learning. Now, learners can acquire knowledge at school, on campus, at home, and even at work, every day of the year, depending on their available time, moods and willingness to learn.

Figure 2 shows a timeline of the mentioned education revolutions with their basic characteristics.

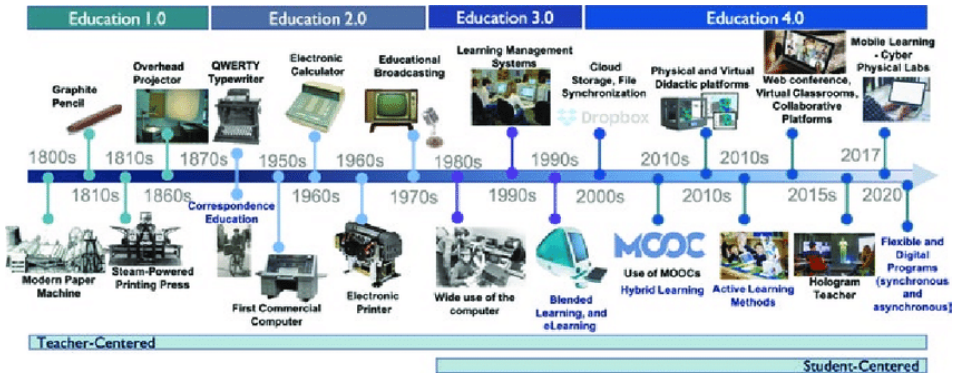

Figure 2. Evolution of technologies and learning methods according to the four periods of education, leading to the Education 4.0-Timeline [6]

Education 4.0 is based on the availability of content. Everything the learner needs is available when he needs it. For this, it is necessary to have a ready-made collection of educational materials that can be offered to learners, especially for students. In this way, they can cover all their needs, whatever they may be. The correct fragmentation of the various learning subjects is essential, as, in this way, we can give the system a certain dynamic, which can be adapted to the student's needs at any time. Learning is not focused strictly on just one specific goal, but is also personalized. It can be integrated easily with other

materials and students or needs for new skills. The latter is especially important after completing formal education, when the need for new knowledge and skills is dictated by the new work environment. Such an approach is typical of the upcoming method of obtaining appropriate Micro-Credentials for a specific professional area and learning content (shorter, topic-oriented learning content with a flexible way of acquiring knowledge, checking it and with the possibility of upgrading). These development facts, development directions and goals are also recognized by the OECD, and guidelines for educational approaches in the future are provided in its documents. [7]

Such an approach enables different ways of cooperation and models of independent learning, where the teacher is more in the role of a mentor (as a provider of knowledge), who (more or less actively), monitors the student's acquisition of knowledge. This is not just about uploading some videos to Youtube and some pdfs, as this approach may be misunderstood, and which we were forced to introduce in the initial period of the Covid-19 pandemic, where the new approach and availability of content for remote learning was indeed ''necessary set up overnight''. It actually means creating a *dynamic learning system* that is in constant interaction with the learner and changes the content offered according to their specific needs at a given time. This is done by including the learner in a heterogeneous group of learners where, although each has their own specific and special needs, they converge at certain points to complete common tasks. [8], [9]

4. Web Development Stages from Web1.0 to Web4.0

The latest state of education, Education E4.0, was made possible by the development of Internet and Web technologies. If, in terms of time, the development of industry from I1.0 to I4.0 took place over about 250 years, major changes in the education system from E1.0 to E4.0 took place in a five times shorter period, i.e., in the last fifty years. Internet and Web technologies, from the first beginnings of Web1.0 to the current state of Web4.0, have developed in ten times less time than the development of the industry from I1.0 to I4.0 in the last 25 years. The latest Web4.0 technologies enable all the advantages that characterize both E4.0 and I4.0. Internet technologies definitely belong to the field of new, modern technologies, which have not only enabled certain improvements in all areas of technology and life, but also enabled completely new solutions.

The Web is the largest transformable-information construct, and its idea was first introduced by Tim Burners-Lee in 1989. [10], [11] Much progress has been made about the Web and related technologies in the past two decades. Web1.0 is

a web of cognition, Web2.0 is a web of communication, Web3.0 is a web of cooperation and Web4.0 is a web of integration. [12] Let's take a brief look at the basic characteristics of each degree which influenced the development of industry and education.
Figure 3 shows the development stages from Web1.0 to Web4.0 with the basic characteristics and differences. [13], [14]

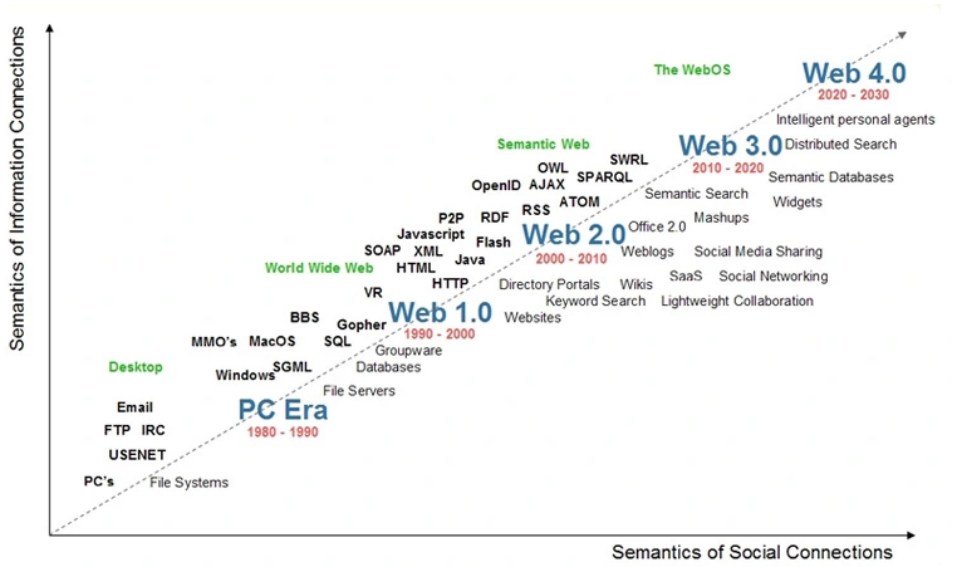

Figure 3. Development stages from Web1.0 to Web4.0 [14]

Web1.0, the first version of the World Wide Web, was developed by Tim Berners-Lee in 1989, and lasted until around 2004/2005. The websites of this era were purely informational in nature, and included only static, read-only content. There were no interactive content or design options, and the links were via hyperlinks. The primary goal of the first websites was to allow everyone to access public information and establish an online presence. Other than that, it was only possible to write and send text emails, while unable to upload or attach images. However, static pages hosted on web servers (managed by ISPS or free web hosting providers) were mostly personal websites. They were very popular and paid for. Websites were often designed by individuals or small groups of people.

Web2.0,with the advent of social networks and a simpler way of communicating from different parts of the world, ''opened up a new, wide world of possibilities'' to many people who, until then, worked in a narrow environment,

in a classical and conventional society. Web2.0 appeared in the early 2000s, and, with the introduction of new technologies, marked the way of using the Web. Blogs, wikis and social media platforms appeared, such as Facebook, Twitter, YouTube or Discord. Thus, users could communicate with each other and with online content in new ways (creating their own content and sharing it with others).With Web2.0 there was a shift from static, read-only content to dynamic, interactive content. Web 2.0 is seen as a people-centered, participatory, read-write web designed for two-way communication. Unlike Web1.0, Web2.0 gives more control to users and provides interaction, bringing about major social changes. All this has led to the spread of the Internet, and also to various mobile devices such as iPhone and Android, leading to the dominance of applications such as WhatsApp, Instagram and others, up to e-shops and the collection and analysis of customer habits.

Web3.0 is a new type of web, that emerged around 2006 and has been defined as the intelligent or semantic web, that includes integration, automation, discovery and data, thus promoting mobility and globalization. Powered by Artificial Intelligence (AI) it makes it easier for users to search, share and combine. It allows a person or computer to start in one database and then move through an infinite number of extensive databases – Big Data. The goal of linked data is to enable computers to do more useful work for us by teaching machines how to read web pages. The main goal of Web3.0 is to make the Web more intelligent and more connected, by using technologies such as Artificial Intelligence (AI), blockchain technology, Machine Learning (ML) and the Internet of Things (IoT), and, thus, it has become even more interesting for industrial use. With Web3.0, the Web can ‘’understand’’ the meaning of content and available data, and connect them in new and meaningful ways. In addition, Web3.0 also enables direct interaction between devices without human intervention. This IoT provides new opportunities for automation and efficiency of all systems.

Web4.0 is (today’s) fourth generation of the web, characterized by a more collaborative and interactive approach to web development. Web4.0 applications are designed to be more user-friendly and allow users to share information and ideas easily. Some of the most popular Web4.0 applications include social networking sites, blogs, wikis, and video sharing sites. Web4.0 represents a shift from traditional web development models to a more collaborative and user-centered approach, so it is suitable for advanced developments and industrial solutions as well as for the process of acquiring knowledge. Although it seems somewhat futuristic, we can say that it has been with us since 2016, except that the methodologies that we have known since before are much more sophisticated with the use of Artificial Intelligence.

5. Correlations Between I4.0, E4.0 and Web4.0

The individual phases of the development of both industry and education and the World Wide Web, which is involved strongly in all the activities of our everyday life, were presented in the previous chapters, including the individual characteristics of each development stage and interdependencies. [15], [16], [17], [18]
We have reached the current state of the I4.0 industry gradually over the past ten years, somewhat since 2011, when experts saw the big changes in the advancement of technologies as revolutionary – a new industrial revolution. All development phases from Industry I1.0 to the latest Industry I4.0, with basic characteristics, are shown in Table 1. [18]

Table 1. Industry I1.0 to I4.0 comparison

Industrial revolution	Time period	Characteristic technology
Industry I1.0	Late 18th century	Mechanical production and steam power
Industry I2.0	Beginning of the 20th century	Electrical drives and production lines
Industry I3.0	Beginning of the1970s	Digital automation
Industry I4.0	Present	Cyber-physical systems

For the current state of Industry I4.0 we could say that it actually (pre)started with the use of semiconductors, and, later, the first microprocessor controllers. The latter have evolved into more user-friendly and flexible programmable electronic devices that have increased the efficiency and flexibility of production in the form of digital automation significantly. The latter is still carried out today in modern automation systems, except that the devices and systems are more intelligent and better connected, even self-learning.
The general development, not only in the field of Industrial Automation, but also of comprehensive industrial production systems, required a completely new set of necessary skills, a faster way of acquiring them and their faster implementation in the working environment. As a result, it was necessary to find new approaches to providing learning content. The Covid-19 pandemic and the forced use of distance learning contributed to a very large extent, not only when imparting theoretical knowledge, but also practical work at a distance, which represents a greater challenge for teaching staff and students.

Apart from this, other facts dictate changes in the way of teaching content and the approach to lifelong learning. Knowledge acquired during formal education years ago is outdated, and new technologies require completely new knowledge

that needs to be acquired. This is also dictated by migration flows of labour force from different backgrounds, as well as the need for further education or the completion of a certain employee profile. All of the above is covered in the current reformation of higher education with the introduction of micro-credentials, shorter educational activities, with targeted content according to the needs of the employee and the possibility of learning 24/7, anytime and anywhere. [18]
Similar to industrial revolutions, educational revolutions can be categorized based on the stage to which they have evolved over the past centuries. These are shown in Table 2. [19]

Table 2. Education E1.0 to E4.0 comparison

Education revolution	Time period	Technology
Education E1.0	Direct, one-to-one transfer of information	Not present
Education E2.0	Knowledge producing	Limited access
Education E3.0	Beginning of the 1970s	Full support for imparting knowledge
Education E4.0	Replacing classrooms	Digital technology revolution in education

The development of education started decades ago, or even centuries ago, when the teaching was still conservative and mainly passive. The teacher acted as the only source of knowledge from which students received all the necessary information.
Thus, the term Education E4.0 appeared during the rise of the I4.0 industrial revolution, which inevitably affected almost everything, especially in the field of Education. Industry I4.0 requires much more from the current education system, in addition to knowledge of various technologies, including teaching methods.
Educational approaches within E4.0 are related directly to the idea of industry I4.0, where one of the main challenges is the sustainable development of production processes ([20]) and the integration of these processes with digital media ([21]). With Industry I4.0, we aim to achieve a higher level of productivity through process monitoring and real-time diagnostics. I4.0 solutions make it possible to increase the efficiency of production and reduce the loss of time and resources used for sustainable orientation ([22]). Realization of the I4.0 vision requires a well-planned educational process. Industry and education must develop evenly, mutually, and their components must be compatible. Therefore, the foundations of modern education must be laid on the assumptions of the I4.0 industry. E4.0 has derived from this.

A modern approach to education and the delivery of individual professional content cannot be introduced without the development of online technologies. The latter not only contributed greatly to the current methods and possibilities of education, but made it possible in the first place. Figure 4 shows a temporal comparison between the educational revolutions, or the stages, and stages of the development of the Web. [18]

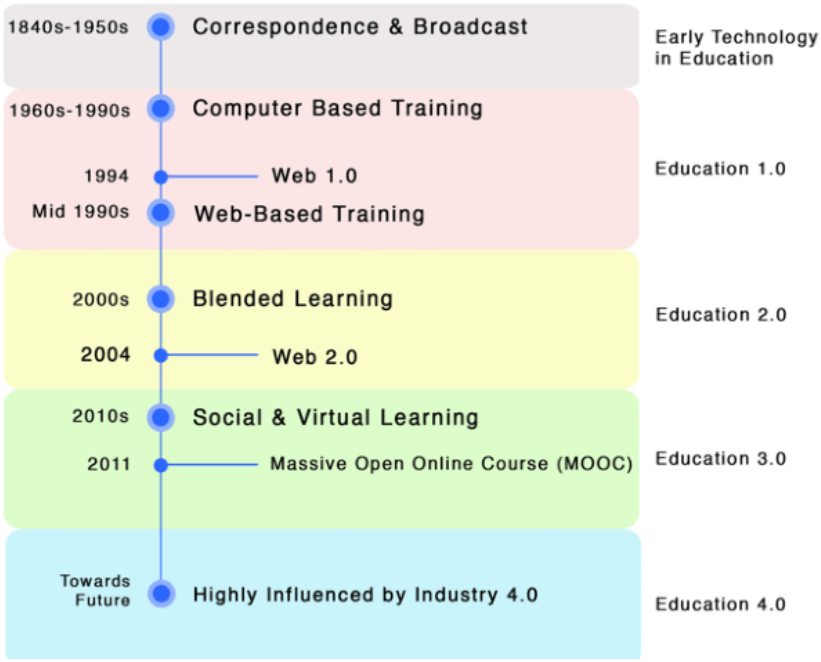

Figure 4.Comparison of Education E1.0 to E4.0 and Web1.0 to Web4.0 [9]

6. Conclusion

The paper begins with the question ‘’Where are we today in terms of the state of technology?’’ and all the ‘’issues’’ that enable, accompany and co-create it. This is not only about the aspect of the state of technology in production systems, which we usually have in mind when we talk about technologies in general, but also about ‘’technologies’’ in the delivery and acquisition of knowledge, and about online technologies that have enabled both the state of development of the industry and the educational process itself and the approach to learning.

New discoveries and knowledge in the field of Technology dictated the introduction of the necessary knowledge into educational processes as well. Thus, with the transformation of the industry from Industry I1.0 to the current state of Industry I4.0, the pedagogical process also changed, from the initial E1.0 to the current E4.0, not only in terms of the necessary learning content, but also new ways of imparting knowledge. Therefore, we can q actually speak of educational revolutions.

Education E4.0 is a new, experience-based education system that, instead of ‘’learning by heart’’ and without understanding what has been learned, responds to the needs of the new world with customized education supported by the use of digital technology. Such an approach to the training of new generations for the needs of Industry I4.0 combines technology, individuality and discovery-based learning, and learners are prepared adequately for the needs of the professions and skills of the future.

With Education E4.0, the concept of education has changed drastically, with some new trends emerging that we are not yet fully aware of. The new education system, which is based on success in life and work and not only on passed exams, points to the necessity of personalized education.

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