Problems and Prospects of Digitalization of Education for Industry 4.0 in Russian Federation*

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Abstract. In the paper, the authors consider the problems and prospects of the digitalization of education for industry 4.0 in our country. The digital transformation of the Russian industry has been developing actively in recent years against the background of very limited financial resources, weak investment activity, and ambiguous business conditions. The Russian industrial enterprises associate an increase in their market share with the introduction of digital technologies in production. Most likely, in the near future, the main factor of economic growth and competitiveness will not be capital, but human potential. Given the accelerating development of technology, the state and entrepreneurs themselves need to pay increased attention to the growth of knowledge employed in the country's economy as a whole and at enterprises, in particular, their constant adaptation to new skills and approaches, as well as the expansion of competencies in various contexts.

Keywords: digital technology, Augmented Reality (AR), Virtual Reality (VR), digitalization, industry 4.0.

1 Introduction

The adopted program "Digital Economy of the Russian Federation" defines a system of specific measures implemented until 2024. Every three years, the Russian Government approves a three-year operational plan, in which the action plans are regularly updated.

The paper's aim is to make research on the trends and prospects for the digitization of education for industry 4.0 in the Russian Federation. It can be divided into tasks:

1) to describe the trends in the introduction of elements of Industry 4.0 in our country;

2) to describe the prospects of digitalization of education for Industry 4.0 in the Russian Federation:

3) to suggest a mathematical model of the effectiveness of the educational process using digital technology.

2 Main content. Development trends of the digitalization of education for industry 4.0 in Russian Federation

In the paper, there were used a variety of research methods to solve this problem, such as analysis, synthesis, mathematical modeling, expert evaluation. Theoretical and applied studies on the research topic [1–20], as well as official statistics, were studied.

The ecosystem of the digital economy of the Russian Federation can be ensured by achieving the following indicators by 2024:

– creation of at least 10 national leading companies

– operation of at least 10 successful industry digital platforms for the main subject areas of the economy;

– introduction of more than 500 successfully operating small and medium-sized enterprises in the field of digital technologies and platforms for the provision of digital services.

High-tech enterprises should develop “end-to-end” technologies based on digital platforms, work in the global market and form around them a system of “start-ups” (research teams and industry enterprises) ensuring the development of the digital economy.

In Russia, the analog of the German program "industry–4.0" is formed by the Government technological track "TechNet" national technological initiative (NTI), which is designed to serve the expected in the 2025-2035 industrial revolution.

It is assumed that industrial digitalization in Russia in 2020-2035 will be abrupt and will affect the engineering processes, production management technology, affecting the very structure of production. It is expected that the implementation of the TechNet project in Russia will be accompanied by an increase in production efficiency. Thus, according to the Ministry of industry and trade of Russia, labor productivity in the economy should increase by 30% by 2024, and the share of machinery and equipment in Russian exports should increase from 8 to 13%.

The program "Digital economy 2024" will also contribute to the growth of labor productivity.

Russia, in our opinion, is far from the last place in the speed of introducing digital technologies.

The cumulative growth of the digitalization of production in our country is about 30% per year. This is higher than the world average (15% per year). State initiatives - the state program "Digital Economy" stimulates the market. Also, the development of the relevant infrastructure is accelerated due to the widespread introduction of industrial Internet, the Road Map of TechNet, which is dedicated to the implementation of IT systems for managing industrial production while creating future factories, and due to the development of the business community.

The restraining effect has depreciation of production assets, lack of standards and underdevelopment of regulatory requirements. In addition, due to budget constraints, it is not always easy for enterprises to find an opportunity to invest in high-tech projects.

In addition, there are many players in the IT market today who offer road maps but do not have solutions that have been tested in real industries. Providers are trying to attract investment to develop finished products. But the lack of a sufficient number of industrial solutions confuses customers, which, in turn, inhibits investment in digitalization of production.

Industrial Internet of Things is an integral part of Industry 4.0. According to international experts, the global IoT market in 2019 will amount to $ 445 billion, including equipment, sensors, sensors, robotic systems, platforms, software, and services.

The Russian market IoT last year amounted to 93 billion rubles, but by 2020 should grow to 270 billion rubles. According to our estimates, by 2019, 1.3 million units of equipment in mechanical engineering and 0.6 million units in other industries will be connected to the industrial Internet in Russia. The volume of the market of artificial intelligence in the industry in monetary terms by 2021 will be about 25 billion rubles, and the industrial Internet of things only in mechanical engineering will exceed 35 billion rubles.

The domestic business has changed its attitude towards innovation. Large Russian enterprises have clear KPI for the digitalization of production.

There is an illustration of various options for forecasting the development of the industrial Internet of Things in the Russian Federation in the coming years (fig. 1)

A recent study by the Ministry of Industry and Trade of the Russian Federation has shown that 63% of industrial enterprises associate an increase in their market share with the introduction of digital technologies in production. A number of enterprises already have a positive experience in implementing such projects.

For example, the enterprise for the production of gearboxes and transmissions managed to increase the load up to 20%, thanks to reliable information on the operation of the machines. At the same time, the savings amounted to more than 120 million rubles in the framework of the investment program. There are already thousands of such examples in our country, each with its own effect. There were cases when it was possible to save € 4.7 million or more when purchasing new machines, because thanks to the monitoring of the machine park with the help of specialized software, it became clear that there are enough operating capacities.

The business realized that digital solutions allow for low capital costs, thanks to the optimization of production processes, to get more effective now than complete modernization. By connecting existing equipment to IoT and its monitoring, it is possible to find new capacities for greater productivity and save hundreds of millions of rubles when purchasing new equipment.

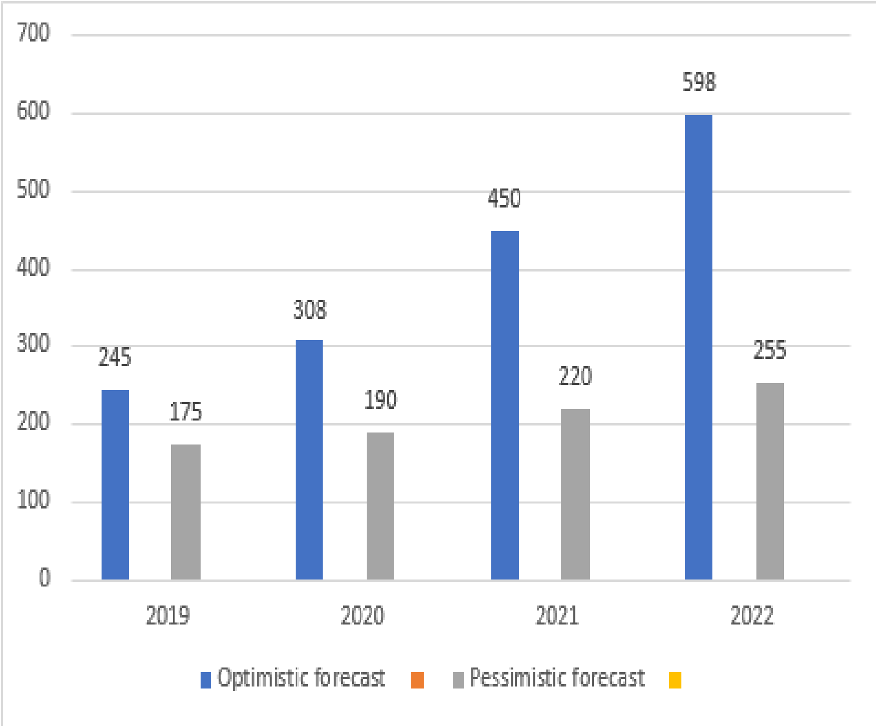

Fig. 1. The various options for forecasting the development of the industrial Internet of Things in the Russian Federation in the coming years (billion rubles).

3 The prospects of digitalization of education for the industry 4.0 in Russian Federation

The innovative way of development is the transition to intellectual work, creating a new, previously non-existent. Today, Russia faces a unique challenge in its history-to form a full-fledged innovative class that will be able to ensure the post-industrial development of the country. The state is required to provide the tools that will help the generation entering into active life to generate ideas and implement them. Such tools can be Augmented Reality (AR) and Virtual Reality (VR), with the help of which students can be told what to think and to create is really cool and fashionable. In addition to education, people should also be interested in modernization and involved in it, and this will happen if the following sentiments are formed: people should want to prove to the world that their nation is worth something; there should be a consolidation of the national elite; modernization should be based on people's own strength and faith in it; patriotism and pride for the country should be cultivated.

The guidelines of activity of management entities digitalization of education and, consequently, the functioning of the centers need to be:

- consistency as a reflection of the relationship and interaction of all elements of the system of program staffing; complexity as the consideration of all aspects of staffing (economic, financial, legal, political, etc.);
- coordination and synchronization of concurrent processes of management of different age groups;
- coordination and synchronization of concurrent processes of control of management entities (public, public-private, public management of program staffing);
- coordination of processes of operational and strategic staffing management (i.e. "simultaneous solution of the tasks of catching-up and rapid development);
- continuity in the implementation of processes of the "education", "upbringing", "talent development" as key elements of the system of staffing;
- succession results in the management of age groups of the population based on the ideology of "Life-Long Learning".

Here are some examples of training for industry 4.0 in our country.

The fund of development of the industry and VTech group of companies developed the platform for training of employees by means of virtual reality (VR). The program allows teaching far off the staff of the enterprises to work with the difficult equipment, its assembly and debugging, to check their knowledge and also to fulfill skills of behavior in working situations.

New specialized virtual services immerse people in the virtual world with realistic 3D models of mechanisms, equipment or vehicles. Also, the platform uses augmented reality technology. With its help, in the course of training, virtual objects are superimposed on a picture of the real world: hints and 3D models. A ready-made industrial solution has already been developed and has proven to be effective for learning. This is a VR simulator for drivers of electric trains in the Central suburban passenger company.

It is possible to give "Rosatom" as the implemented examples of the use of technologies of virtual reality. The tool which would allow optimizing the construction process was necessary for them for effective construction of energokblok of nuclear power station: carry out detailed modeling of the plan of works, change the sequence of actions depending on the diagram of deliveries of contractors and subcontractors and minimize risks and effects of delays.

The system of virtual reality like VE CADWall consisting of the big flat screen and several projectors outputting the seamless image in 3D - a format in scale 1:1 became such a tool. The system of interactive interaction provides tracking of movement of the person before a virtual scene, and the suit and gloves of virtual reality allow it to interact with virtual objects: fulfill build processes, ensuring coordination, collecting and interchangeability of details. Besides, the system of Aerospace Forces for holding conferences and meetings in the headquarters of construction was integrated into a VR system. At the moment the system is used by Rosatom for service and control of the process of construction of the NPP and also for training of personnel and the presentations.

One more example — the first center of virtual reality in the field of domestic shipbuilding which appeared in. Already for three years, he allows solving such problems as:

design and verification of working technologies in the course of the creation of products;

working off of technologies of mounting/dismantling of the equipment in ship rooms with use of electronic dummies;

the analysis of optimality of placement of pipelines, elements of ventilation systems and the equipment in ship rooms;

evident representation to customers of results of works (including planning and arrangement solutions of ship-building productions);

"virtual walks" on models of products, objects, and productions; rendering engineering services to the third-party enterprises and organizations for the analysis on technological effectiveness of products and to the execution of a complex of calculations.

As the best domestic and foreign experience shows, practice-oriented training based on the regular implementation of technical projects of increasing complexity is a successful direction of training technical specialists who can independently think, generate constructive ideas, make decisions and seek their execution. Within the framework of such an ideology of training for Industry 4.0, students acquire the necessary teamwork experience in production, the practice of presenting and defending their own ideas, and responsibility for decisions made.

4 The mathematical model of the training process for Industry 4.0

The purpose of the application of mathematical methods in the analysis of train-ing processes for Industry 4.0 is to describe the processes and patterns of this type of training, identify factors and phenomena affecting the process of developing a student's knowledge and developing effective learning management technologies based on the results obtained.

When describing didactic processes that are continuous functions of time, analytical dependencies are used, using, as a rule, the differential, probabilistic, and statistical relations of the parameters studied. In them, the estimated values can be the speed of transmission, assimilation, and forgetting of educational information, a change in the state of the level of professional training of the subject of training, etc.

Therefore, the system of equations describing the growth of knowledge in the process of such preparation is as follows:

$$\begin{cases} \frac{dL}{dt} = K\left(L_{max^{(t)}} - L\right) \\ \frac{dL_{max^{(t)}}}{dt} = \delta L_{max^{(t)}} \end{cases} \qquad (1)$$

Here L is the current amount of student knowledge, L_{max} - the amount of knowledge that must be mastered in order to become a specialist in a given profession, k, δ – are the growth rates of knowledge of a student and a professional in a given profession, respectively.

Solving the lower equation of the system (1) describing the development of scientific knowledge, we obtain:

$L_{max^{(t)}} = L_{max^{(o)}e^{\delta t}}$ (2)

Substituting solution (2) into the upper equation of system (1), we obtain the equation for the dynamics of student knowledge:

$\frac{dL}{dt} = K\left(L_{max^{(o)}e^{\delta t}} - L\right) = -KL + KL_{max^{(o)}e^{\delta t}}$ (3)

We transform the solution (3) L in the form:

$L = e^{-kt}x(t)$ (4)

Substituting (4) into (3), we obtain the equation for x (t):

$-KE^{-kt}x + E^{-kt}\frac{dx}{dt} = -KE^{-kt}x + KL_{max^{(o)}e^{\delta t}}(5)$ (5)

Or:

$dxdt{=}KLmaxoE\delta{+}kt$ (6)

The solution of equation (5) is:

$x = x(o) + \frac{KL_{max^{(o)}}}{\delta+k}\left(E^{(\delta+k)t} - 1\right)$ (7)

Substituting (6) into (4) we obtain the learning dynamics L (t):

$(t) = \frac{KL_{max^{(o)}}}{\delta+k}\left(E^{\delta t} - E^{-kt}\right) + x(o)E^{-kt}$ (8)

When t = 0, (7) is:

$L(o) = x(o)$ (9)

Substituting this result in (7), we get

$L(t) = \frac{KL_{max^{(o)}}}{\delta+k}\left(E^{\delta t} - E^{-kt}\right) + L(o)E^{-kt}$ (10)

Formula (10) describes how the growth rate of a student's knowledge required to master a given profession will change. After the considerable time has passed, this process can be described as follows:

$L(t) \approx \frac{KL_{max^{(o)}}}{\delta+k}E^{\delta t}$ (11)

5 Conclusions

Based on the opinions of the leaders of large and medium-sized industrial enterprises, it can be concluded that the digital transformation of the Russian industry has been developing actively in recent years against the background of very limited financial resources, weak investment activity, and ambiguous business conditions. Of course, the level of immersion of the enterprises of the processing complex into digitalization processes is not yet deep, but progress is obvious. It is necessary to pay attention to the fact that due to the rapid changes occurring in the world today in the area of introducing information technologies, economic agents should be strategically focused on the availability, training, and retraining of qualified personnel in this field. If a company wants to become a business leader in its type of economic activity, it needs to learn how to work based on the concept of targeting highly competent personnel. Today, highly qualified specialists are the most valuable asset for a business.

Most likely, in the near future, the main factor of economic growth and competitiveness will not be capital, but human potential. Given the accelerating development of technology, the state and entrepreneurs themselves need to pay increased attention to the growth of knowledge employed in the country's economy as a whole and at enterprises, in particular, their constant adaptation to new skills and approaches, as well as the expansion of competencies in various contexts. Obviously, in the foreseeable future, there will be an explosion of productivity in the world as a result of a wave of new technologies. It is productivity that is today the most important factor determining long-term economic growth and improving the quality and standard of living of the population. The state, for its part, apparently needs to help businesses by focusing on an increase in centralized financial investments in human capital - education, health care, and science.

References

1. Adam Mussomeli, Doug Gish and Stephen Laaper, “The rise of the digital supply network: Industry 4 enables the digital transformation of supply chains,” Deloitte Insights, December 1, (2016)
2. Akhavan, P., Ale Ebrahim, N., Fetrati, M.A., Pezeshkan, A.: Major trends in knowledge management research: a bibliometric study. Scientometrics, 107(3), 1–16 (2016).
3. Bauer H., Patel M., Veira J. The Internet of Things: sizing up the opportunity. New York (NY): McKinsey & Company. (2016).
4. Brenna Sniderman, Kelly Monahan, and John Forsythe. “3D opportunity for engineers: Using behavioral science to help build a new mindset,” Deloitte Insights, January 25, (2016)
5. Geissbauer R., Schrauf S., Koch V. et al. Industry 4.0 – Opportunities and Challenges of the Industrial Internet assessment // PricewaterhouseCoopers. (2014)
6. Gerbert P., Lorenz M.Rüßmann M. et al. Industry 4.0: The future of productivity and growth in manufacturing industries // BCG. (2015).
7. Global factory automation market (2017) // Statista. URL: https://www.statista.com/statistics/728562/global-factoryautomation-market-by-manufacturer/(2017)
8. Hermann Mario, Pentek Tobias, Otto Boris. Design Principles for Industrie 4.0 Scenarios: A Literature Review//Technische Universitat Dortmund, (2015).

9. Herter J., Ovtcharova J. (2016). A Model based Visualization Framework for Cross Discipline Collaboration in Industry 4.0 Scenarios // Procedia CIRP. Vol. 57. P. 398–403.
10. Hoffmann R.Investment Opportunities in Industry 4.0 – Industrial Revolution «Made in Germany» // Ecovis. (2016).
11. Jay Lee, Behrad Bagheri, Hung-An Kao. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems// Manufacturing Letters 3. P. 18-23. (2015)
12. Industry 4.0: How to navigate digitization of the manufacturing sector // McKinsey. URL: https:// www.mckinsey.com/business-functions/operations/ourinsights/industry-four-point-o-how-to-navigae-thedigitization-of-the-manufacturing-sector. (2015)
13. Kazak, A.N., Dorofeeva, A.A. Prospects for the use of service robots in the resort-recreational sphere "Proceedings of the 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus P. 1409-1411 (2019)
14. Kazak, A.N., Filippov, D.M. Development of In-wheel Motor for Vehicles "Proceedings of the 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus P. 1406-1408 (2019)
15. Malte Brettel, Niklas Friederichsen, Michael Keller, Marius Rosenberg. How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective World Academy of Science, Engineering and Technology//International Journal of Mechanical, Aerospace, Industrial, Mechatronic, and Manufacturing Engineering. Vol. 8. No 1. (2014)
16. Meissner H., Ilsena R., Auricha J. C. Analysis of Control Architectures in the Context of Industry 4.0 // Procedia CIRP. Vol. 62. P. 165–169. (2017)
17. Richard Baldwin, The Great Convergence: Information Technology and the New Globalization (Cambridge,Massachusetts: The Belknap Press of Harvard University), (2016).
18. A. A. Sinitsyn. Features of the Information-analytical System Application for Estimation the Support Areas for Creation of the Results of the Intellectual Activity of the Research and Educational Institutions//Biosciences Biotechnology Research Asia. December. Vol. 11 (3). P. 1807-1813. (2014)
19. Schlaepfer R. C., Koch M., Merkofer P. Challenges and solutions for the digital transformation and use of exponential technologies // Deloitte. (2015)
20. Schwab K. The Fourth Industrial Revolution: what it means, how to respond // World Economic Forum. (2016).