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Science 4.0 as a Model of Scientific Activity in an Innovative Environment of Industry 4.0

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ABSTRACT

Technological innovations in the generation, storage, transmission, and processing of data have transformed traditional scientific activities and contributed to the accelerated development of the concept of "data-driven science." The article analyzes the image of Science 4.0 in a new format since organizing and managing scientific activities with the widespread use of the Industry 4.0 technological platform has become relevant here. A four-level classification of stages in the development of science and the use of e-Science as a technological platform for Science 4.0 is proposed. The essence of Science 4.0 is revealed in the analysis of works devoted to scientific research with broad involvement of the internet of things, cyber-physical systems, artificial intelligence, cloud computing, big data analytics, and other intelligent solutions. Implementation of the proposed concept contributes to an increase in the efficiency of scientific research and supports solutions for the operational management of science.

KEYWORDS

Artificial Intelligence, Big Data Analytics, Cloud Computing, Cyber-Physical Systems, e-Science, Industry 4.0, Internet of Things, Science 4.0

INTRODUCTION

Science and the knowledge it creates have played a key role in the development of civilization, stimulating progress and opening up new horizons of opportunity. Science provides tools to understand the world around us, develop technology, improve living conditions, treat diseases, and solve complex problems. It is a driving force in human history, shaping society, enriching culture, and promoting social development. For example, in the Stone Age, based on numerous observations and experiments, bronze and iron tools were created, which created the conditions for the transition of mankind to a completely new stage of development.

In the second half of the 18th century, processes of accelerating industrial production, known as the first industrial revolution, began in some countries of Western Europe and North America.

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Parallel to this growth in production is explosive progress in scientific discoveries and inventions. The continuous development of science, education, and production continues during the periods of the second, third, and fourth industrial revolutions. Today we stand on the threshold of a super-smart society 5.0, which is creative and human-centric. This new direction of development promises the integration of advanced technologies, smart use of data, and close interaction between man and machine. This era provides unique opportunities to improve lifestyles, improve education, and create more flexible and innovative environments for social interaction.

The fourth industrial revolution has been counted since 2011 when the Industry 4.0 concept was announced at the initiative of the German federal government with the participation of universities and private companies (Kagermann et al., 2013; Lee et al., 2015). Its main task was to develop and implement innovative information technologies in production systems to increase the efficiency and competitiveness of the national industry. Similar industrial modernization programs exist in other countries. For example, back in 2014, the State Council of China unveiled its ten-year national plan, "Made in China 2025", which aims to transform China from a global workshop into a global manufacturing power (Xu et al., 2018).

Industry 4.0 is characterized by a high level of sophistication and full networked integration of products and manufacturing processes. This concept represents a new industrial phase of production systems by integrating new and converged technologies that add value to the entire product lifecycle. Industry 4.0 is based on advanced manufacturing or the concept of intelligent manufacturing, that is, on an adaptable system in which flexible lines automatically adjust production processes for different types of products and changing conditions. This allows for increased quality, productivity, and flexibility and can also help to produce customized products on a large scale and in a sustainable manner with better resource consumption. The chart below (Figure 1) shows the top 10 Industry 4.0 trends impacting companies in 2024.

The use of artificial intelligence (AI) techniques across devices and processes is shaping the main trend in Industry 4.0. Collecting data through cloud and edge computing and developing cybersecurity solutions enables companies to create the building blocks for smart factories. Advanced robotics solutions, including autonomous mobile robots, cobots, and swarm robotics, as well as robotic software development, are also an important part of Industry 4.0 trends.

However, Industry 4.0, based primarily on innovative information and communication technologies (ICT) of the 21st century, contributes to the creation of new trends in the development and integration of science and education in general.

It should also be noted here that throughout the history of mankind, science and education have been interconnected and developed in parallel. The interrelation and integration of science and education, as producers of new knowledge, have always been relevant and reflected in the research

Figure 1. The top 10 Industry 4.0 trends (based on Startus-insights, 2024)