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Article

Innovation and engineering education: New challenges for achieving sustainable development goals

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Abstract: This article is an analysis of global trends in the field of socio-economic development, which in modern conditions is determined by innovative technological engineering solutions. Innovation is new knowledge embodied in engineering technologies that can meet the needs of mankind's development. However, changes caused by scientific and technological progress radically change not only human life but also its natural habitat. The effect of the use of a large number of technological solutions for humans is positive (a decrease in the share of heavy manual labor, an increase in life expectancy, etc.), and for the environment, it is negative (depletion of soils, pollution of the atmosphere and water bodies, etc.). The result of technological development, which humanity has today, forces us to revise the fundamental elements of technological development, shifting priorities from increasing the diversity of social consumption to the ecological depletion of the planet, and this, in turn, requires a change in the values of professional engineering thinking, which is formed in the learning process.

Keywords: sovereignty; technological innovations; socio-economic development; knowledge economy; engineering solutions; innovative knowledge

1. Introduction

The development of humanity at the present stage depends more than ever on the ability to produce new knowledge or innovation. The production of new knowledge and its use in socially significant processes helps to survive not only for individual organizations but also for national economies; therefore, for the successful formation of the knowledge economy, specialists are needed who are able to create knowledge and implement it into demanded innovative solutions that ensure competitiveness and development. The economy of knowledge, being the economy of breakthrough technological engineering solutions that change a person's life, also changes the requirements for a person and his capabilities.

Many processes caused by digital innovation solutions are global in nature, causing the transformation of national economies, changes in national development priorities, changing the daily life of a person, and changing the requirements of society for the social realization of a person. Strategically important changes in society's requirements for a person are changes in the professional sphere, which leads to the transformation of the global labor market and, therefore, a change in the requirements and demand for the level and quality of vocational education, a set of demanded skills and competencies in a specific field of professional activity, and opportunities for professional vertical and horizontal growth, which determines the social and economic status of a person in society.

However, dynamic socio-technological development also has a negative socio-economic effect, which manifests itself in the uneven material distribution of benefits, global climate change, depletion of soil, flora, fauna, and other necessary resources for the existence of mankind, which, according to the theory of needs, A. Maslow is basic (physiological needs and security needs) and determine the very fact of human existence, therefore, human civilization [1,2].

2. Theoretical foundations

Rapid innovative development that creates life-saving technologies, as evidenced by an increase in life expectancy (according to statistics in 2023, the average life expectancy on earth was 72 years, while a hundred years ago, even in developed countries, it was 55–60 years [3], caused irreparable damage to the environment, provoking threats of the possibility of not only promising development but also the very fact of the existence of mankind. The problems of significant depletion of vital resources and irreversible changes in natural habitats are a global problem that needs to be resolved as soon as possible. So, for example, according to the statement of climatologists, 2023 was the warmest year in the entire history of climate observations, while 10% of days in terms of temperature exceeded the climatic norm, which is an indicator that climatic changes on Earth are irretrievable and technogenic in nature [4]. In the current conditions, humans are faced with the task of becoming an innovative knowledge economy based on high-tech and high-tech production, preferably a closed cycle (zero-waste production), using renewable energy sources with minimal negative impact on the environment (green technologies), which is evidence of concern for future generations and is also regarded as a factor that can restrain the speed of further climatic changes associated with negative technological impacts.

One of the strategically important requirements for the development and establishment of an innovative knowledge economy is its ability to generate and apply knowledge-intensive innovations for the benefit of humanity, not to create "innovations" for their painful, sometimes useless introduction into the economy. An example demonstrating this statement is the creation, production, and use of plastic, which at one time was considered a breakthrough technology. Its use was promoted in every possible way in all areas of activity. Plastic production has skyrocketed from 2 million tons in 1950 to more than 438 million tons in 2017, and plastic production is expected to reach 1.1 billion tons per year by 2050 [5]. However, the negative consequences of its use overlapped with the entire positive effect of its use.

- impossibility of decomposition in the natural environment (appearance of harmful substances in the decomposition process, long term of the natural decomposition process (from 1000 years to 700 years and more);
- difficulties of complete disposal (high costs, new plastic disposal technology is required);
- plastic recycling is more expensive than its production;
- the ingress of plastic microparticles into a living organism causes oncological diseases (there are cases of plastic microparticles in the respiratory tract of the human embryo, in the cells of tissues and internal organs of humans, and even in fish);

- disruption of the ecosystem in places of accumulation (release) of plastic, associated with the mass death of animals, which leads to violations of the food chain and irreversible changes in regional flora and fauna;
- According to some reports, the world's plastic waste weighs about the same as the world's population, due to the impossibility of its processing and decomposition.

In the age of information technologies, computerization, the development of artificial intelligence technologies, cybernization, etc., it is impossible to build an innovative knowledge economy that contributes to the containment of negative technogenic influence on the environment without engineering solutions with an effective environmental component. The need to create and implement increasingly complex technological innovations determines the high level of engineering thinking and education in demand, as well as the high level of human capital development. Since the transformation of new knowledge into innovation is through technology, engineering solutions become meaningful in any activity, and the requirements for engineering education itself are changing as rapidly as the technologies that humanity develops and masters.

The development of humanity is inextricably linked with the acquisition of new knowledge, which determines the direction of evolution. Throughout the history of human development, knowledge was regarded as a strategic resource, whose accessibility was limited for a certain part of society. In the modern world, thanks to the dissemination and strengthening of humanistic principles of social interaction and the development of information technologies, knowledge has become more accessible, but this does not mean that it has ceased to be regarded as a strategic resource that determines progress and well-being. Countries with high human capital indices tend to have high educational development indices and are characterized as high-tech [6]. The development of the knowledge economy can be seen as a global socio-economic process that gives knowledge the status of a key resource and source of development. However, if we consider knowledge from an economic point of view, then it should be a competitive product that is "bought", therefore it is not knowledge itself that has value, but a new product (technology, products, goods, etc.) in which it was realized through innovative characteristics or properties. New properties should enhance the value of the product, thereby increasing its usefulness and attractiveness to the consumer.

Innovative information technologies, which today determine the socio-economic development of not only individual organizations but also national economies, providing them with security, are a product of engineering knowledge. Scientific and natural knowledge, which is engineering, needs a symbiosis with social (humanitarian) knowledge to be used for the production of new knowledge since social knowledge determines the potential consumer's needs, values, and needs, which together give innovation as new knowledge economic value and social utility. In order for engineering to be able to meet the needs of modern socio-technological development, it is necessary to change not only the quality of engineering education but also the content of the educational process, taking into account the high requirements for specialists in engineering specialties, including in the development of the ecology of consciousness and environmental culture.

World development trends are characterized by dynamic technological processes, the complexity of which is increasing. The struggle for technological leadership in the field of engineering solutions sometimes turns into a global environmental disaster, as is the case with plastic. In such circumstances, it is crucial that the engineering profession have a structured learning approach, not only in university education but throughout the professional activities of practicing engineers. One of the main goals of continuous training for engineers is to master new knowledge, practices, and competencies both in the field of engineering and in related areas of knowledge that can make engineering solutions more efficient and less harmful to the environment. The implementation of such principles in engineering education will require significant efforts on the part of teachers, employers, and professional societies, as well as on the part of the state, since engineering technological innovations form the basis of national competitiveness and technological and intellectual sovereignty.

3. Methods and materials

This study is analytical in nature and therefore used a comparison, comparative, and problem analysis of current global trends in the development of technological innovations, engineering solutions, and engineering education, as well as assessments of these trends by specialists (sociologists, economists, ecologists, engineers, etc.), including the authors of this work.

Humanity realized the importance of harmonious development back in 1972 [7,8]: industry must meet the development needs of society but at the same time not cause irreparable technogenic damage to the environment. During the time that has passed from 1972 to the present day, humanity has changed a lot, and the conditions in which it is necessary to achieve sustainable development have changed (**Figure 1**).

- Socio-economic development is largely determined by the capabilities and properties of the digital environment, which develops dynamically, penetrating into all areas of human activity and creating new areas of activity.
- Socio-economic development has a pronounced non-uniform character, which is largely determined by irreversible environmental changes. As can be seen from **Figure 1**, the more dynamic the development of digital technologies, the more intense the depletion of the environment.
- Between the main components that determine sustainable development, the conflict of interests takes on consequences that threaten the existence of mankind.
- Engineering solutions and technological innovations become a link capable of creating not only innovative, unique products that meet the needs of new ways but also find a compromise between the needs of humanity for continuous development and the need of humans as a biological species for the preservation of a habitat suitable for existence (**Figure 1).**
- Achieving sustainable development in the digital environment is achievable only if engineering solutions and technological innovations are created by specialists who, among other competencies, will have the competencies “ecology of consciousness” and environmental thinking and will have a real opportunity to use these competencies as priorities in professional activities. These competencies will contribute to the ability not only to critically assess

technological innovation, but also to strategically analyze the possible promising consequences of its use, both constructive and destructive.

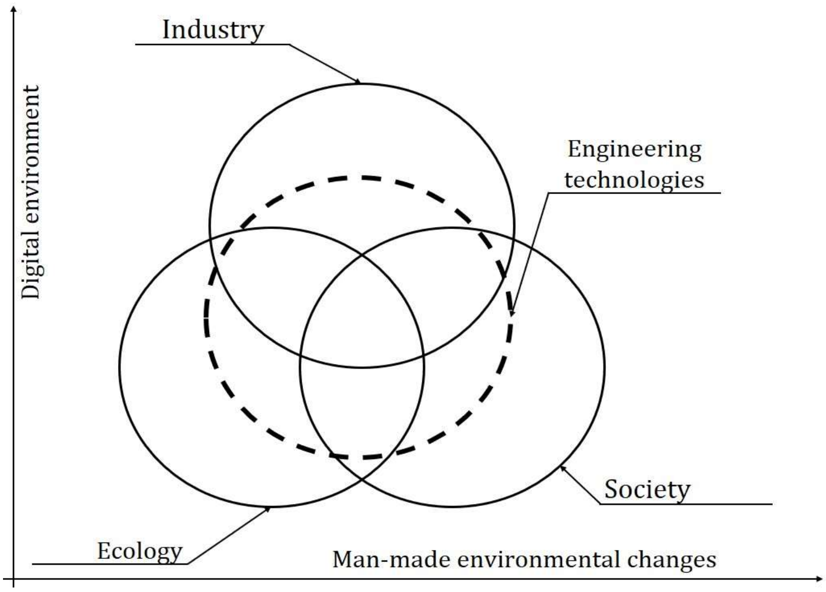

Figure 1. Model of sustainable development in modern conditions (compiled by the authors).

Sustainable development has evolved from a desirable state for the modern human being into a vital necessity, the achievement of which is based on innovative technologies that can solve the conflict of interest between the need for continuous development and the resource capabilities of the environment. Modern development is defined as technological; therefore, engineering solutions, along with information solutions, penetrate all spheres of human life. An example of such technology is the "smart city" technology (Russia, Moscow), which, thanks to innovative engineering solutions, contributes to more harmonious interaction and development of the main life-supporting infrastructures of the city (transport, social, logistics, information, industry, etc.). The interaction of urban services thanks to innovative engineering solutions becomes more structured and, therefore, more accessible and convenient, both for ensuring urban management processes and for living in an urban environment.

The use of engineering technologies also changes the professional language in many areas of activity, but the most noticeable changes can be observed in economics and management, since the effectiveness of these areas of activity largely depends on the effectiveness of innovative engineering solutions: business processes, organization architecture, etc. Innovation as a result of the transformation of new knowledge into a demanded product, as already noted, is the main technological development or technological progress. However, "technological progress is not at all invented by loners who are struggling with the task in isolation from everyone else; almost all innovations are the processing or improvement of existing technologies" [9]. Such an explanation of the nature of the origin of innovation allows us to consider innovation as a constructive result of the interaction of industry, science, and engineering education (**Figure 2**).

- Science is designed to respond to the needs of society by offering new knowledge, the use of which contributes to the partial or complete satisfaction of urgent needs. Science offers solutions that are relevant to its current state and development. Scientific progress expands the resources and capabilities of science over time; socio-economic development provokes the emergence of new needs or the desire to satisfy needs in a new way; and the production of innovative scientific knowledge occurs, which can be considered an improvement of the "old" [9].
- Production for survival, competitiveness, and ensuring the economic development of not only its own but also that of others is obliged to materialize innovative scientific knowledge into a product, taking into account consumer requirements. (monetization). Product quality, the speed with which industry responds to changes in social needs and demands, and the readiness to implement and produce innovative solutions depend on technological engineering capabilities and resources.
- Engineering education, directly or indirectly (through engineering specialists), largely determines the quality of the innovative scientific knowledge obtained (the technical support of scientific research), the possibility of its use in various fields of activity (ensuring effective intersectoral communications), and the and the technological capabilities of the production of an innovative product (production technologies).

According to the model of technological development in the digital environment (knowledge economy) presented in **Figure 2**, innovation can be considered a synergistic effect of the constructive interaction of science, engineering education, and production. Such a demand for high-quality engineering education in a dynamically changing digital environment presupposes a high level of continuous adaptability of engineering education to the needs of production and science. One of the obvious solutions is to maintain the quality of engineering education that meets the pace of modern technological development—this is continuity throughout the professional activity of a specialist engineer.

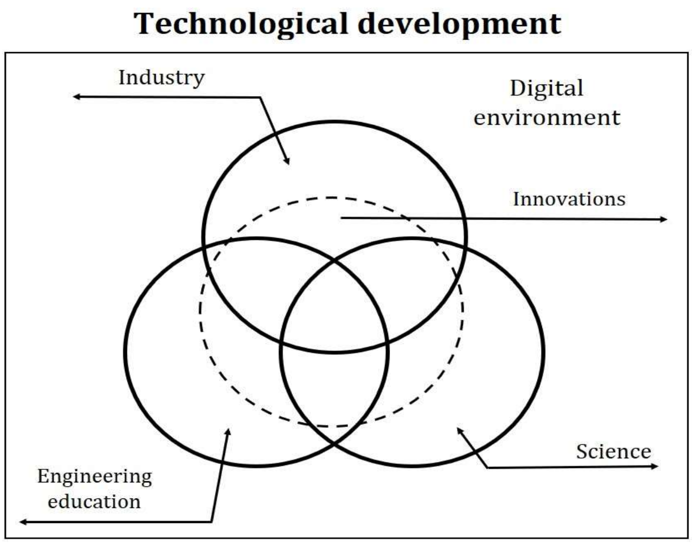

Figure 2. Model of modern technological development (compiled by the authors).

4. Results

Following the development of digital technologies, which have radically changed many areas of human activity, there are global changes in the requirements for the quality and properties of human capital as the main source of all technological innovations. The need for innovation is at the heart of modern socio-economic development, but producing innovation in a tough competitive environment requires:

- greater specialization, which determines changes in the requirements for the training of highly qualified specialists and, first of all, the engineering direction;
- flexibility of innovative technologies that increase the efficiency of their use, which determines the need for related competencies, both among the creators of innovations and those who use them in practical activities;
- allocation of funds (investments) for research and scientific and technical developments, which determines the need for highly qualified scientific and technical specialists with a high level of professional creative and productive thinking (an urgent requirement for human capital).

1) Dynamic changes in needs that occur in the knowledge economy are the root cause of the current challenges of modern engineering practice, assuming a wider range of professional skills and skills in related fields than those provided by Russian academic engineering education at the moment. The ongoing changes in global technological development contribute to the realization of the strategic importance of technological innovations for the economic competitiveness of the Russian economy and the formation of technological sovereignty. There is a worldwide awareness and recognition that technological leadership in innovation is the core of national well-being, competitiveness, and development, ensuring technological sovereignty and national security in a knowledge economy. This fact, which determines the importance of innovation, is the basis for the expediency of the global ranking of countries according to the innovative development index, in which Russia in 2022 ranked 47th among 132 world economies [6]. Since Russian society has to build technological sovereignty in conditions of political instability and another international polarization, such conditions give the goal of “achieving technological sovereignty” a strategic status, the achievement of which largely determines national security. However, an analysis of advanced technological countries, including Switzerland (the country that ranks first in the world ranking for innovative development in 2022), the USA, Canada, and Sweden, shows that the formation of technological sovereignty is a long-term resource-intensive process that requires, first of all, large investments, both from the state and from private investors and businesses. The Russian economy and society, taking into account world experience, create the necessary technological base for the formation of a knowledge economy that ensures national security and development.
2) In the modern world, one of the critical restraining factors of innovative development is the limitations caused by global changes in the ecosystem that ensure the existence of mankind as a whole, which is reflected in such scientific theories as the Concept of Marginal Growth (1972) [7,8], the Concept of Planetary Boundaries (2010) [10], the Concept of Great Acceleration (2015) [11], etc. The

disruption of the ecosystem's ability to heal itself caused by innovative technological solutions and man-made human intervention (it is worth noting again that not all technologies in the long-term perspective turned out to be as effective as they seemed initially) suggests that humanity, which has violated its environment of existence, will create new technologies and rules for interaction (use) with the environment in order to at least slow down the devastating impact.

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References

1. Maslow AH. A theory of human motivation. Psychological Review. 1943; 50(4): 370-396. doi: 10.1037/h0054346
2. Abulof U. Introduction: Why We Need Maslow in the Twenty-First Century. Society. 2017; 54(6): 508-509. doi: 10.1007/s12115-017-0198-6
3. Visasam. Life expectancy in the world by country in 2023-2024 (Russian). Available online: https://visasam.ru/emigration/vybor/srednyaya-prodolzhitelnost-zhizni-v-mire.html (accessed on 14 July 2024).
4. Euronews. Official: 2023 recognized as the hottest year ever (Russian). Available online: https://ru.euronews.com/green/2024/01/09/green-copernicus-weather-report-2023-ru (accessed on 14 July 2024).
5. Plus-one. Annual plastic waste weighs as much as the world's population (Russian). Available online: https://plus-one.ru/ecology/2022/02/28/ezhegodnye-othody-plastika-vesyat-stolko-zhe-skolko-naselenie-zemli (accessed on 14 July 2024).
6. Gtmarket. Available online: https://gtmarket.ru/ratings/education-index-25.01.2024 (accessed on 14 July 2024).
7. Meadows DH, Meadows DL, Randers J, Behrens III WW. The Limits to Growth: A report for the Club of Rome's Project on the Predicament of Mankind. Universe Books; 1972. doi: 10.1349/ddlp.1
8. Guixiani DM. Limits of Growth—First Report to the Club of Rome. Biosphere Electronic Journal. 2002; 2.
9. Basalla G. The Evolution of Technology. Cambridge University Press; 1988.
10. Rockström J, Steffen W, Noone K, et al. A safe operating space for humanity. Nature. 2009; 461: 472-475. doi: 10.1038/461472a
11. Steffen W, Broadgate W, Deutsch L, et al. The trajectory of the Anthropocene: The Great Acceleration. The Anthropocene Review. 2015. doi: 10.1177/2053019614564785