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ON THE EFFECTIVENESS OF THE RELATIONSHIP BETWEEN THE ART OF ENGINEERING AND THE TASKS OF ENGINEERING ACTIVITY WITHIN THE FRAMEWORK OF ITS SYSTEMATIC APPROACH TO INNOVATION

***Abstract**: in the article, the authors, when switching to a two-level training option (bachelor's and master's degrees), focused on preparing masters in technical areas, found that a group of relatively new disciplines has appeared, which, first of all, should include the methodology of scientific creativity, protection of intellectual property, fundamentals of scientific research, technical aesthetics, philosophy and methodology of science. In this regard, the practice of teaching the above training courses, as well as the experience of production and research work convincingly prove not only the need to introduce such subjects into the master's training system, but also the urgent need to understand the relationship of the educational material in question with the practice of engineering and scientific activities, in including publications about these features. Just as in the 19th century blocks of academic disciplines were formed related to the targeted training of specialists in engineering specialties, so now there is a need to form a new block of academic subjects that reflect the needs of innovative development of society. A new block, reflecting the level of development of modern civilization and focused on the humanistic path of its development, is the following group of disciplines: fundamentals of engineering, history of science and technology, philosophy of science and technology, methodology of scientific and technical creativity, protection of intellectual property, technical aesthetics, fundamentals of scientific research. With such an organization of training, one can count on the emergence of graduates of higher educational institutions who master the basics of engineering and are capable of independent innovative activities. In this article, the authors made the first attempt to combine the material necessary for students in preparing the above courses into a single complex called "Fundamentals of Engineering."*

Key words*: masters, bachelors, fundamentals of engineering, higher education institutions, innovative activities, engineering art, functional theory of art, sociological relevance.*

Language*: English*

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Introduction

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The general principles of the main principles of engineering ethics are the support and development by engineers of the purity, honor and dignity of the engineering profession. To do this, engineers must:

Use your knowledge, skills and abilities to increase human well-being.

Serve the public, employers and customers fairly and impartially.

Respect the competence and prestige of the engineering profession.

Uphold the disciplinary standards of professional and technical communities.

Basic canons of engineering ethics

Engineers, in the performance of their professional duties, must place the safety, health and welfare of society above all else.

Engineers must carry out work only within the scope of their competence.

Engineers must respond objectively to public inquiries.

Engineers in their professional field act as loyal representatives or trustees for each employer or customer and must avoid conflict.

Engineers should build their professional reputation on integrity and should not compete unfairly with others.

Engineers should support their own professional development and provide opportunities for professional development to engineers under their supervision.

Typical scenarios of conflict situations.

Situation "Paradox"

The formula of any invention is drawn up in such a way that it considers exclusively the positive aspect. However, each invention, in its internal essence, is based on the resolution (removal) of a technical or social contradiction in its dialectical interpretation and development (this thesis is developed in more detail in the “Theory of Solution of Inventive Problems”). Therefore, in every innovation there are inevitably and then always manifest negative consequences. This provision especially concerns environmental issues. Such situations are observed in all typical technical innovations: an increase in engine power leads to increased environmental pollution; an increase in flight speed leads to the appearance of ozone holes; An increase in the carrying capacity of vehicles leads to the destruction of roads and soil, etc. What should an engineer do? Where are the boundaries of ethical and unethical, moral and immoral technical solutions?

Situation "Good and Evil". We are talking about military inventions. The engineer understands that the invention is aimed at destroying industrial facilities, natural resources, technical means, and enemy manpower. The engineer, as a performer and manager of work, is professionally prepared for this type of activity. However, he lives in the real world and understands that devoting his life to the direct or indirect destruction of other lives is clearly evil.

What should a future engineer do during his training? During the period of designing military equipment? During the period of organizing work and managing other people?

Situation “Spiritless Automation” The issue of new technologies that make it possible to automate production is being discussed. Products put into production give birth to a world devoid of soul, a world that promotes the development of inertia, impersonality, and without spirituality. Panel and block construction of houses gave rise to dull neighborhoods and “gray” residents. Furniture made from particle boards consists of identical walls and tables with sharp, right angles, which respectively affect the human psyche: prickly, sharp angles appear in the behavior of the growing and already grown-up generation.

What should an engineer do? Should we cancel the automation of production processes? How to build both cheaply and beautifully? How can we make sure that things produced in continuous production bring joy to people?

Situation “Internal conflict”

The company has a large order, for example, for the production of an automatic line. However, individual units and components are not sufficiently developed and require improvement. The alternative is this: either a long but reliable way to debug individual units, or a relatively quick production of the entire line at once, for which the customer is already paying a lot of money, which has a beneficial effect on the financial situation of the engineer himself.

What to do? Argue with management, whose prestige depends on the timing of the order? Give information to the customer without informing the management of your company? Silence?

Situation “Innovation is routine”

A typical problem when designing new technology. The device is designed the old fashioned way. Where electronics can be used, mechanics or hydraulics are used. The engineer understands that he needs to take a risk and give the new design a try to break into the market. But management is afraid of failures, inoperability and unreliability and therefore is “pursuing” an outdated, but already proven option.

What should an engineer do? Resign yourself? Conduct research yourself? Looking for sponsors?

Situation “Instant result”

The age-old debate about quality, quantity and cost. There are two options for completing any order. The first is to design and make things that are truly strong, reliable and durable.

The second is to imitate strength, reliability and durability through the use of externally similar materials and design solutions (color, shape, weight, speed, etc.). At the same time, the main attention is paid not to the product itself, but to advertising and packaging. Many companies from the so-called developing countries took this path: the “yellow assembly” version of personal computers, toys from China, etc. What should an engineer working in a company do according to the second option? Don't think about the consequences? Struggle to improve quality? Quit your job?

Situation “Domestic priority” A Russian company offers an organization (possibly state-owned) its own invention for use in the production of products. The invention promises high efficiency and low implementation costs. But the organization is going to negotiate the purchase of similar products in one of the Western countries, for which its representatives are going to travel to this country in the near future. The engineer, who must evaluate the proposal as an expert, is reminded of the priority of developing relations with this country (political aspect) and of the interest of managers in the trip (personal aspect). How should an engineer behave if the effectiveness of a domestic invention is obvious to him?

Situation "Service invention"

An engineer works on an invention during office hours, using office equipment. When he is close to completing the work, he leaves the company and sells the product as his own invention. Perhaps the engineer received a low salary and, moreover, irregularly.

How to evaluate an engineer's behavior from an ethical point of view?

Situation "Choice"

The problem of fairness and reliability in engineering. An engineer works for a government organization that prepares reports on the environmental impacts of projects currently planned by the government. The engineer reports the results of his work to management, after which the manager asks him to change some of the conclusions presented in the report and/or remove some data from it.

What should an engineer do?

Situation "Personal Interest"

The engineer is expected to make an unbiased decision in the best interests of the client, but the engineer has his own interests (related to investment, family relationships, etc.) that may influence the decision. For example, an engineer is expected to help a company decide which product to purchase for the company's needs, and the engineer is the owner (or partner) of a company that offers those products. Should an engineer remove himself from a situation in which he has a conflict of interest? Should the engineer tell the client that self-interest makes him biased?

Situation "Security"

The engineer is concerned about the safety of the project. Events can develop as follows. The engineer reports his concerns to his boss, but the boss is reluctant to take any action and advises him to remain calm. The engineer must decide whether to “sound the siren”, i.e. contact the authorities, the press, etc. At the same time, the employer can treat the engineer very well. How to combine a loyal attitude towards the employer with protecting the interests of society? When should an engineer “sound the siren”?

“Risk” situation (an aggravated version of the “safety” situation)

An engineer must make difficult decisions regarding the degree of risk associated with the equipment he is designing. How to decide on the acceptable level of risk?

Situation “Young specialist” (a specific version of the situation “Innovation - routine”)

The circumstances are such that you have to choose between a traditional and a new solution that promises increased efficiency and reduced costs. The choice, however, should be based only on preliminary testing. The young engineer's boss unexpectedly informs a group of colleagues that the recommendations must be substantiated within two days. At an engineering school, a young employee had the opportunity to research a new device, but now, in production conditions, there is no time for thorough research. Nevertheless, the device is promising. The engineering team agrees with the boss and recommends an old, proven device. The boss instructs a young employee on how to write a report praising an old device and recommending its use. The report should not contain a word about a new alternative. What should an engineer do?

Summarizing the above, it should be noted that against the backdrop of an increase in the number of publications devoted to certain aspects of engineering work, the scarcity of studies in which it would be considered as a spiritual and practical activity becomes noticeable. The creativity of an engineer has not yet been studied deeply enough in the sociological and philosophical literature. Scientific, technical and engineering activities as a cumulative source of technological innovation in a number of important aspects are outside the field of research. Therefore, the need arose not so much to optimize the processes of scientific and technical creativity and scientific and technical activity, but to develop a general concept for the further development of a system for training specialists with higher technical education and a methodology for managing this system. The creation of a new paradigm for the educational process has become not only a pedagogical, technological or environmental problem, but also becomes a philosophical and socio-economic problem, on the successful solution of which scientific and technological progress throughout the country depends. It should be noted that until now the process of both theoretical and practical understanding of the categories "engineering activity", "engineering thinking", "scientific and technical creativity" has developed in such a way that its psychological, logical and epistemological aspects have received the greatest development, and general sociological , in essence, have been studied very little, and, as a rule, are in the nature of general recommendations that are difficult to actually implement in the socio-technical activities of an engineer. Therefore, it is natural that the public consciousness is dominated by the idea of scientific, technical and engineering activity as a special kind of spiritual activity, as if divorced from creativity in general and especially from art. Without accepting the limitations of such views, the author came to the conclusion that engineering activity should be considered as a dialectical unity of change in the object and subject of activity, as a constant divergent-convergent process of scientific and technical activity, including its subject, spiritual and organizational components. Engineering activity can be understood and revealed only through a specific historical study of socio-technical and socio-economic processes. Such an analysis makes it possible to understand the inextricable connection between the method of production and scientific and technological progress, scientific and technological progress and culture, the connection between engineering activity and art, with the moral values of a creative person. Modern highly industrialized and largely technocratic society is in dire need of such theoretical works that carry the potential of practicality and make it possible to harmonize the processes of scientific and technical activity with the help of technological innovations. It should also be noted that there has been a sharply increased public need to unite representatives of different scientific disciplines in solving technical problems. This is confirmed by the material incentives Japanese and American firms provide for scientists and engineers to obtain second and third degrees, including the study of foreign languages and non-technical sciences. The real embodiment of this trend is the synector teams in manufacturing performance analysis consulting firms. An example indicating the negative impact of differentiation of sciences is the division of engineering departments of a higher educational institution into departments for equipment and technology in the same branch of production. Such a separation, formally convenient for organizing the educational process and for compiling a range of specialties, led to a deep and long-term mutual alienation of the style of engineering thinking of process engineers and mechanical engineers, as a result of which many unsuccessful and ineffective decisions arose in the design and manufacture of technical objects. Giving universal recommendations for changing the entire system of higher technical education is not a realistic task. This work is only an attempt to fill the "blank spots" that have arisen between the socio-philosophical and subject-technical areas of training in the education system, with the help of concrete sociological and concrete methodological research.

Solving the problems posed in the work is complicated by the fact that during times of crisis many social contradictions appear that are inherent in the existing social system. Therefore, this study does not claim to solve all problems associated with scientific, technical and engineering activities. Considering the multifaceted nature of engineering activity in the light of the onset of a new period in the education system, conditioned by the need to develop students' systems and computer styles of thinking, the author puts forward the following thesis as a basic one: the process of development of natural intelligence should not be identified with the development of increasingly universal artificial intelligence systems, including including computerization. The authors also disagree with the statements that engineering activity will become art only when, on the basis of fully automated and computerized labor, the techniques and methods of scientific and technical technology are combined with artistic creativity. The emergence of value-based approaches to human activity is a long-standing humanistic tradition. Mythology is actually considered the beginning of humanitarian culture. Religion divided the world into material and immaterial (mystical, otherworldly, supernatural), which led to an awareness of the importance of the spiritual in this world, which can also be attributed to humanistic cultural studies. Philosophy develops a rationalistic picture of existence, based on the human mind and scientific achievements. The humanistic orientation of philosophical concepts is expressed in value systems developed by philosophy. As shown in this article, art, including technical art (techne), originating in the springs of myth-making, religious teachings, and philosophy, ultimately led humanity to the development of rationalism, which degenerated in the 20th century into technicism and technocracy. There has been a shift in the value system towards greater satisfaction of human material needs. In the history of its development, humanity has moved further and further away from truly humanistic ideals, moving away from the social-humanistic direction of progress towards scientific and technological progress. Frightened by the results of such a movement, which led to an environmental and moral catastrophe, the world community, at least its leading part, is trying to change the course of human development towards humanization. This process is most important for the education system. In the education system itself - to humanize the process of technical education. Using various sociocultural approaches (social, philosophical, systemic, structural-functional, general systems theory), we tried to formulate a technology paradigm for the formation of engineering thinking associated with the destruction of ideologies of utilitarian-pragmatic goals. We also tried to contribute to the work of streamlining the mass of recommendations, conglomerative in form and eclectic in content,introducing a sociotechnical approach to solving technical problems using NTT and innovative technologies. In contrast to the descriptive (descriptive) method of constructing humanistic concepts adopted in socio-philosophical works, the study proposes a constructive definition of the methodology for moving the system of higher technical education along the path of humanization. To reveal this approach, the present study raised issues of dialectics, ethics and aesthetics as necessary.

Over the past decades, society's requirements for specialists have significantly transformed. In addition to being highly qualified in their field, workers in science, technology, and management must be capable of creative activity and self-improvement. Engineering activity began to have a planetary character, technogenesis became commensurate with natural scales, covering the entire territory of the earth. The humanization of scientific and technological progress to mitigate technocratic blows should be directed primarily towards the humanization of the process of education of engineers. Nowadays, the disciplinary, narrowly subject paradigm of education continues to operate, fostering “chauvinism of special disciplines.” Those who call for a shift in the training of engineers to a paradigm shift, to the introduction of a problem-based method, and the like, are right, in fact. The difficulty of such a transition lies in the fact that there are no simple and quick solutions leading to successful results in education. It is obvious that the transition period requires not only time, but also special techniques. During this period, an understanding should come of how to move from technical knowledge, how to move from technocratic thinking to sociotechnical knowledge, to humanistic thinking.

First of all, the purpose of education must be changed; it is not knowledge itself that is important, but the development of personality with the help of knowledge. Such goal setting requires solving the problem of teaching students creativity and self-improvement. It is not enough to call for internalist activities focused on self-education. Tools for this activity need to be developed. If this is successful, then both the student and the graduate engineer will be able to take advantage of the content and scope of knowledge that is already available in existing educational programs, using this knowledge to humanize technical activities. The stated position is the main goal of this work. It is to achieve this goal that it is shown how, with the help of a sociotechnical approach, using the polyvariance of such concepts as “consumer properties” and “result quality”, one can arrive at a full-fledged creative educational process.

Therefore, in this article, significant attention is paid to the consideration of the transcendental in engineering activities, i.e. such categories as faith, intuition, imagination, fantasy, creativity, “working” for the humanization of engineering thinking. The introduction of such conventional concepts as “efficiency coefficient” is associated with the need for an instrumental and constructive description of innovative processes in engineering activities. The ability to operate with these concepts will enable the engineer not only to adapt to innovation, but also to actively participate in the creative process and master the art of solving real life problems. The tools that the NTT methodology has in its arsenal will help the engineer make the transition from a system of conceptual knowledge to a system of instrumental knowledge, and move on to real creativity.

The search for effective criteria for optimizing engineering activities is a fundamental point to which considerable attention is paid in the study. The anthropological aspect of performance results can be realized with a sufficiently in-depth analysis of the concept of “result quality”. This will help in teaching to move from explanatory and illustrative methods to problem-search methods.

A few words about the semiotic (linguistic) aspect of engineer training. The main operational means of engineering thinking is the ability to express one’s thoughts using symbolic means and understand the meaning of regulatory texts, the form of which can take different forms: diagrams, drawings, specifications, etc. That is why it is necessary to use a large amount of illustrative material, which allows a methodical, step-by-step introduction to the subject of training, who has already learned the language of “technical graphics” from special courses (where, in addition to drawings and diagrams, various formulas can also be included, expressing graphical dependencies in a different symbolic form), to the social and philosophical categories revealed in our research using the language of the constructive and conceptual apparatus of the systems approach. For this reason, we considered it necessary to provide in the appendix a dictionary of concepts, which should form the basis of an engineer's thesaurus and reveal to the learner the main categories of an engineer's humanistic thinking. As we part with the reader, let us draw his attention once again to the fact that in addition to knowledge acquired in a rational way, an engineer, relying on a system of moral values, in real life uses will, emotions, intuition, faith and other irrational components of human activity. Therefore, the strategy of higher technical education should be associated with the growth of the student's self-awareness, with training that performs the function of humanizing the individual.

The authors hope that the material presented in the article will help Russian engineers develop creative abilities, develop a sense of confidence in their knowledge and realize life goals through education and engineering.

Main part

There are quite a few different definitions and various interpretations of the concept of "technology". Their content varies depending on the specifics of the activity that they define and the field of knowledge in relation to which the definition is given. One of the most common and most general approaches can be given in the following interpretation.

A technique is a set of techniques aimed at achieving a goal. Or in another version: technology is a set of techniques aimed at combating the forces of nature and interchanging matter.

A more modern version of the definition is as follows: technology is a set of skills, abilities, techniques and knowledge that allow humanity to use the reserves of raw materials and energy available in nature. The following definition is quite capacious and quite accurate: technology is an activity aimed at satisfying human needs, which leads to changes in the material world.

Variants of definitions used, as a rule, in real production conditions include the following: technology is all the material conditions necessary for the production process to take place. Or: technology is the means of labor developing in the system of social production. There are also options for socio-economic approaches to defining the concept under consideration. Technology is a set of means that, based on a given situation, allows the most satisfactory way to achieve the intended goal; technology is a set of actions of a knowledgeable person aimed at dominating nature; technique is a skill whose methods are external to the goal.

As can be seen from the analysis of the above definitions, the concept of "technique" is based on categories such as art, skill (techne), or master of skill (technicos). If, with a very general consideration of the process of technology development, we can say that technology is based on the use of the laws of nature, then with a more in-depth analysis, we can distinguish two sources of the process of technology development, namely:

use of achievements of natural science;

social basis of technology.

Natural science, while guiding and demonstrating possible solutions to technical issues, does not in itself determine either the direction, volume, or pace of their resolution. It is possible to understand the direction of development of technology only based on the social conditions within which the development of technology takes place. Technology, unlike science, does not develop outside a specific method of production. The economic laws of a given social system, determined by the method of production, help to understand the origins and directions of development of technology. The implementation of innovations and inventions depends to a large extent on economic conditions. Often, inventions remain unrealized due to unfavorable socio-economic conditions.

In passing, we note that to invent means, by working creatively, to create something new, previously unknown. Or in a more academic and technical version of the definition: an invention is a new and significantly different technical solution to a problem that produces a positive effect. To summarize, we can highlight the following features of the development of technology, namely:

technology is directly related to the laws of natural science, and economic phenomena are related to the laws of natural science through technology;

revolutionary transformations in technology (industrial and scientific-technical revolutions) occur through the accumulation of elements of a new quality (innovation processes);

The dynamics of technology development depends on the social (socio-economic) system.

At the same time, the goals of technology development can be divided into two groups:

improvement of technology and production (scientific aspect of development);

improvement of production itself (production aspect of development).

The first group of goals is determined by social life, the second by the technical needs of production.

If the goals of development include social, economic, aesthetic, psychological, political and others, then the motives for the development of technology can include: passion for invention, ambition, ease of labor, improvement of financial situation, domination over others, etc.

Particularly noteworthy is the role of individuals and peoples in the development of technology. The importance of major scientists, inventors and engineers lies in the fact that they, before others, notice the contradictions that arise in production, and, relying on the achievements of modern science and technology, develop solutions that most fully and correctly meet the needs of production and open up prospects for the further development of science and technology. technology. Each nation, depending on specific historical conditions, makes its own contribution to the development of world technology.

Thus, the authors of pioneering inventions in heating engineering were the Russian inventor Ivan Ivanovich Polzunov (1728–1766), the English inventor James Watt (1736–1819), and the French scientist Sadi Carnot (1796–1832). The founders of many achievements in the field of aviation were: German engineer Otto Lilienthal (1848–1896), Russian inventor Alexander Fedorovich Mozhaisky (1825–1890), American aircraft designers and pilots brothers Wilbur Wright (1867–1912) and Orville Wright (1871–1912). The history of technology is a science that studies the general laws of development of productive forces in different periods of the development of human society. Or more specifically, the history of technology is a science that shows the development of the means of labor in the system of social production, both in connection with the forms and methods of labor, and especially in connection with the object (subject) of labor. From the point of view of the natural sciences, the history of technology shows how man is more and more actively and deeply mastering the laws of nature, ensuring a deeper and more versatile use and application of the matter and energy of nature. From a social point of view, the history of technology reveals the social driving forces, the social conditions for the development of technology and shows the role of individual creators of technology. The world surrounding a person consists of nature, society and technology. In relation to natural phenomena, to phenomena of social life and to technical phenomena, the laws of dialectics apply. Dialectics (from the Greek dialektike - the art of conversation, argument) is a theory and method of understanding reality in its development and self-movement, the science of the most general laws of development of nature, society and thinking. The most important categories of dialectics are: contradiction, quality and quantity, chance and necessity, possibility and reality. These categories, as well as the basic laws of dialectics - the unity and struggle of opposites, the transition of quantitative changes into qualitative ones, the negation of the negation - are directly related to the processes associated with the development of invention. At the same time, in the development of technology two types of opposites can be distinguished, namely:

technology and social conditions for its use;

the struggle of opposites in technology itself.

Technology develops at the intersection of natural science and social life. The laws of natural science (physics, chemistry, biology) give an idea of the potential capabilities of technology. The laws of social development determine the very development of technology. For a correct and deep understanding of the processes of technological development, it is necessary to know the laws of development not only of technical (usually applied) sciences, but also the fundamental laws of natural and social (humanitarian) sciences.

As an example, we give the stages of development of metalworking (Table 1).

Table 1. Stages of metalworking development

Stage number	Type of processing	Shape of the processed surface
1	Metal cutting	Processing by point
2	Processing by broaching, rolling	Processing by line
3	Stamp processing	Surface treatment
4	Processing by volume	Crystallization process

The history of technology reveals the connection between technology and science, shows how scientific principles are formed under the influence of practical needs and how science develops technology. Technology can be considered as a set of things and processes united by man into artificially created systems that have the elements and structure necessary for these artificially created systems to function and be used as material means of purposeful human activity (primarily labor and especially production). Table 2 shows the periods of technology development and their chronology associated with the development of European civilization.

Table 2. Periods of technology development

Period No.	Name of the period and its contents	Chronological framework of the period
1	The emergence, development and spread of simple tools of labor in the conditions of the primitive communal method	700–600 thousand BC e. — 4–3 thousand BC e.

	of production	
2	The emergence, development and spread of complex tools of labor under the conditions of the slave-owning mode of production, powered by humans	4–3 thousand BC e. - 4th–5th centuries n. e.
3	The development and spread of complex tools of labor under the conditions of the feudal mode of production, driven by the forces of nature	4th–5th centuries n. e.
4	The emergence of prerequisites for the creation of machinery in manufacturing conditions	14th–15th centuries - end of the 18th century - beginning of the 19th century
5	Distribution of working machines based on the steam engine under the conditions of the capitalist mode of production	end of the 17th century - beginning of the 19th century — 70s of the XIX century.
6	Distribution of a system of machines based on an electric drive under conditions of a monopolistic production method	70s of the XIX century. - beginning of the 20th century
7	The emergence, development and spread of automata and automated machine systems	beginning of the 20th century — 60s of XX century.
8	The emergence, development and dissemination of information technologies	60s of XX century. - beginning of the 21st century.

Along with the biological relationship that man has in common with all living nature, he has a specific type of material interaction with nature - the process of labor. The level of development of tools and means of labor determines the nature of this relationship. The concept of “production” reflects the fact that human labor activity is productive in nature - in the process of labor, things are created that can satisfy one or another human need. People, producing the material goods necessary for life, at the same time produce and reproduce their social relations of production, into which they enter in the labor process. The nature of these relations is determined not by the will and consciousness of people, but by the achieved level and the needs of the development of their material productive forces. Therefore, the concept of production also expresses the fact that labor activity is social in nature and is carried out within the framework of material social relations.

The concept of “method of production” characterizes a historically specific, qualitative definition of production. At the same time, it should be noted that during all periods of technological development there was an accumulation and addition of technical means, many of which took a frozen form (bow, oar, sail, windmill, hammer, etc.). In this sense, some methods of production as technologies exist in our time: manual work on a potter's wheel, transportation of goods on a cart, etc.

A mode of production is a historically determined method of obtaining material goods; unity of productive forces and production relations. The method of production is the basis of any socio-economic formation. The replacement of one method of production by another occurs in a revolutionary way. At the same time, the method of production is the material basis of a socio-economic formation, determining its characteristics, and changes in the method of production determine the development of socio-economic formations, the transition from one function to another. The development of the mode of production is subject to the general sociological law of the correspondence of production relations to the nature and level of productive forces.

Productive forces are a system of subjective (human) and material (technology) elements that carry out “exchange of substances” between society and nature in the process of social production. Productive forces form the leading aspect of the method of production. Each stage of the productive forces corresponds to certain production relations. In the process of their development, productive forces come into conflict with existing production relations. From stimulating forms of development of productive forces, these relations turn into their fetters. If necessary, we will provide a definition of the concept of “labor”. Labor is a purposeful activity of a person, during which he, with the help of tools of labor, influences nature and uses it to create objects necessary to satisfy his needs. The labor process includes labor itself, objects of labor and means of labor. In the process of labor, people enter into production relations.

Production relations are a set of material economic relations between people in the process of social production and the movement of a social product from production to consumer. Production-economic relations differ from production-technical relations in that they express the relations of people through their relations to the means of production, i.e. property relations. Production relations give all social phenomena and society as a whole a historically determined social quality.

Production relations are the social form of productive forces. Productive forces and production relations together constitute two sides of each mode of production and are connected with each other according to the law of correspondence of production relations to the nature and level of development of the productive forces. As they develop, productive forces outgrow the framework of existing production relations and begin to slow down the further development of production. The contradiction between productive forces and production relations is growing, turning into conflict. It is resolved in a social revolution that destroys outdated and establishes new relations of production corresponding to the developed productive forces. A new method of production is emerging. The primitive communal system is the first socio-economic formation of human society. The main features of this formation are the absence of both classes and the state itself, as well as the absence of exploitation. Inventions in the primitive communal method of production are associated with the emergence and spread of simple tools. The invention of tools meant that an object given by nature (stone, stick, bone, shell) was turned into an organ of human activity.

Labor activity in the production of tools led to the development of productive forces. First, in primitive society, a division of labor by gender and age arose; then there was a social division of labor in two directions: cattle breeding and agriculture. The development of productive forces led to a contradiction between them and production relations. The opportunity arose to obtain a surplus product, and, consequently, to create an individual farm.

Table 3 shows an enlarged diagram of the main stages in the development of technology in the primitive communal system. As a commentary on the most significant inventions of this period, it is necessary to mention the emergence of methods for making fire by friction and drilling, as well as the development of a whole group of various hunting weapons. These include: loops for birds and animals, crossbows, spring traps. The invention of the knot made it possible to create snares and lasso. Groups of houses (the first settlements) with floors and walls coated with clay also appeared. Figure 1 shows the logic of the invention of the bow, from the appearance of a closed structure (Figure 1, a), the possibility of using human organs (Figure 1, b, c) to the possibility of movement in space (Figure 1, d). With the subsequent development of technology, we can observe the transformation of the ideas shown in the figure into a whole series of inventions: flat springs, membranes, springs, spiral springs, etc.

Table 3. The main stages in the development of technology of the primitive communal method of production

Epochs	Time	Types of tools	Technological processing	Dwellings	Branches of the economy	Stages of formation	Stages of technology development
Ancient Paleolithic	800,000 before n. e. — 40 000 BC e.	Hand chopped. Incisors. Bone tools. Pointed points	Upholstery. Receipt plates Application of fire	Caves	Gathering	Herd. The origin of the tribal system	The emergence of simple tools
Late Paleolithic. Mesolithic. Early Neolithic	40,000 before n. e. — 4000 BC e.	Silicon cutters. Bow and arrow. Clay dishes. Axes, knives	Skol. Modeling	Earthlings. Buildings made of piles	Hunting	Matri-arhat. Tribal system	Accumulation of simple tools
Late Neolithic. Chalcolithic	4000 to n. e. — 3000 BC e.	Axes with lugs. Saws. Hoes, sickles. Copper weapon	Grinding. Drilling. Sawing. Spinning. Weaving. Copper hammering	Mud dwellings	Cattle breeding. Hoe farming	Patriarchy. Heyday tribal system	Appearance complex tools labor

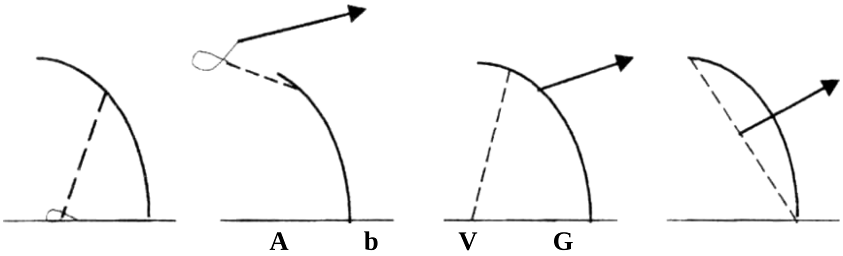

Figure 1. Scheme of using forces:
a - shaft; b - throwing arrow; c - trap; g - onion

Private property and property arose, which began to lead to the disintegration of the primitive communal system. Thus, technology and various technical inventions contributed to changing the system with the help of a social revolution. Inventions under the slave-owning method of production are associated with the development and spread of complex tools. The production relations of the slave system are characterized by the private ownership of slave owners in the means of production, as well as in the worker himself—the slave. The main feature of the slave-owning mode of production is the exploitation of the slave, who performs the function of a “living thing.”

The development of technology during this period was slow, since production was based on the labor of slaves who were not interested in improving tools and labor processes. The division of labor that arose under the slave system led to its specialization and to changes in the tools of labor. For example, a hammer takes on the following forms: blacksmith's, carpenter's, shoemaker's, stonemason's, etc. The specialization of labor also led to the invention of the plow, mill, presses (for grapes and olives), stamping and etching of metals, soldering, and technology for making sour bread. Conscious attempts arose to replace human power with animal power and natural resources (water and wind power). A class of merchants emerged, which determined a number of new areas of development in technology and production: improvement of roads, creation of means of transportation (wheeled carriage, sailing ship) and containers, luxury goods, money. Military equipment also continued to improve (iron swords, iron armor, fortress walls, siege weapons). A division into mental and physical labor arose. “Professional” inventors appeared - Archimedes (c. 287-212 BC), Heron of Alexandria (c. 1st century), and theorists - Aristotle (384-322 BC), Euclid (3rd century). BC.).

There are many inventions related to the production of metals. The first artificial alloy of copper and tin, bronze, was produced. The so-called Bronze Age began (3 thousand - 1 thousand BC). Mass production of weapons using bronze castings becomes possible. The Iron Age in Europe (first millennium BC) was preceded by the invention of iron in Egypt (2800 BC) and China (2357 BC). The greatest invention was the cheese-making process (using leather bellows) for producing iron. The first blower appeared in Egypt around 1580 BC. e. Surface hardening and welded iron were known in Armenia around 1400 BC. e.

The plow, plow, and iron ax are widely used in agriculture. Various irrigation structures appeared - dams, water-lifting devices (shadufs). Drawer wheels and Archimedean screws could be used as drainage mechanisms. The principles of leverage and counterbalance used in them are now widely implemented in both household and industrial equipment.

The specialization of crafts led to the invention of the potter's wheel; in 4–3 thousand BC e. in the Ancient East, in the 7th century BC. e. in the Northern Black Sea region, in the 9th–10th centuries AD. e. in Central Rus' and Germany. Spindles and looms were also invented, mainly for processing flax.

Major changes were also taking place in the construction industry. During excavations of ancient cities, paved streets, water pipes, and sewers were discovered. In Ancient Babylon there were three defensive walls up to 8 m thick. The Great Wall of China, the construction of which began in the 4th–3rd centuries BC. e., had a length of up to 4000 km and a height of up to 10 m. Arches and vaults were invented. Concrete was invented by the ancient Greeks. For example, the Roman Pantheon had an outer diameter of 43 m, a height of about 22 m, a wall thickness of about 7 m and a cast concrete dome. Brick making began in Egypt (4000 BC). First, wooden and then bronze nails, as well as various blocks for lifting weights, began to be used. Engineer Diad led the siege of Tire (under Alexander the Great) and other cities. He invented and used collapsible siege towers, a drill for drilling walls, and battering rams for destruction. During the siege of the city of Rhodes (304 BC), a siege tower 53 m high on 8 wheels was built. During the siege of Syracuse (213–212 BC), Archimedes built throwing machines as defensive mechanisms that could throw stones and arrows weighing up to 150–200 kg over distances of 500–1000 m.

Means of transportation were also improved. Rollers were widely used to move heavy loads; in 4 thousand BC e. Carts with wheels appeared in India. The wheel with a hub appeared in 2 thousand BC. e., then wheels with spokes and metal axles appeared. Rafts steered by poles were used, and trireme ships appeared with three rows of oars and a crew of 150–200 people. Greek Lithius in 325–320 BC. e. traveled to the Arctic Circle and back through the Strait of Gibraltar to England and Norway.

The needs of production and natural science led to the invention of sun (3rd century BC) and water (Ancient Egypt) clocks. Heron of Alexandria wrote the work “On the Art of Making Automata,” which describes how to obtain automatic movement of figures using simple mechanisms using weights, blocks, gears, and levers. He also invented the aeolipile, or “heron’s ball,” which receives rotational motion with the help of steam. Chemical processes appeared: the preparation of paints, wine, soap; alchemy arose, which existed from the 1st to the 16th centuries. The general conclusion for the period of the slave-owning mode of production may be the following. A transition was made from stone tools to metal ones, as well as to the cultural cultivation of plants, iron smelting was mastered, construction was developed (the formation of cities), military equipment was used mainly for the extraction of slaves. The main motive force was people and animals. Feudal production relations presuppose the feudal lord's full ownership of the land, the means of production, peasants and artisans. It should be noted that the serf peasant, unlike slaves, could have some means of production that were used for his own needs.

Under the feudal mode of production, serious changes occurred associated with the separation of the city from the countryside. In the 11th century there were 86 cities in Rus', in the 12th century another 120 were added, and by the beginning of the 13th century there were already about 250 cities. The average number of inhabitants in a Russian city was 10–20 thousand people, which corresponds to 20–30 houses in a modern microdistrict. In such a large city for that time as London, in the 14th century there were 40 thousand people.

There is a process of uniting artisans into workshops. Guilds are a feudal form of craft organization (the origin of the word craft is “handicraft,” i.e., tools powered by humans). At the beginning of the 14th century in Paris there were more than 300 workshops, employing about 5.5 thousand artisans. Inventions in the feudal mode of production are associated with the process of dissemination of complex human-powered tools.

The main inventions and discoveries of this period: an alloy of copper and zinc - brass, a horizontal loom, window glass, the production of paper, glasses, compasses, gunpowder, automatic watches. New industries arose related to book printing, windmills, sailing ships, a plow with an iron share and knife, and a harrow with iron teeth.

The appearance of blast furnaces in Europe in the mid-14th century led to the creation of mountain towns in which artisans lived - miners engaged in mining, producing tools, weapons, jewelry, and minting coins. The first provisions of mining law were developed in the Czech Republic. The first mining law was introduced in 1249 by King Wenceslas for the mountain town of Ihlava. Exploration work was often carried out with the help of a “magic vine”. An artisan miner took a fresh birch rod, split its end and, holding the split parts of the rod with both hands, walked through the area. When approaching minerals (ore), the rod should have deflected downwards. This method has been used in Europe for several centuries. The first mention of black powder - an explosive mixture consisting of potassium nitrate, sulfur and charcoal - dates back to 1232 (China). Black gunpowder appeared in Western Europe in the 14th century and was used for about 500 years.

Paper appeared in Europe in the 11th–12th centuries (it was invented in China by Chai Lun in the 2nd century). The main operations in paper production include: cooking paper pulp, such as bamboo or rags or straw, washing and grinding the pulp, casting sheets and drying. Printing from printing boards also first appeared in China in the 9th century AD. e. A print made in this way is now called an engraving. The relief image on the board is covered with paint, after which a sheet of paper is pressed against it. In the 11th century, the Chinese blacksmith Bi-Sheng (Pi-sheng) made letters from clay and fired them. Thus, he was the first in the world to use movable type. In the 13th century, bronze letters were introduced in Korea instead of clay ones. The first person to print from movable type in Europe was Johann Guttenberg (1400–1468). He improved the use of metal typesetting. First, a matrix was made, a lead alloy was poured into it, and a letter was cast. They began to be placed in typesetting cash desks. Around 1440, hand-operated printing presses were developed with a capacity of about 100 impressions per hour. From 1440 to 1500, more than 30 thousand book titles were published, with a circulation of about 300 copies per book. These books were called incunabula. In total there are about 40 thousand titles with a total of approximately 500 thousand copies. In Rus', the founder of book printing was Ivan Fedorov (c. 1510–1583). In 1564, together with his assistant Fyodor Mstislavets, he published the first dated book “Apostle”.

Glasses appeared in Europe in the 13th century, in Venice. In the 14th–15th centuries, glass grinding was actively developing, especially in Holland. Following the invention of glasses, the telescope and microscope were invented. The first mention of a compass dates back to the 3rd century BC. e. in China. In Europe, the compass appeared only in the 12th–13th centuries. Alchemy, astrology, magic, and the cabalistics of numbers became widespread in the field of natural science. The German chemist and physician Joachim Becher (1635–1682), speaking about this period, wrote: “Eight things the learned and the inquisitive sought tirelessly to find, namely: the philosopher's stone, the elixir of long life, glass softening agents, eternal light, the hyperbole of concave glass, degree of longitude, perpetual motion, squaring a circle" (the ancient problem of constructing a square equal in size to a given circle).

The scientist and physician Ibn Sina (Avicenna) (c. 980–1037), who lived in Iran (Central Asia), developed the "Canon of Medicine" in the twenties of the 11th century, which served as a guide for physicians for five centuries. The scientist Abu Reyhan Muhammad ibn Ahmed al-Biruni (973 - ca. 1050), who lived in Khorezm (an ancient state of Central Asia), created the work "Collected Information on the Knowledge of Precious Metals." He also developed a device for determining the specific gravity of minerals.

The main conclusion about the period of the feudal mode of production can be as follows. The growth of technology was slow and was based mainly on the use of hand tools. Karl Marx (1818–1883) wrote about this period: "Feudal relations ceased to correspond to the developed forces of production. They slowed down production. Free competition has taken their place." At first, competition took place between artisans. Then, from among the most wealthy craftsmen, future capitalists grew up. The process of a new social stratification of society began. And the capitalist system requires, namely:

firstly, the presence of a large number of poor or low-income people, legally free, but deprived of the means of production;

secondly, the accumulation in a few hands of the monetary wealth necessary for the creation of capitalist enterprises.

There was a process of initial accumulation of capital, which K. Marx defined as the historical process of separation of the producer from the means of production. This initial period of capitalist production was called simple capitalist cooperation. In handicraft production, large workshops are formed. The need of production processes for a large number of people and a large expenditure of energy necessitated the creation of machines. There are two ways of development, or two forms of development of manufactories, namely:

an association of artisans of different specialties - heterogeneous manufacture (for example, carriage and saddle makers, coppersmiths);

bringing together artisans of the same specialty in one workshop (for example, the production of needles).

You can compare the productivity of different production methods. An ordinary artisan could produce about 20 needles per day. In an 18th-century needle manufacturing factory, 10 workers produced 48 thousand needles per day.

The main features of manufactories include the division of labor, the use of simple tools, improvement, specialization and differentiation of tools. For example, at the ironworks in England (18th century) over 500 types of hammers were used.

The main engine in industry (during this period) was the water wheel. Technical characteristics of such an engine: power up to tens of kilowatts, speed from 1 to 10 rpm, efficiency factor (efficiency) - 0.3–0.5. A comparison of the capabilities of humans, animals and water wheels is shown in Table 4.

Table 4. Performance Comparison

Energy source	Productivity kgf/sec
Human	5.5–9.6
Animals (donkey, bull, horse)	11.2–40
Wheel	131–175

A number of achievements in domestic technology are associated with this historical period. Russian mechanic and inventor A.K. Nartov (1694–1756), who worked in the Artillery Department, invented drilling machines, an optical sight and much more. Russian inventor Ivan Petrovich Kulibin (1735–1818) created a number of original mechanisms; in particular, a clock equal in size to a duck egg and consisting of 427 parts, as well as a tiny automatic theater with moving figures of people and the performance of various melodies. In November 1735, Russian masters father and son Motorina cast the Tsar Bell, installed in the Moscow Kremlin. Its characteristics: weight - 200 tons, height - 6.3 m, diameter 6.9 m, wall thickness from 27 to 40 cm. Cast iron cannonballs appeared in the 15th century, and wheeled carriages for cannons appeared in the 16th century. Smoothbore artillery existed for about 500 years (1350–1850). In 1586, Russian foundries cast the Tsar Cannon, which was also installed in the Moscow Kremlin. Its caliber is 900 mm, barrel length 5.5 m, barrel weight 4 tons, core weight 2 tons, charge weight 480 kg.

There was active development in other areas as well. The English student W. Lee invented the knitting machine in 1589. Clock designs were improved. Sundials have been known since the third millennium BC. e. Mechanical tower clocks appeared in the 13th century; spring portable clock - at the end of the 15th century. The Dutch mechanic, physicist, astronomer

Christiaan Huygens (1629–1695) wrote the book “Pendulum Clocks,” which describes the use of an elastic spiral and a balancer. The origin of official invention is associated with the establishment of privileges for inventions. Table 5 shows the chronological sequence of introduction of relevant legislation in various countries.

Table 5. Introduction of privileges for inventions

A country	Year
England	1623
USA	1787
France	1791
Russia	1812
Holland Netherlands	1817
Spain	1820
Austria	1820

In the process of invention, authors encountered many difficulties and even open confrontation. For example, in Holland, the laws of 1623, 1639, 1648 prohibited the use and use of a tape machine (textile production). The inventor was sentenced to life imprisonment. Similar measures have often been used in other countries. And only in the middle of the 18th century these laws were repealed. It is impossible not to mention the most famous scientists and naturalists of this period, who had a tremendous influence on the development of science and technology. First of all, this is the Italian artist, scientist, engineer Leonardo da Vinci (1452–1519). His works are related to mathematics, physics, mechanics, astronomy, geology, botany, anatomy and physiology. He developed design diagrams for a parachute, a helicopter, a tank, lathes and weaving machines, and a printing machine. Leonardo da Vinci wrote: “Iron rusts without finding a use, and the human mind, without finding a use, withers.”

Polish astronomer Nicolaus Copernicus (1473–1543), who developed the heliocentric system of the world - a doctrine proving that the Earth is one of the planets rotating around the Sun and its axis. In 1543 he published the book “On the Revolution of the Heavenly Spheres.” Italian physicist and astronomer Galileo Galilei (1564–1642) is the founder of mechanics. He performed many practical works related to the study of simple machines, atmospheric pressure, motion in a resistive medium, etc. In 1609–1610, he designed the first microscope with a magnification of up to 300 times.

Many scientists worked fruitfully in the field of natural science. German astronomer Johannes Kepler (1571–1630) discovered the laws of planetary motion. The English mathematician, astronomer, and physicist Isaac Newton (1643–1727) formulated the basic laws of classical mechanics. The German physician and naturalist Philip Paracelsus (1493–1541) contributed to the rapprochement of chemistry and medicine. The naturalist Andreas Vesalius (1514–1564) wrote a book On the Structure of the Human Body. The English scientist William Harvey (1578–1657) discovered blood circulation. The Italian physicist and mathematician Evangelist Torricelli (1608–1647) invented the mercury barometer and discovered the phenomena of atmospheric pressure and vacuum. The German physicist Otto von Guerick (1602–1686) invented an air pump in 1650, created an electric machine, and in 1654 carried out the famous experiment with the Magdeburg hemispheres. The English physicist William Gilbert (1540–1603) in 1602 published the essay “On the Magnet, Magnetic Bodies, and the Great Magnet, the Earth.” In fact, this is the first book about electricity. The American scientist Benjamin Franklin (1706–1790) produced electric sparks by flying kites during thunderstorms and thereby proved that lightning is an electrical phenomenon (1752). He also invented the lightning rod and flat capacitor. Mikhail Vasilyevich Lomonosov (1711–1765) is rightfully considered the first Russian natural scientist. He laid the foundations of physical chemistry, formulated the principle of conservation of matter and motion, created a number of optical instruments, and much more. Through the division of labor within production, manufacture simplified many operations, which were reduced to such simple movements that it became possible to replace the worker's hand with a machine. The main engine of manufactories becomes a hydraulic wheel (hydraulic water engine). Two social classes are formed: capitalists and workers. The main feature of this period is the invention and distribution of working machines in industry. This process determines the main signs of the transition from manufacturing to machine production. At the same time, a working machine is understood as the main part of the entire machine as a whole, which directly affects the object of labor and expediently changes its shape. The other two parts of the machine - the engine and the transmission mechanism - exist to power the working machine. The main feature of a capitalist factory, which distinguishes it from manufacture, is the use of machine cooperation. K. Marx distinguished between two types of cooperation of machines, namely:

simple cooperation (for example, a weaving factory includes a homogeneous class of machines);

cooperation of dissimilar machines (completing production with a system of machines).

The Industrial Revolution of this period is associated with the transition from manufacturing production and manufacturing organization to machine technology and the factory system. It is customary to divide the process of the industrial revolution into three stages: the appearance of working machines in textile production, the invention of a universal heat engine (steam engine) and the creation of working machines in mechanical engineering. The beginning of the development of fabric production in England is directly related to the passage by English industrialists (in 1719 through Parliament) of a special law prohibiting the import of Indian cotton fabrics. The chronology of inventions and events in this area, often of a dramatic nature, is as follows. In 1733, the English worker John Kay (1704–1774) invented a mechanical (aircraft) shuttle for a weaving machine. Weaving began to outstrip spinning. The spinners did not have time to serve the weavers. English mechanic James Watt (1736–1819) invented the first working spinning machine. In 1784, he took out a patent for it, and in the eighties of the 18th century, a revolt of weavers against machines arose. John Kay was forced to flee. He died in obscurity. In 1764, weaver James Hargreaves (1720–1778) invented the spinning jenny machine (patent 1770). In 1767, the spinners destroyed all the looms in Hargreaves' house. The inventor of the Jenny died in poverty. However, already in 1788, 20 thousand Hargreaves machines were working in industry. In 1769, a patent for a spinning machine was taken out by Richard Arkwright (1732–1792).

The introduction of steam-powered weaving machines led to the disappearance of a whole layer of workers who worked on handlooms. Of the 860 thousand weavers who worked in England at the beginning of the 19th century on handlooms, in 1834 about 200 thousand remained. Many died of starvation. Between 1780 and 1825, the Luddite movement arose in England (its organizer was the worker John Ludd). Workers destroyed factories and killed engineers and inventors. R. Arkwright was forced to defend factories from the Luddites with weapons in their hands. In 1769, a law was even introduced that made anti-machine speeches punishable by death. At the beginning of the 19th century, the gap between weaving and spinning was overcome. It required the development of other industries, such as bleaching, calico printing and dyeing. During the manufacturing period, the forces of animals, wind and water were widely used. But these energy sources, in addition to their advantages, also had a number of disadvantages. Animals could only be used for certain types of work; the wind is fickle and uncontrollable; Water is not available everywhere and its availability depends on the time of year and weather.

The factory method of production required the creation of a powerful engine, universal in technical application and under human control. Such an engine was supposed to free industry from dependence on natural energy sources, i.e. make it possible to concentrate production anywhere. The history (chronology) of inventions of the steam-atmospheric machine is given below.

The ancient Greek scientist and engineer Archimedes (c. 287–212 BC) invented the steam engine. The first to use steam for propulsion was the Greek Heron of Alexandria (1st century). The Italian Leonardo da Vinci left a description of the steam engine. The French physicist Denis Papin (1647–1714 (1712)) described the steam-atmospheric cycle in 1690 and invented the steam boiler and safety valve. The Englishman T. Savery (1650–1715) took out a patent for a steam pump in 1698, which he called “The Miners' Friend.” The pump could pump out water from a depth of up to 10 m. The Englishman Thomas Newcomen (1663–1729) created a new pump design in 1711. Its power reached 8 horsepower, and it could pump water from a depth of up to 80 m.

Interestingly, Newcomen was unable to obtain a patent for his pump, since Savery's patent was drafted in such a way that it reserved for the inventor any possibility of using water vapor. Therefore, Newcomen and his assistant were forced to make contact with Savery.

Russian inventor Ivan Ivanovich Polzunov (1729–1766) was the first to propose a universal heat engine with two cylinders. This is what he wrote in his report dated April 26, 1763: “In order to achieve this glory (if forces allow) for the Fatherland and for the benefit of the whole people, due to the great knowledge in the use of things that are still very familiar today (following the example of other sciences), to introduce into custom." However, Polzunov did not receive support. He had few funds. In May 1766, at the age of 37, he died of transient consumption. In August 1766, the machine was launched. In 43 days of operation, the machine brought in a profit of about 12 thousand rubles. In November 1766, the boiler leaked. The car was stopped and after a few years it was forgotten.

The Englishman James Watt (1736–1819) began work with Newcomen's atmospheric steam engine in 1764. His main reasoning boiled down to the following. To obtain a strong vacuum under the piston, complete condensation of the steam is necessary, i.e. strong cooling of the cylinder. To avoid loss of steam, it must be released into a hot cylinder. With the existing design, these two conditions cannot be met. In 1769 he took out a patent for a capacitor. Watt was invited to the position of chief mechanic in Soho (near Birmingham in the USA). The plant in Soho received letters from entrepreneurs from various industries with requests to produce machines not only for pumping water. The patent for a double-acting machine - a universal heat engine - was taken out in 1784. The main differences of such a machine were the following, namely:

double-action principle - steam acts on one side or the other of the piston;

a spool is used - steam is supplied to different cavities of the cylinder;

a flywheel is used to level out uneven rotational motion;

Watt's parallelogram was introduced.

The latter requires some explanation. Watt could not use a connecting rod-crank mechanism to obtain rotational motion, since a patent was taken for such a transmission by the Frenchman Picard. Therefore, in 1781 he took out a patent for a new method of converting a rocking motion into a continuous rotational one. K. Marx wrote: “...Watt’s great genius is revealed in the fact that the patent he took in April 1784, giving a description of the steam engine, is portrayed not as an invention only for special purposes, but as a universal engine for large-scale industry...” .

50 years later a steam hammer appeared, and 67 years later (1851) a steam engine for ocean-going steamships was presented at the London Industrial Exhibition. Over time, a contradiction arose between the manual technique of making machines and the need for their production. During the manufacturing period, mechanical engineering did not exist as a branch of industry. Only those inventions could have a revolutionary significance for mechanical engineering, as a result of which the tool would pass from the hands of the worker to the mechanism.

Russian inventor Andrei Konstantinovich Nartov (1693–1756) proposed the design of a lathe with a support. The English mechanic Henry Model (1771–1831) invented the cross slide for a lathe in 1794. With the introduction of the support, the machine began to operate with capabilities unattainable even by the most skillful human hand. With the use of supports, all metalworking machines begin to improve and turn into machines. Revolving, grinding, planing, and milling machines appear. In 1807, Model received a patent for an improved steam engine. At the beginning of the 19th century, he invented a hole-punching machine and designed a micrometric caliper, which he named “Lord Chancellor”. The unusually inventive Model did not bother much about obtaining patents. It happened that he was threatened with a lawsuit by people who stole his inventions and issued patents for themselves.

The precision of machine production began to improve. English machine tool builder Joseph Whitworth Whitworth (1803–1887) invented the first measuring machine in 1851. Measurements using his devices were accurate to 0.01 and 0.001 mm. He also introduced gauges and the very idea of thread standardization. It is no coincidence that England at that time was called the “workshop of the world.”
Around 120 BC. e. The Greek poet Antinater of Sidon described the seven wonders of the world. All of them were located in the eastern Mediterranean and made up the following list:

Great Pyramid of Giza.
Hanging Gardens of Babylon.
Temple of Artemis at Ephesus.
Zeus statue in Olympia.
Mausoleum in Halicarnassus.
The Colossus of Rhodes.
Alexandrian lighthouse.

Let us analyze the above-mentioned wonders of antiquity, giving for each of them the corresponding temporal, geographical and technical and economic characteristics.

Great Pyramid of Giza (Pyramid of Cheops) Built for Pharaoh Khufu in 2580 BC. e. The construction site (Giza) is located opposite Cairo, the capital of Egypt. About 100 thousand people participated in the construction, which lasted 20 years. More than 2 million blocks were used, each of which weighed more than 2.5 tons. The side of the base of the pyramid is 230 m, the height is 147 m. The pyramid was built without the use of mortar, the outer blocks are polished white limestone.

Hanging Gardens of Babylon

Built around 600 BC. e. for the wife of Nebuchadnezzar II (605–562 BC) Amytis in the area of the ancient city of Babylon, located on the banks of the Euphrates River south of Baghdad, the capital of modern Iraq. The gardens consisted of rows of terraces with a total maximum height of 40 m and were equipped with an irrigation system.

Temple of Artemis at Ephesus

The last king of the ancient state of Lydia, Croesus (595–546 BC), decided to build a temple in honor of the Moon goddess. The city of Ephesus (currently the territory of Turkey) was chosen as the construction site. The temple was built in 560 BC. e. and consisted of about 120 marble columns up to 20 m high, installed on a foundation platform 131 m long and 79 m wide.

Zeus statue in Olympia

Citizens of the city of Olympia, located in southwestern Greece, decided to build a temple of Zeus, built in 466–456 BC. e., statues of Zeus. The 13 m high statue was erected in 435 BC. e. Ivory plates imitated leather, and gold sheets imitated the god's robe. The throne was inlaid with ebony and precious stones. Subsequently, the statue was transported to Constantinople and burned in Istanbul in 462.

mausoleum in Halicarnassus

The mausoleum was a tomb for King Mausolus (377 (376)–352 BC) and his wife Artemisia. Place of construction - the city of Halicarnassus (currently Bodrum) in Turkey. The mausoleum rose approximately 43 m above the ground. A chariot was installed on top. The time of construction is approximately 350 BC. e.

The Colossus of Rhodes

The decision to build the statue was made by the people of the island of Rhodes, located in the Aegean Sea, in honor of the victory in the battle. The Colossus took about 11 years to build and was completed around 280 BC. e. The material was bronze, the outer surface was covered with bronze plates. The statue was destroyed 50 years later by an earthquake.

Alexandrian lighthouse

In fact, it was the world's first real professional lighthouse. It was erected on the island of Pharos in the Mediterranean Sea, near Alexandria. The lighthouse took about 20 years to build and was completed around 280 BC. e. The total height of the lighthouse was 117 m; a spiral ramp for carts with fuel was built inside. In good weather, the lighthouse was visible at a distance of up to 50 km. The architect Sostratus decided to perpetuate his name. It was carved on a stone under cement with the name of King Ptolemy Philadelphus. In the 14th century, the lighthouse was destroyed by an earthquake.

Wonders of the Middle Ages

The list of structures classified as wonders of the world of the Middle Ages includes unique structures made in the period from 500 to 1500. By analogy with the previous list, we first give a general list of them, and then give a brief description:

Cave of Ten Thousand Buddhas.
Great Zimbabwe.
Angkor Wat.
Krak de Chevalier.
Salisbury Cathedral.
Alhambra.
Tenochtitlan.

Cave of Ten Thousand Buddhas (Wanfodang)

Religious building associated with Chinese Buddhism. Located on the banks of the Yellow River in Eastern China. It is a whole series of caves with a total of about 100 thousand Buddhas. In one of the largest, square-shaped caves, there is a sculpture of a sitting Buddha about 17 m high. In the same cave there are 10 thousand bas-relief figurines of Buddhas. Construction time: 680. Has survived to this day.

Great Zimbabwe

It is a fortress in the form of an ellipse with a wall 250 m long and up to 10 m high. Inside there is a conical tower 9 m high, built without mortar. The material was a mixture of clay and crushed stone - dagi. The fortress was built in Zimbabwe (Africa) around the 8th century and existed until the 17th century. It was discovered by Europeans in 1867.

Angkor Wat

Angkor Wat - the temple of God Vishnu (Hinduism) was built at the beginning of the 12th century in the city of Angkor Thom - the capital of the Khmer Empire, in the north-west of Cambodia. It was a three-story building with towers up to 60 m high. The temple was built by about 5 thousand artisans and 50 thousand workers. The city was destroyed in 1431 and discovered by a French missionary in 1850.

Krak des Chevaliers

The castle was built around 1142 for the crusader knights in Syria on the shores of the Mediterranean Sea at an altitude of 650 m above sea level. The castle has two walls with 13 towers and could accommodate a garrison of up to 2 thousand people with horses and a food supply of up to 5 years. Nevertheless, in 1271, the castle was captured through cunning. Has survived to this day.

Salisbury Cathedral

Located in the city of Salisbury in southern England. Construction time: 1225–1258. Built of stone on a foundation only one meter thick. Below is a natural layer of gravel. The length of the cathedral is 144 m, the height in the middle is 25 m. The height of the tower together with the spire is 123 m (built in 1285–1315). In 1386, a striking clock was installed on the tower, although without a dial. Has survived to this day.

Alhambra

A citadel fortress built by the Muslim Moors for defense in the 8th–9th centuries. Located near the city of Granada in Andalusia, southern Spain. In 1492, Spanish Christians expelled Muslims from the Alhambra. In the XIII-XIV centuries, the fortress was turned into a beautiful palace with 23 towers and 4 gates. The length is about 1 km, the maximum width is 300 m.

Tenochtitlan

The city of Tenochtitlan is the center of the Aztec Empire (Indian hunters). Located in the southern part of modern Mexico City in Mexico. It was built in 1415 and was the largest city of that time with a population of 100 thousand to 500 thousand people, stone houses, temples and palaces. In the center of the city there was a pyramid 30 m high. Tenochtitlan was destroyed by the Spaniards in 1521.

Wonders of the world of our time

In the second half of the 20th century, so many grandiose structures arose on land and on water that it is not possible to describe them even briefly within the framework of this publication. Therefore, from the entire variety of artificial structures, by analogy with previous periods, only seven were selected, the most characteristic of various areas of engineering activity:

Opera House in Sydney.
Channel Tunnel.
Kansai Airport.
Concorde plane.
Aswan Dam.
Sears Tower skyscraper.
Kennedy Space Center.

Opera House in Sydney

In 1950, a competition for the theater project was announced. Construction lasted from 1959 to 1973 in Sydney (Australia) on the bay. The main dimensions of the theater: length 185 m, width 100 m, maximum height 67 m. A distinctive feature is the roof of the theater in the shape of giant sails.

Channel Tunnel

The longest underwater tunnel. Connects the mainland (France) with the island (England). The first proposal to build a tunnel arose in 1802. The tunnel was built in 1987–1994. Its length is more than 50 km at a depth of 45 m below the seabed. The tunnel is divided into 3 sections. There are separate sections for rail and road transport. Traveling through the tunnel takes about 35 minutes, with a maximum speed of 160 km/h.

Kansai Airport

The first airport not built on land. The construction site was Osaka Bay, 5 km from the Japanese island of Honshu. The artificial island for the airport took 5 years to build and was completed in 1994. The island was built at a depth of twenty meters. The following materials were used for backfilling: sand, earth, crushed stone, reinforced with steel frames. Overall dimensions of the island: length 4 km, width 1.25 km. The 1,700 m long airport building is supported by 900 columns. The airport is connected to land by a bridge with roads and railways.

Concorde airplane

The Concorde supersonic high-speed transport aircraft was built in Britain (Filton) and France (Toulouse). The first aircraft was built in 1969. In 1997, there were 14 Concordes on the lines (a total of 16 were built). Technical characteristics of the aircraft: length 62.1 m, wingspan 25.5 m, maximum lift height 18,300 m, maximum speed 2 times the speed of sound (sound speed 1225 km/h), fuel volume about 960 thousand liters, landing 100 seats. Main flight routes: London - New York, Paris - New York.

Aswan Dam

Built on the world's longest river, the Nile, near Aswan (Egypt). The project belongs to Germany, construction was carried out with the help of the Soviet Union in the period from 1960 to 1971. The length of the dam is about 3.6 km, height 111 m, width at the top 40 m, at the bottom 925 m. After the construction of the dam, Lake Nasser was formed, about 50 km long.

Sears Tower skyscraper

Tallest building in the world (until 1998). Built in Chicago (USA) in 1973. It was built over three years by 2,400 workers. The total height is 540 m. The building has 104 high-speed elevators, divided into three lift zones. Six automatic machines constantly wash the building's 16 thousand windows. At an altitude of 412 m there is an observation deck, which offers views up to 80 km away.

Kennedy Space Center

The space center was built at Cape Canaveral (Florida, USA). In 1969, a man was launched to the Moon. The assembly of the devices was carried out in a building 160 m high. Transportation to the launch site, located 5 km from this building, was carried out using a special tractor with a crew of 26 people.

H. Emerson (1853–1931), in his book “The Twelve Principles of Productivity,” written in 1911–1914, notes that those ideas of faith, hope, love and beauty that were embedded in the seven wonders of the ancient world are practically absent in modern world. As an example, he cites seven American buildings of that time:

Panama Canal.
Train stations in New York.
New York Ship Canal.
Improving inland water communications.
American Navy.
Underground New York roads.
Skyscrapers with elevators.

All these structures “suffer” from a utilitarian, purely pragmatic approach with their corresponding perception and impact. It can be stated with regret that most modern engineering structures can also be attributed only to purely commercial, unspiritual “achievements” of humanity

In the world around us, four classes of objects can be distinguished: inanimate nature, living nature, technology, and thinking beings - people. Technology is the main means of human influence on inanimate and living nature, as well as a means of human interaction with nature. These connections and interactions are divided into four groups of systems:

technology is a subject of labor;
man - technology;
technology - nature;
technology - society (society).

The structure, functioning and development of technology are simultaneously subject to three groups of laws: the laws of nature, the laws of society and the laws (regularities) of technology. Technical laws are laws of goal implementation and are based on the realization of human needs. There are two groups of laws of technology: laws of structure and laws of development of technology. For a better understanding of the further material, we will introduce a number of definitions.

The technosphere is the totality of all operating, inactive and recycled technical objects, all material results and consequences of their activities for a certain space. By technical object (technical system) we mean a tool, machine, device, weapon, structure, etc. We will call everything that has a specific function an element of a technical object. We define a set of technical objects that have the same function as a class of technical objects, and we denote mass-produced technical objects that have the same function and design as a generation of technical objects.

When moving from the previous generation of technical objects to the next one, the function of a technical object usually remains unchanged, but its design changes and some criteria are improved. Below are tables with a list of groups of typical external and internal criteria for objects (Tables 6 and 7).

Table 6. Internal object criteria

No.	Groups and subgroups of criteria
1	Functional criteria a) performance: labor productivity; reliability; mechanization; automation: speed of movement or processing; physical parameters; continuity of the processing process; b) accuracy: manufacturing; measurements: hitting the target; management; c) durability
2	Technological criteria a) labor intensity of production; b) technological capabilities; c) use of materials; d) time and complexity of design; e) time and labor intensity of repairs
3	Economic criteria a) costs of materials; b) energy costs; c) costs of obtaining information
4	Anthropogenic criteria a) ergonomics; b) beauty; c) safety; d) environmental friendliness

Table 7. External object criteria

No.	Criteria (patterns) of development
1	The period of time between the great inventions that caused the technical revolution is monotonously decreasing (from hundreds and tens of thousands of years in the Stone Age to tens and several years at the present time)
2	The period of time from scientific discoveries to their implementation is monotonously decreasing (from hundreds and tens of years in the 18th–19th centuries to several years at present)
3	The period of time between two mass-produced technical objects that have the same function is monotonically decreasing (from tens of years in the 19th century to several years today)

Conclusion

The general principles of the main principles of engineering ethics are the support and development by engineers of the purity, honor and dignity of the engineering profession. To do this, engineers are obliged, namely:

Use your knowledge, skills and abilities to increase human well-being.

Serve the public, employers and customers fairly and impartially.

Respect the competence and prestige of the engineering profession.

Uphold the disciplinary standards of professional and technical communities.

Engineers, in the performance of their professional duties, must place the safety, health and welfare of the public above all else.

Engineers must carry out work only within the scope of their competence.

Engineers must respond objectively to public inquiries.

Engineers in their professional field act as loyal representatives, or fiduciaries, for each employer or customer and must avoid conflict.

Engineers should build their professional reputation on integrity and should not compete unfairly with others.

Engineers must support their own professional development and provide opportunities for professional development to engineers under their supervision.

Typical scenarios of conflict situations Situation “Paradox”

The formula of any invention is drawn up in such a way that it considers exclusively the positive aspect. However, each invention, in its internal essence, is based on the resolution (removal) of a technical or social contradiction in its dialectical interpretation and development (this thesis is developed in more detail in the “Theory of Solution of Inventive Problems”). Therefore, in every innovation there are inevitably and then always manifest negative consequences. This provision especially concerns environmental issues.

Such situations are observed in all typical technical innovations: an increase in engine power leads to increased environmental pollution; an increase in flight speed leads to the appearance of ozone holes; An increase in the carrying capacity of vehicles leads to the destruction of roads and soil, etc.

What should an engineer do? Where are the boundaries of ethical and unethical, moral and immoral technical solutions?

Situation "Good and Evil"

We are talking about military inventions. The engineer understands that the invention is aimed at destroying industrial facilities, natural resources, technical means, and enemy manpower. The engineer, as a performer and manager of work, is professionally prepared for this type of activity. However, he lives in the real world and understands that devoting his life to the direct or indirect destruction of other lives is clearly evil. What should a future engineer do during his training? During the period of designing military equipment? During the period of organizing work and managing other people?

Situation “Spiritless Automation” The issue of new technologies that make it possible to automate production is being discussed. Products put into production give birth to a world devoid of soul, a world that promotes the development of inertia, impersonality, and lack of spirituality. Panel and block construction of houses gave rise to dull neighborhoods and “gray” residents. Furniture made from particle boards consists of identical walls and tables with sharp, right angles, which respectively affect the human psyche: prickly, sharp angles appear in the behavior of the growing and already grown-up generation.

What should an engineer do? Should we cancel the automation of production processes? How to build both cheaply and beautifully? How can we make sure that things produced in continuous production bring joy to people?

Situation “Internal conflict”

The company has a large order, for example, for the production of an automatic line. However, individual units and components are not sufficiently developed and require improvement. The alternative is this: either a long but reliable way to debug individual units, or a relatively quick production of the entire line at once, for which the customer is already paying a lot of money, which has a beneficial effect on the financial situation of the engineer himself. What to do? Argue with management, whose prestige depends on the timing of the order? Give information to the customer without informing the management of your company? Silence?

Situation “Innovation is routine”

A typical problem when designing new technology. The device is designed the old fashioned way. Where electronics can be used, mechanics or hydraulics are used. The engineer understands that he needs to take a risk and give the new design a try to break into the market. But management is afraid of failures, inoperability and unreliability and therefore is “pursuing” an outdated, but already proven option.

What should an engineer do? Resign yourself? Conduct research yourself? Looking for sponsors?

Situation “Instant result”

The age-old debate about quality, quantity and cost. There are two options for completing any order. The first is to design and make things that are truly strong, reliable and durable. The second is to imitate strength, reliability and durability through the use of externally similar materials and design solutions (color, shape, weight, speed, etc.). At the same time, the main attention is paid not to the product itself, but to advertising and packaging. Many companies from the so-called developing countries took this path: the “yellow assembly” version of personal computers, toys from China, etc.

What should an engineer working in a company do according to the second option? Don't think about the consequences? Struggle to improve quality? Quit your job?

Situation “Domestic priority” A Russian company offers an organization (possibly state-owned) its own invention for use in the production of products. The invention promises high efficiency and low implementation costs. But the organization is going to negotiate the purchase of similar products in one of the Western countries, for which its representatives are going to travel to this country in the near future. The engineer, who must evaluate the proposal as an expert, is reminded of the priority of developing relations with this country (political aspect) and of the interest of the leaders in the trip (personal aspect).

How should an engineer behave if the effectiveness of a domestic invention is obvious to him?

Situation "Service invention"

An engineer works on an invention during office hours, using office equipment. When he is close to completing the work, he leaves the company and sells the product as his own invention. Perhaps the engineer received a low salary and, moreover, irregularly.

How to evaluate an engineer's behavior from an ethical point of view?

Situation "Choice"

The problem of fairness and reliability in engineering. An engineer works for a government organization that prepares reports on the environmental impacts of projects currently planned by the government. The engineer reports the results of his work to management, after which the manager asks him to change some of the conclusions presented in the report and/or remove some data from it.

What should an engineer do?

Situation "Personal Interest"

The engineer is expected to make an unbiased decision in the best interests of the client, but the engineer has his own interests (related to investment, family relationships, etc.) that may influence the decision. For example, an engineer is expected to help a company decide which product to purchase for the company's needs, and the engineer is the owner (or partner) of a company that offers those products.

Should an engineer remove himself from a situation in which he has a conflict of interest? Should the engineer tell the client that self-interest makes him biased?

Situation "Security"

The engineer is concerned about the safety of the project. Events can develop as follows. The engineer reports his concerns to his boss, but the boss is reluctant to take any action and advises him to remain calm. The engineer must decide whether to “sound the siren”, i.e. contact the authorities, the press, etc. At the same time, the employer can treat the engineer very well. How to combine a loyal attitude towards the employer with protecting the interests of society? When should an engineer “sound the siren”?

Situation "Risk"

(exacerbated version of the “security” situation)

An engineer must make difficult decisions regarding the degree of risk associated with the equipment he is designing.

How to decide on the acceptable level of risk?

Situation “Young specialist” (a specific version of the situation “Innovation - routine”)

The circumstances are such that you have to choose between a traditional and a new solution that promises increased efficiency and reduced costs. The choice, however, should be based only on preliminary testing. The young engineer's boss unexpectedly informs a group of colleagues that the recommendations must be substantiated within two days. At an engineering school, a young employee had the opportunity to research a new device, however, now, in production conditions, there is no time for thorough research. Nevertheless, the device is promising.

The engineering team agrees with the boss and recommends an old, proven device. The boss instructs a young employee on how to write a report praising an old device and recommending its use. The report should not contain a word about a new alternative.

What should an engineer do?

Summarizing the above, it should be noted that against the backdrop of an increase in the number of publications devoted to certain aspects of engineering work, the scarcity of studies in which it would be considered as a spiritual and practical activity becomes noticeable. The creativity of an engineer has not yet been studied deeply enough in the sociological and philosophical literature. Scientific, technical and engineering activities as a cumulative source of technological innovation in a number of important aspects are outside the field of research. Therefore, the need arose not so much to optimize the processes of scientific and technical creativity and scientific and technical activity, but to develop a general concept for the further development of a system for training specialists with higher technical education and a methodology for managing this system. The creation of a new paradigm for the educational process has become not only a pedagogical, technological or environmental problem, but also becomes a philosophical and socio-economic problem, on the successful solution of which scientific and technological progress throughout the country depends. It should be noted that until now the process of both theoretical and practical understanding of the categories “engineering activity”, “engineering thinking”, “scientific and technical creativity” has developed in such a way that its psychological, logical and epistemological aspects have received the greatest development, and in general - sociological, essentially, have been studied very little and, as a rule, are in the nature of general recommendations that are difficult to actually implement in the sociotechnical activities of an engineer. Therefore, it is natural that the public consciousness is dominated by the idea of scientific, technical and engineering activity as a special kind of spiritual activity, as if divorced from creativity in general and especially from art. Without accepting the limitations of such views, the author came to the conclusion that engineering activity should be considered as a dialectical unity of changes in the object and the subject of activity, as a constant divergent-convergent process of scientific and technical activity, including its subject, spiritual and organizational components. Engineering activity can be understood and revealed only through a specific historical study of socio-technical and socio-economic processes. Such an analysis makes it possible to understand the inextricable connection between the method of production and scientific and technological progress, scientific and technological progress and culture, the connection between engineering activity and art, with the moral values of a creative person. Modern highly industrialized and largely technocratic society is in dire need of such theoretical works that carry the potential of practicality and make it possible, with the help of technological innovation, to harmonize the processes of scientific and technical activity.

It should also be noted that there has been a sharply increased public need to unite representatives of different scientific disciplines in solving technical problems. This is confirmed by the material incentives Japanese and American firms provide for scientists and engineers to obtain second and third degrees, including the study of foreign languages and non-technical sciences. The real embodiment of this trend is the synector teams in manufacturing performance analysis consulting firms. An example indicating the negative impact of differentiation of sciences is the division of engineering departments of a higher educational institution into departments for equipment and technology in the same branch of production. Such a separation, formally convenient for organizing the educational process and for compiling a range of specialties, led to a deep and long-term mutual alienation of the style of engineering thinking of process engineers and mechanical engineers, as a result of which many unsuccessful and ineffective decisions arose in the design and manufacture of technical objects. To give universal recommendations for changing the entire system of higher technical education is an unrealistic task. This work is only an attempt to fill the “blank spots” that have arisen between the socio-philosophical and subject-technical areas of training in the education system, with the help of specific sociological and specific methodological research.

Solving the problems posed in the work is complicated by the fact that during times of crisis many social contradictions appear that are inherent in the existing social system. Therefore, this study does not claim to solve all problems associated with scientific, technical and engineering activities. Considering the multifaceted nature of engineering activity in the light of the onset of a new period in the education system, conditioned by the need to develop students' systems and computer styles of thinking, the author puts forward the following thesis as a basic one: the process of development of natural intelligence should not be identified with the development of increasingly universal artificial intelligence systems, including including computerization. The author also does not agree with the statements that engineering activity will become art only when, on the basis of fully automated and computerized labor, the techniques and methods of scientific and technical technology are combined with artistic creativity. The emergence of value-based approaches to human activity is a long-standing humanistic tradition. Mythology is actually considered the beginning of humanitarian culture. Religion divided the world into material and immaterial (mystical, otherworldly, supernatural), which led to an awareness of the importance of the spiritual in this world, which can also be attributed to humanistic cultural studies. Philosophy develops a rationalistic picture of existence, based on the human mind and scientific achievements. The humanistic orientation of philosophical concepts is expressed in value systems developed by philosophy. As shown in this article, art, including technical art (techne), originating in the springs of myth-making, religious teachings, and philosophy, ultimately led humanity to the development of rationalism, which degenerated in the 20th century into technicism and technocracy. There has been a shift in the value system towards greater satisfaction of human material needs. In the history of its development, humanity has moved further and further away from truly humanistic ideals, moving away from the social-humanistic direction of progress towards scientific and technological progress. Frightened by the results of such a movement, which led to an ecological and moral catastrophe, the world community, at least its leading part, is trying to change the course of human development towards humanization. This process is most important for the education system. In the education system itself - to humanize the process of technical education.

Using various sociocultural approaches (social, philosophical, systemic, structural-functional, general systems theory), we tried to formulate a technology paradigm for the formation of engineering thinking associated with the destruction of ideologies of utilitarian-pragmatic goals. We also tried to contribute to the work of streamlining the mass of recommendations, conglomerative in form and eclectic in content, by introducing a sociotechnical approach to solving technical problems using NTT and innovative technologies. In contrast to the descriptive (descriptive) method of constructing humanistic concepts adopted in socio-philosophical works, the study proposes a constructive definition of the methodology for moving the system of higher technical education along the path of humanization. To reveal this approach, the present study raised issues of dialectics, ethics and aesthetics as necessary.

Over the past decades, society's requirements for specialists have significantly transformed. In addition to being highly qualified in their field, workers in science, technology, and management must be capable of creative activity and self-improvement. Engineering activity began to have a planetary character, technogenesis became commensurate with natural scales, covering the entire territory of the earth.

The humanization of scientific and technological progress to mitigate technocratic blows should be directed primarily towards the humanization of the process of education of engineers. Nowadays, the disciplinary, narrow-subject paradigm of education continues to operate, fostering “chauvinism of special disciplines.”

Those who call for a shift in the training of engineers to a paradigm shift, to the introduction of a problem-based method, and the like, are right, in fact. The difficulty of such a transition lies in the fact that there are no simple and quick solutions leading to successful results in education. It is obvious that the transition period requires not only time, but also special techniques. During this period, an understanding should come of how to move from technical knowledge, how to move from technocratic thinking to sociotechnical knowledge, to humanistic thinking.

First of all, the purpose of education must be changed; it is not knowledge itself that is important, but the development of personality with the help of knowledge. Such goal setting requires solving the problem of teaching students creativity and self-improvement. It is not enough to call for internalist activities focused on self-education. Tools for this activity need to be developed. If this is successful, then both the student and the graduate engineer will be able to take advantage of the content and scope of knowledge that is already available in existing educational programs, using this knowledge to humanize technical activities. The stated position is the main goal of this work. It is to achieve this goal that it is shown how, with the help of a sociotechnical approach, using the polyvariance of such concepts as “consumer properties” and “result quality”, one can arrive at a full-fledged creative educational process.

Therefore, in this article, significant attention is paid to the consideration of the transcendental in engineering activities, i.e. such categories as faith, intuition, imagination, fantasy, creativity, “working” for the humanization of engineering thinking. The introduction of such conventional concepts as “efficiency coefficient” is associated with the need for an instrumental and constructive description of innovative processes in engineering activities. The ability to operate with these concepts will enable the engineer not only to adapt to innovation, but also to actively participate in the creative process and master the art of solving real life problems. The tools that the NTT methodology has in its arsenal will help the engineer make the transition from a system of conceptual knowledge to a system of instrumental knowledge, and move on to real creativity.

The search for effective criteria for optimizing engineering activities is a fundamental point to which considerable attention is paid in the study. The anthropological aspect of performance results can be realized with a sufficiently in-depth analysis of the concept of “result quality”. This will help in teaching to move from explanatory and illustrative methods to problem-search methods.

A few words about the semiotic (linguistic) aspect of engineer training. The main operational means of engineering thinking is the ability to express one’s thoughts using symbolic means and understand the meaning of regulatory texts, the form of which can take different forms: diagrams, drawings, specifications, etc. That is why it is necessary to use a large amount of illustrative material, which allows a methodical, step-by-step introduction to the subject of training, who has already learned the language of “technical graphics” from special courses (where, in addition to drawings and diagrams, various formulas can also be included, expressing graphical dependencies in a different symbolic form), to the social and philosophical categories revealed in our research using the language of the constructive and conceptual apparatus of the systems approach. For this reason, we considered it necessary to provide in the appendix a dictionary of concepts, which should form the basis of an engineer’s thesaurus and reveal to the learner the main categories of an engineer’s humanistic thinking.

As we part with the reader, let us draw his attention once again to the fact that in addition to knowledge acquired in a rational way, an engineer, relying on a system of moral values, in real life uses will, emotions, intuition, faith and other irrational components of human activity. Therefore, the strategy of higher technical education should be associated with the growth of the student’s self-awareness, with training that performs the function of humanizing the individual.

The authors hope that the results of their research presented in the article will help Russian engineers develop creative abilities, develop a sense of confidence in their knowledge and realize their life goals with the help of their education and the art of engineering.

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