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SYSTEM APPROACH TO THE ANALYSIS OF PROFESSIONAL COMPETENCE OF AN ENGINEER

The article reviews and analyses using of system approach to the analysis of professional competence of an engineer. Engineers' training upgrading is one of the most important acmeological tasks. An engineer, as a subject of innovative activity, is the central figure of scientific and technological progress; the implementation of the tasks that the country solves depends to a great extent on his independence, professional competence, readiness for constant self-training. It is determined that any professional activity arises based on the needs of a society. However, as a professional one, engineering activity was generated only by large-scale machine production, which required the development of a certain system of knowledge, abilities and skills as the basis of expedient human activity. With the growth and complexity of industrial production, the engineering activity was mainstreamed, the proportion of engineers in the total number of industrial production personnel increased, there were structural changes in the engineering and technical workforce. At the same time, their professional qualifications were changing. Effective engineering demanded further expansion of technical, sociological and fundamental general technical knowledge, their accumulation, i.e. spacious mind and at the same time the ability to understand narrow specific issues in accordance with the specialization. When analyzing the course units programs of the specialties of this profile, it was found out that the basis for most of the skills listed above should be laid in the classroom session (lectures, seminars and laboratory classes). Moreover, the formation of skills occurs in a variety of academic disciplines that have weak interdisciplinary connections. Unfortunately, the further development of the skills laid down at the previous stage of training is not always foreseen. This contributes poorly to the formation of the system of skills that students need so much for their future professional activities.

Keywords: *system approach; an engineer; professional competence; of professional competence of an engineer.*
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СИСТЕМНИЙ ПІДХІД ДО АНАЛІЗУ ПРОФЕСІЙНОЇ КОМПЕТЕНТНОСТІ ІНЖЕНЕРА

У статті розглядається та аналізується використання системного підходу до аналізу професійної компетентності інженера. Підвищення кваліфікації інженерів – одне з найважливіших акмеологічних завдань. Інженер, як суб'єкт інноваційної діяльності, є центральною фігурою науково-технічного прогресу; реалізація завдань, які вирішує країна, значною мірою залежить від його незалежності, професійної компетентності, готовності до постійної самопідготовки. Визначено, що будь-яка професійна діяльність виникає на основі потреб суспільства. Проаналізувавши навчальні програми спеціальностей цього профілю, з'ясувалося, що основу більшості навичок, перерахованих вище, слід закладати на заняттях (лекції, семінари та лабораторні заняття). Більше того, формування навичок відбувається під час вивчення різних навчальних дисциплін, які мають слабкі міждисциплінарні зв'язки.

Ключові слова: *системний підхід; інженер; професійна компетентність; професійна компетентність інженера.*

Formulation of the problem. Engineers' training upgrading is one of the most important acmeological tasks. An engineer, as a subject of innovative activity, is the central figure of scientific and technological progress; the implementation of the tasks that the country solves de-

pends to a great extent on his independence, professional competence, readiness for constant self-training.

Analysis of research and publications. Many foreign and domestic scientists have been engaged in the problem of researching the professional competence of the engineer: L. Vashchenko, V. Vvedensky, M. Zhaldak, I. Ziazun, M. Kornilova, O. Lokshina, T. Mishinina, N. Nichkalo, O. Ovcharuk, O. Pometun, A. Khutorsky, O. Savchenko, S. Sysoyeva, O. Semenog and others.

The above mentioned helps to outline the aim of the research, which is to analyse using of system approach to the analysis of professional competence of an engineer.

The statement of basic material. UNESCO, with the participation of such authoritative international organizations as FEANI (Europe) and ABET (America), associations of engineering education and societies of engineers, developed requirements for an engineer of the 21st century. These requirements can be summarized as follows: 1) steady, conscious and positive attitude to one's profession, sphere of activity, desire for continuous personal and professional improvement and development of one's intellectual potential; 2) high professional competence, mastery of the entire set of fundamental and special knowledge and practical skills necessary in labour activity; 3) knowledge of modeling, forecasting and design methods, as well as research and testing methods which are necessary to create new intellectual and material values; 4) understanding of trends and main directions of engineering and technology development and scientific and technological progress in general; 5) high communicative willingness to work in a professional and social environment; 6) integrity of the worldview, orientation towards a healthy lifestyle of the personality of a specialist, as a representative related to the intellectuals of a social and professional group, etc. [1].

The main functions of engineers. Any professional activity arises based on the needs of a society. The roots of engineering go back to the distant past. However, as a professional one, engineering activity was generated only by large-scale machine production, which required the development of a certain system of knowledge, abilities and skills as the basis of expedient human activity [2]. With the growth and complexity of industrial production, the engineering activity was mainstreamed, the proportion of engineers in the total number of industrial production personnel increased, there were structural changes in the engineering and technical workforce. At the same time, their professional qualifications were changing.

Effective engineering demanded further expansion of technical, sociological and fundamental general technical knowledge, their accumulation, i.e. spacious mind and at the same time the ability to understand narrow specific issues in accordance with the specialization [2].

As various scientists note [2], the profession of an engineer, having emerged as an occupation related to the application of knowledge in the practice of construction and industry, has turned today into an extensive kind of professional activity, covering practically all spheres of material and spiritual production, management.

In a broader sense that meets the trends of modern scientific and technological progress, the main feature of engineering and the leading feature of this profession is the application of scientific knowledge in all areas of production and management.

Let us remark, however, that although science is now in the first place, engineering activity is not turning into the activity of a scientist. Noting this, E. Crick writes that scientists are working in order to study, explain and classify natural phenomena. The main desire of a scientist is to enlarge the awareness of people [6]. An engineer, on the contrary, seeks to create a real apparatus, device, or to develop a process that is utilitarian. An engineer creates everything in a work process called design (unlike a scientist whose main task is the research). The design process is the essence of engineering.

The above mentioned does not mean that people who are mainly engaged in science never solve engineering problems, just like engineers do not do any research in search of solutions to their tasks. The main thing that distinguishes a scientist and an engineer is what they are working on and the final result of their work [2].

In order to distinguish one professional activity from another, it is necessary to determine the subject, means and product of this professional activity. In this regard, an engineering activity can be called a professional activity, the subject of which is scientific knowledge, the product is a project of some system or the system itself. E. Crick says that there are many engineering specialties specified by that field of knowledge which an engineer needs to solve basic problems [6]. Despite various specialties, the main task of all engineers is the same – to create systems that turn materials, energy, information into a more useful form. Within all engineering specialties you need to master the basic techniques of work.

The nature of basic engineering skills can be determined on the basis of the idea of the structure of engineering activity. In modern manufacturing, an engineer performs several interrelated professional

functions. Depending on the fulfillment of certain duties, three main groups of engineers are distinguished:

Group 1 – engineers preparing the production. The main functions for them are research, design;

Group 2 – engineers directly involved in production. Their main functions are technological, mechanical repair, commissioning, etc.;

Group 3 – engineers engaged in production management. Their main functions are supervisory, analysis and computation, controlling.

Briefly, this can be formulated as follows: the activity of an engineer is reduced to designing, optimizing, organizing the interaction of the components of the system "man – raw materials – energy – machine – production". Common to the successful fulfillment of all these engineer functions is the need to anticipate the behaviour of a certain system: a device under development; production link, whose work is optimized; a team that is being organized. Foresight comes to developing a model whose behaviour approximates the expected behaviour of the system.

An attempt to describe the structure of engineering activity was made by J. Dickson [1]. He proposed a scheme of engineering analysis, in which the main stages of the formulation and solution of any engineering problem are distinguished. According to J. Dickson an engineering analysis requires, firstly, a clear definition of the problem or issue that must be addressed. After the task is determined and the solution plan is shaped, an engineer proceeds to develop a model (on paper or in the laboratory). The model should be so simple that it can be analyzed in an acceptable time, and at the same time so complex that the results obtained from it are sufficiently informative. The analysis of this model should be based on the application of physical principles and finding numerical results. This also includes checking, evaluating, summarizing and optimizing the results. As follows from the scheme, one of the first stages of engineering analysis is the stage of model building. Without this stage, further progress in solving the engineering problem is almost impossible.

Methods for investigating the processes of all types faced by engineers are based on the use of models. The description of any real process begins with idealization in such a way that it can be described using a finite set of quantities x (t); y (t), which describe the essential aspects of the process. And this leads to description of the processes occurring in any system using differential equations. Such an equation can describe the behaviour of a satellite or rocket, multivibrator or cyclotron: in the economic field, the development of the steel industry or the fluctuations of our economy, i.e. it is equally suitable for describing processes of various physical nature [1]. Ya. I. Khurgin and V. P. Yakovlev also believe that the process of cognition of any phenomenon is a simulation [1].

In the structure of engineering activity, one can distinguish the same components as N. V. Kuzmina distinguishes in the structure of pedagogical activity, namely design, gnostical, constructive, organizational and communicative ones [4]. Particular attention should be paid to the constructive component of the activity, because it basically determines all professional activities. For different professions, there is specificity in other components, but the most important difference is precisely in the constructive one. The set of constructive skills required by a doctor for a successful surgery differs from the corresponding set for an engineer, teacher, etc. Therefore, having considered the structure of the constructive component of engineering activity, it is possible to determine the skills that are necessary for an engineer of any specialty for a successful professional activity.

The engineering design process is the process in which the constructive component of engineering activity is most fully manifested. This process is presented by a flowchart taken from the work of J. Dixon [1]. The core of this process is engineering analysis. It consists of eight main steps. We will single out the four most important ones: 1) the statement of the problem, 2) the model building, 3) the application of physical principles for the analysis of the analytical model, 4) the assessment of the results and providing recommendations in a representative style.

And the skills necessary for successful activity at these stages are: 1) the ability to choose the most suitable physical principle for the analysis of the model, 2) the ability to formulate (set the task), 3) the ability to apply the main general principles for the analysis of the model, 4) the ability to rationally plan the experiment, 5) the ability to take into account the errors of the physical experiment correctly, 6) the ability to present the results in a representative style, 7) the ability to provide recommendations.

To test the hypothesis that the ability to model physical phenomena is fundamental in engineering, we conducted a sample survey of researchers and research engineers of physical research institutes.

Features of engineers of physical specialties activities. The modern era poses the challenge for researchers to deepen knowledge about the psychological processes of productive activities. The study of engineering activity is of particular relevance, since the development of technology poses the tasks of a deeper and faster implementation of scientific achievements – the scientific effect should turn into the final socially useful product in a shorter time and more efficiently. In particular, the creation of so-called

scientific-production complexes is responsible for this goal.

There are many approaches to the study of engineers training systems. In publications devoted to the problems of training a future engineer at a university, the most often considered is the set of skills, abilities, personal qualities necessary for successful professional activity: professiograms, models of engineers of various profiles are developed. In these studies, the most important business qualities, intelligence features of engineers, etc. are identified. It is necessary to know not only what knowledge and to what extent the future specialist needs, but also the psychological characteristics of professional activity; the role of various mental components: sensory processes, mental actions, motor skills, attention, etc. Moreover, it is necessary to highlight their specific weight in the structure of a professional's activity.

An analysis of occupational methods appear in the works of M.A. Dmitrieva, V.A. Ganzen, G.V. Sukhodolski, A.I. Naftulyev, G.S. Nikiforov and others.

From the psychological sciences, labour psychology and engineering psychology are indicated here. Their objects are somewhat different. In the study of activity, as noted by G.V. Sukhodolski, on the basis of general problems and general tasks, the psychology of labour and engineering psychology are not differentiated [3]. The distinction can only be achieved in focal points in two directions. Firstly, engineering psychology does not study any labour activity, but the activity of specialists in the systems "man-machine", "man-robot" and in ASM, while the psychology of labor examines in principle any labour activity, even unskilled laboir. In this regard, engineering psychology is included in the psychology of labour. Secondly, in engineering psychology, emphasis is placed on designing human activities as a means and conditions for designing an effective "man-machine" system, while in labour psychology, emphasis is placed on assessing personal qualities, on the formation of human abilities and professional skills depending on the requirements of the profession. In this regard, engineering psychology and the psychology of labour act as different disciplines. But some methods of engineering psychology can be extended to other types of professional activity. Here we first of all note the work of B.F. Lomov, V.P. Zinchenko, V.P. Rubakhin, A.A. Krylov and others, aimed at studying the psychological mechanisms of activity.

Earlier, we showed that from the point of view of the structure of engineering activity, one of the main skills that an engineer should possess is the ability to model. Considering that this skill is most typical for engineers of physical specialties, at the first stage we set the task to find out the characteristic features of the activities of these engineers.

The subjects were physical engineers from research institutes; research laboratories of enterprises and research and production associations – a total of 237 engineers. In doing so, we used the recommendations of V.Ya. Yadov [5]. The main method at this stage was the questionnaire method. Characteristics of the sample: 55% of the engineers surveyed have experience of more than five years, and 45% – less than five years. 72% are satisfied with their work, the remaining 28% are more likely are than not. 56% of the surveyed engineers have proceedings or inventions. The features of the activities of the engineers included in our sample are: 1) a very vast area of activity, 2) diverse types of activity, 3) activity at the borderline of many specialties, 4) various degrees of necessary training depending on the place of work, 5) quick amortization of knowledge. The decisive role in the emergence of these features is played by the factors of the scientific and technological revolution.

The results of the analysis of the questionnaires indicate that the mental activity of physical engineers proceeds in continuous connection with the practical one. In activity, a combination of sensory and verbal-logical cognition is most often needed; requirements for labour intensity are unstable; for successful professional activity knowledge of a sufficiently large amount is required.

Cognition of the environment and regulation of human behaviour is carried out using models of reality. In engineering psychology, a concept – a figurative-conceptual model – was introduced . The basis of such models is the coordination of spatial and verbal elements. In our study, this process is considered in the application to models of physical phenomena, which assumes the presence of the following elements: 1) the original image; 2) verbal constructions associated with the image; 3) symbolic images as intermediate elements of the model. Therefore, it was the figurative thinking of physical engineers that was the subject of a preliminary study.

Engineers, whose work experience is less than five years, believe that for professional activities imaginative thinking should have a higher degree of development. With growth of work experience, the desired degree of development of all the qualities of visual thinking falls. However, both groups of engineers are unanimous in their appreciation of the same qualities of visual thinking. At the level of operating images that were previously perceived, both those and others believe that engineers should be able to reproduce from the memory and mentally compare images between them. At the level of image reconstruction, engineers must anticipate the upcoming change

in the image, create an integral image from separate parts. At the level of creative imagination, the most important is the creation of new structural and technical images. Thus, as a result of this preliminary study, the nature of the mental activity of a physical engineer was revealed; the most important qualities of students' visual thinking that are necessary to be developed in the process of professionally-oriented training are identified.

Let us remark that the existing system of training engineers in many respects contributes to the formation of strict stereotypes of engineering thinking. Under the conditions of accelerating pace of technological development with the increasing role of the human factor, it is very important to orientate university pedagogy towards the search for ways to form a creative engineer who can easily perceive a new, and not just technically competent specialist.

Based on the structure of professional skills, in each component of the activity, the basic skills that are necessary to be formed for students' future successful work were identified.

Conclusions. When analyzing the course units programs of the specialties of this profile, it was found out that the basis for most of the skills listed above should be laid in the classroom session (lectures, seminars and laboratory classes). Moreover, the formation of skills occurs in a variety of academic disciplines that have weak interdisciplinary connections. Unfortunately, the further development of the skills laid down at the previous stage of training is not always foreseen. This contributes poorly to the formation of the system of skills that students need so much for their future professional activities.

To combine these discrete skills, to bring their level of formation to a high level is possible in the process of students completing tasks based on a model of engineering activity, even a simplified one.

For further research, the working hypothesis is put forward that those types of self-directed work of students that are based on the model of professional activity (scientific and educational research, course and diploma design) can make a big contribution to the formation of the entire selected system of professional skills. In this case, an essential condition is the existence of a relationship between these types and an integrated approach to their organization.

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"Важливо вірити, що талант нам дається не просто так – і що за будь-яку ціну його потрібно для чогось використовувати".

Марія Склодовська-Кюрі
французький педагог

"Ніхто не зможе побудувати для Вас міст, на якому Ви повинні перетнути потік життя, ніхто, крім Вас самих."

Фрідріх Ніцше
німецький філософ