Integration and differentiation in science and their practical significance

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Abstract. The article deals with the laws of dialectics, methods of cognition in science, integration and differentiation as two components of science advancement. The factors causing uneven development of these components are presented. General laws specific for various dynamic systems and forms of movement, general principles of understanding the surrounding world, which enable to combine knowledge of various subjects into a single, integral, harmonious system are presented. The authors of the article emphasise the need to integrate science, education and production, and identify the main problems that arise when implementing integrative programs. The competence-based approach in education, the need to focus on professional qualities, the socio-cultural orientation of the individual, intellectual maturity, and making non-standard decisions are emphasized. Systematization and interdisciplinary differentiation of the components of professional skills, which indicates the development of modern science, the engine of which is differentiation and integration are important for the integration of science and education.

1 Introduction

The fundamental laws of dialectics being an integral part of modern philosophy theoretically determine the development of matter, knowledge, consciousness in its various forms.

The life of society, its functioning is one of the forms of social consciousness. Consequently, the laws of dialectics including the Law of the unity and struggle of opposites establishing that everything that exists consists of opposite principles, which, being united in nature, exist in constant struggle and contradict each other are applicable to its description. This interaction between them is a constant internal source of movement and development of everything that exists.

Science is one of the forms of social consciousness; it is a sphere of human activity aimed at obtaining and systematizing objective knowledge about reality.

Unlike ordinary knowledge with fragmentary results, obtained randomly and being impossible to combine into a coherent system, science is a type of activity aimed at purposeful systematic knowledge obtaining.

Accordingly, science as a specific type of human activity has formed its own system of cognition methods, develops according to its own internal rules, which, of course, obey the fundamental laws of dialectics, including the law of unity and struggle of opposites.

Initially, science arose as a single system, integrally uniting the entire amount of knowledge received by that time. In this form, it was defined as “philosophy”, which meant “love of wisdom”. The philosophy of that time united all the fields of science known to us now, and philosophers were experts in all areas. A scientist who studied geometry was also strong in astronomy, and in the theory of matter. No wonder we consider Aristotle and Pythagoras philosophers, because they tried to create a single picture of the world known to them.

2 Materials and Methods

That is, at the initial stages of development, science was an integrated system of knowledge about everything. Leonardo Da Vinci and Mikhail Lomonosov known for their inventions, research, and development in many fields of science, can be considered typical universal scientists.

However, in reality, science being a part of social consciousness complies with general laws. It is characterized by the dialectical interaction of two opposite processes: differentiation being the separation of new scientific disciplines from a previously unified whole; and integration being the merging of these disciplines into a single whole. Both of these trends took place at all stages of science development, but the degree of their interaction and the priority of one trend over the other constantly changed. This was determined both by the tasks of science itself and by the demands of the society in which it was formed.

Differentiation was prioritized since the 17^{th} – 18^{th} centuries. This was caused primarily by the needs of developing production, and for which an in-depth development of individual scientific areas was necessary. This first caused the division of the former

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science into "pure" philosophy as a science of society and consciousness, and into "natural science", from which other branches of practical knowledge (mathematics, chemistry, physics, and other branches) later emerged. It should also be noted that this was facilitated by the rapid development of technology, which contributed to significant improvement of the applied apparatus of science (devices, tools, research methods). As a result of this differentiation, many scientific disciplines each having its own subject and research methods arose. On the one hand, such a narrowing of the subject of study of each scientific discipline had its positive aspects, namely the possibility of an in-depth study of the phenomena under consideration and an increase in the productivity of scientific research.

On the other hand, as Albert Einstein noted, the activities of individual researchers are inevitably drawn to an increasingly limited area of general knowledge during science development. This specialization leads to the fact that a single common understanding of science, without which the true depth of the research spirit necessarily decreases, hardly keeps up with the science development; it threatens to deprive the researcher of a broad perspective reducing him/her to the level of an artisan [1].

It should be noted that, a tendency to merge different disciplines having a common subject of study arose during the further development of scientific disciplines. Thus, biologists studying the living organisms functioning found out that a large role in their functioning is played by chemical processes in cells caused by various enzymes that start and correct their metabolism. Specifically, new disciplines, such as biochemistry, chemical physics, geophysics, and other disciplines began to emerge at the junction of scientific areas. This enabled to carry out more voluminous research using methods previously applied in different disciplines.

Such a stage in the emergence of combined scientific disciplines took place in the late 19th and early 20th centuries. That is, its integration became noticeable along with the science differentiation, which contributed to increasing the possibilities of obtaining new scientific knowledge. Science moved to a qualitatively new, higher level of integration in the second half of the 20th century.

The knowledge of the laws common to various dynamic systems and forms of motion (the laws of conservation, communication and control, transmission and storage of information, structural and functional laws) mainly determines the integration of sciences. If earlier scientific directions were unified in connection with the commonality of a narrow subject of research or the similarity of methods, now the understanding of the World has changed radically. The world began to be perceived as a whole. The catalyst for this truly revolutionary rethinking of the purpose, tasks, and state of the modern understanding of science as a whole was the rapid development of such general scientific areas of knowledge as cybernetics, information theory, synergetics, whose outcomes can be applied in all other branches of science.

These new sciences raised the problem of determining the general principles of completely different systems functioning. Thus, the processes of controlling technical devices and living systems are similar with regard to cybernetics since they are based on obtaining, storing and processing information. The concept of information is associated with the receipt of new data, messages about an object, interaction of subjects and objects. From the standpoint of information theory, all systems differ only in the amount of information they contain regardless of their origin. That is, the informational characteristics of things are a new method of their knowledge.

Therefore, synergetics offers an approach in which the world is considered as a universal process of its self-organization, and self-organization is inherent not only to a person being an active subject, but also to a system of any of the following levels: chemical, biological, technical, social. Within the framework of the synergetic approach, the world is no longer considered as a set of elementary particles, but is presented as a set of processes whose development is greatly contributed by chance moments (fluctuations and bifurcations) bringing qualitative changes to systems.

Such complex sciences also include the general theory of systems, whose foundations were laid in the period of Antiquity, but the complete theory in the modern presentation was proposed by the Austrian theoretical biologist Ludwig von Bertalanffy. He presented the world as a collection of systems with certain characteristics. At the same time, an important feature of such systems, especially living and social ones is the constant circulation, reception and transmission of information, as well as management processes based on it. Systems can be open or closed, dynamic or static. Within the framework of this theory, science in general is an open dynamic system.

3 Results and Discussion

In this regard, priority is given to ideas about the world, the Cosmos as a whole. Integrative pictures of the world are built based on the results of individual scientific disciplines united by a common understanding. At an early stage in the development of science philosophy moved away from other natural science and technical disciplines, and now this unified picture of the world is being formed with the help of the laws of philosophy.

V.I. Vernadsky considered the greatest phenomenon of scientific thought of the 20th century to be the following idea: for the first time, all the currents of human spiritual creativity that hitherto had little dependence on each other, and sometimes no dependence, merged into a single whole. Therefore, the turning point in the scientific understanding of the Cosmos coincides with the simultaneous profound change of the human sciences. On the one hand, these sciences merge with the sciences of nature, on the other hand, their object changes completely [2].

These ideas were developed in the second half of the 20th century. In modern science, integration is not only

the summation, addition or rapprochement of various scientific disciplines, but also their deep interaction based on the identified general principles of perceiving the surrounding world, which contributed to combining the knowledge of different subjects into a single, integral, harmonious system.

In turn, the study of specific problems arising from the analysis of the interaction of various sciences within a single model leads to the emergence of new blocks of social science, natural science and technical knowledge, the formation of new areas of research, which is a reflection of the differentiation trend.

The use of a single model of the world enables to re-evaluate the problems scientists face in a particular branch of science. The fundamental approach, which assumes the commonality of tasks, goals, and methods, enables to consider issues from different angles and use methods developed in other fields of science when solving them [3].

When integrating the sciences, knowledge mainly ascends from the abstract to the concrete, when a simpler and more abstract category precedes the concrete one. In this case, methods of synthesis and deduction prevail, and serve as a means of perception of more general laws of objective reality. And if in general the science of the 17^{th} – 18^{th} centuries was mainly of analytical nature, as a result of which differentiation was predominant and leading in its development, then at the present stage the dialectic of the relationship between differentiation and integration is that the leading role belongs to integration, and differentiation turns into a necessary means and one of the main integration forms. Differentiation and integration have once again changed places [4].

The spread of scientific knowledge is closely related to education. An analysis of the connection between integration and differentiation and education shows the present time development of a dialectical process in which differentiation is accompanied by integration, the most diverse areas of scientific knowledge of the world interpenetrate and combine into a single whole, and various methods and ideas interact [5].

With the progressive differentiation of scientific knowledge, the problem of the general crisis of education, indicated by Ch. P. Snow in the middle of the 20^{th} century arises. Snow believed that the differentiation of science was a consequence of the specialization of industries. Scientific and technological development has become so intense that the education system fails to adapt. The amount of information increases so rapidly that the trainees cannot perceive it. The authors of [6] investigated the problem based on the methodology of F Klein and Yu. Lednev, the laws of synergetics, and offered a three-level scheme for dividing scientific knowledge in the field of laws of nature: natural phenomena, laws of nature, and the field of symmetry principles. According to the authors, such a division will optimize the structure of the content of general education enhancing its disciplines integration and reduce the acuteness of the education crisis associated with differentiation.

The integration of science and education is one of the main tasks of the Strategy for the Development of Science and Innovation in the Russian Federation at the present time. In the article [7], the authors analyze the problems of interaction between science, education and production. In 2007, the Law of the Russian Federation No. 308-FZ "On Amendments to Certain Legislative Acts of the Russian Federation on the Integration of Education and Science" was adopted. Over the past 15 years, a network of large innovative scientific and educational complexes being federal universities has been formed on a competitive basis and has included 29 universities of the country, which have received the status of national research universities with appropriate material and technical support.

The steady motivation of employers to change the practice of developing the personnel potential of enterprises in identifying competencies when hiring employees determines new requirements for the preparation of educational programs through the development of professional standards. The competence-based approach enshrined at the regulatory level in Russia since 2009, which involves the development of universal, general professional and specialized professional competencies in the learning process, also contributes to the integration of science, production, and education. Specialized databases of evaluative means of knowledge and competencies of specialists have been created, new forms of educational and methodological work, electronic packages of educational and research materials, modules of disciplines for self-study and distance learning have been identified, which allow integrating scientific knowledge into the learning process and forming the competencies necessary for production [8–10]. Educational methodological complexes for general education and special disciplines, a bank of test tasks for intermediate and final control have been created at the State Maritime University named after Admiral F.F. Ushakov (Novorossiysk) to train creative, energetic, initiative, enterprising, thinking outside the box and conscientious specialists. The complexes are guided by the International Convention on the Training, Certification of Seafarers and Watchkeeping of 1978, as amended (STCW Convention), as well as the federal law "On Education in the Russian Federation". The article [8] describes the conceptual foundations for the development of a test bank for state final certification of the graduates of maritime educational organizations, provides a mathematical and statistical model of the bank of test items for assessing the predictability of testing in the system of maritime educational organizations.

Foreign languages skills are among the most important competencies of a maritime transport specialist. The university has developed innovative aspects of basic and foreign language training of maritime transport specialists [9, 10]. Considering the pedagogical conditions of sailor's professional qualities development including classes at the University and maritime practice, the modules of integrated training sessions in basic technical disciplines and teaching foreign languages have been created. It has been established that the technology of interdisciplinary interaction and the computer support module developed

from the standpoint of integrative-contextual learning enables to recreate a professional context and improve the quality of cadets' language training.

When organizing cadets' research activities of the State Maritime University named after Admiral F.F. Ushakov the integration of basic scientific and professional knowledge is applied. The article [11] presents a solution to the problem of developing methodological foundations for organizing research activities of students in the process of distance learning using computer support in the aspect of studying the topic of linear programming in the department of mathematical disciplines. This approach enables to reach the research level of training when building mathematical models and their graphical representation, which benefits understanding of the possibilities for obtaining the result, their practical use in terms of mathematical and software tools.

The methodology for conducting a physical laboratory workshop at the University implies the development of general and professional competencies of a marine specialist, research skills, analytical thinking, ability to plan an experiment and analyze the result [12]. The use of mathematical apparatus for calculating the result and errors, graphical representation of the results using software and mathematical modeling is another example of integration in education.

The educational process aimed at the formation of a technically oriented personality should include both professional knowledge and knowledge of a sociocultural nature, which instill the internal culture of the individual, responsibility, social maturity, intellectual courage, readiness for an open dialogue, making extraordinary decisions in a crisis world. Teaching of socio-humanitarian disciplines in a technical university should be filled with the following philosophical problems: technology and morality, technology and aesthetics, technology and culture, technology and politics, the problems of the essence of scientific and technical creativity, the professional culture of an engineer, the prospects for technology development, technosphere formation [13–15].

The analysis of the problem of correlation between integration and differentiation focuses on the natural sciences. The formation of the entire spectrum of competencies required by production is possible only with the harmonious development of a person who has both a broad outlook and deep narrow professional training.

4 Conclusion

Systematization and interdisciplinary differentiation of the components of professional skills is important for the integration of science and education. The role of human knowledge in the field of related sciences has greatly increased, which is due to the current level of development of science and production. Interpenetration of sciences, enrichment with research methods and techniques for solving important practical problems and training specialists is a very urgent task at the present time. Science and higher education cannot effectively develop in isolation, and the level of their development determines the country's competitiveness in the global space.

Thus, it can be argued that the process of development of modern science continues, and its engine is the struggle and unity of two trends being differentiation and integration.

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