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The phenomenon of science in the challenges of transdisciplinarity: the search for paradigmatic responses to social turbulence

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Abstract. The article discusses the features of the transdisciplinarity of science in actively developing areas of science. The author emphasizes the difference between transdisciplinarity and interdisciplinarity and polydisciplinarity. In conditions of social turbulence, when the development of science and technology is ahead of changes in society, it becomes necessary to compensate for the lag with paradigm decisions. Since the Enlightenment and the positive science of Auguste Comte, science as a special kind of human intellectual activity aimed at achieving new knowledge and its dissemination has undergone significant changes. The subject of research has become so reduced that instead of clear boundaries between sciences, points of intersection appear. Future research, cognitive science, artificial intelligence research, and others are considered as actively developing modern transdisciplinary studies. Jean Piaget's contribution to the development of semantics and pragmatics of the term "transdisciplinarity" is demonstrated. In 1998, UNESCO officially documented the importance of addressing the issue of transdisciplinarity. In 2013, in the United States, the American Academy of Science and Culture, ARISE-2 published a report, which testified to the necessity to make a transition in American science from interdisciplinarity to transdisciplinarity.

Keywords: history of science, transdisciplinarity, interdisciplinarity, phenomenon of science, paradigm, social turbulence

1 Introduction

The term "transdisciplinarity" is used to characterize scientific areas, the subject of which lies on the border of several separate sciences and outside the framework of scientific disciplines. The need to expand the scientific worldview was largely facilitated by the scientific and technological revolution of the 20$^{\text{th}}$ century. In the 60-70s, the disciplinary approach ceased to fully satisfy the needs of society, and the need arose for a deeper and more intensive insight into the essence of the laws of nature and society. To replace the disciplinary approach, an interdisciplinary approach was proposed, which allowed different sciences with different methodologies and terms to cooperate. The term "transdisciplinarity" was proposed by Jean Piaget: "Finally, at the stage of interdisciplinary relations, we can hope to see the success of a higher stage

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that would be 'transdisciplinary', which would not be content with achieving interaction or reciprocity between specialized studies, but would place these connections in a total system without a stable boundary between disciplines" [12].

Referring to the words of the famous physicist Charles-Eugène Guye (1866-1942), Jean Piaget described a special vision of the current situation: "...our sciences at the present time remain incomplete due to purely phenomenalistic distinctions: we know the physics of the inanimate, but we still do not know enough the physics of the body in the process of life and still less the physics of the nervous system of the individual in the process of life. It is necessary to think in such a way that, as this scientist said, physics would again become truly 'universal' only after it included biology and even psychology. It goes without saying that if this were possible, then we would then be at the full level of transdisciplinarity" [12].

Researcher Cyrille Rigolot in the article *Transdisciplinarity as a discipline and a way of being: complementarities and creative tensions* (2020) argues that considering transdisciplinarity as a discipline and a way of being can lead to a new understanding of the potential and effectiveness of transdisciplinary approaches. He is convinced that complementarity can be seen in terms of personal inclinations towards discipline and space for the expression of a way of life in academia. "Transdisciplinarity is a promising notion, but its ability to efficiently address the world's most pressing issues has been intensively debated. To date, most debates have been structured by identifying several types of transdisciplinarity, generally with a theoretical versus practical dichotomy, and their possible linkages. In the last two decades, important efforts to mutualize methodologies and theories have led to the emergence of a discipline of integration and implementation, which enables the conception of transdisciplinarity as a discipline" [13]. Robert C. Scharff & David A. Stone in their article *Transdisciplinarity Without Method: On Being Interdisciplinary in a Technoscientific World* (2022) describe the problem as follows. "Questions about what experts need to know to facilitate their collaboration in interdisciplinary situations are usually answered with proposals concerning the technical methods, epistemic ground rules, and explanatory theories that one applies "across" disciplines, just as such methods, rules, and theories are applied "within" a discipline. However, (post-Husserlian) phenomenology offers something better. Instead of following the traditional route of looking for general conditions that apply to collaborative practice, phenomenology turns to what actually happens in collaborative experience and shows that success is not just a function of applied procedures, even when they are in play" [15]. The authors argue that their use of the term "transdisciplinarity" is as far as possible from system-theoretical descriptions of the organization of disciplines, but close to phenomenological explanations of the actual disclosure in the experience of active participation in collaborative practices. What the authors mean has nothing to do with the term introduced by Jean Piaget, as pointed out by the researchers themselves. However, this confirms the presence of pluralism in the understanding of both the term and the issue.

2 The problem of branches of science in the history of philosophy

To understand the essence of the phenomenon of science, it is necessary to study the etymology of this concept, which in turn will clarify some of the connotations. The Online Etymology Dictionary contains the following explanation of the etymology of the term "science": "**science (n.)** mid-14c., 'state or fact of knowing; what is known, knowledge (of something) acquired by study; information;' also 'assurance of knowledge, certitude, certainty,' from Old French *science* 'knowledge, learning, application; corpus of human knowledge' (12c.), from Latin *scientia* 'knowledge, a knowing; expertness,' from *scienc* (genitive *scientis*) 'intelligent, skilled,' present participle of *scire* 'to know"' [6]. The original meaning of the word was probably "to separate one thing from another, to distinguish" (Proto-Indo-European root meaning "to cut, split," extension of root *sek- "to cut"). A Proto-Indo-European word has given a name to a particular kind of human activity in many languages. However, it is necessary to pay attention to the meaning of the verb from which the word "science" comes. This verb means division, and fragmentation into parts, which is essentially consistent with the task of the scientist — to break the problem into components for further analysis. Thanks to the division, there is an opportunity for detailed study, literally "the study of details". Since the 14th century in English, the word "science" has meant nothing more than theology and philosophy. In a broad sense, this term was used to mean "book learning". However, it was a special branch of human learning and knowledge. Because of scientific activity, a systematized knowledge about certain groups of objects or abstractions was formed. Already in the late Middle Ages, science was understood as "empirical knowledge", that is, knowledge was obtained as a result of learning, obtained through the formation of one's own experience. Later in the 15th and 16th centuries, science was understood in a more concrete sense as collective human knowledge. This knowledge was also obtained as a result of personal experience, but already in conjunction with the results of systematic observations and experiments.

Modern experimental natural science was born only at the end of the 16th century. The Protestant Reformation and the Catholic Counter-Reformation prepared its emergence. The religious experience of the Middle Ages was rethought, just as the scientific experience was rethought — the work of Copernicus and Galileo led to the abandonment of Ptolemy's astronomy. The Scientific Revolution — the period of the emergence of modern science during the Early Modern Age, when discoveries in such fields of science as mathematics, physics, astronomy, biology, and chemistry radically changed the views of nature and society. The authorship of the new scientific methodology belongs to the British philosopher Francis Bacon, who in his book *Novum Organum, sive Indicia Vera de Interpretatione Naturae* (*New organon, or true directions concerning the interpretation of nature*, 1620) moves from the traditional deductive approach to the inductive method. This is due to the fact that the speculative assumptions of authoritative thinkers about single facts are not as important as the identification of an empirical fact that shows the presence of a pattern. Rene Descartes and Isaac Newton create their concepts entirely on

experimental knowledge; this was a radically new kind of knowledge in comparison with the ancient medieval tradition. In the 19th century, science became professional, and the concept of "scientist" began to mean a profession. They were not just amateurs, lovers of experiments, enthusiasts, but professionals, certified experts. In the 19th century, the main institutions of modern science developed, they became an integral part of the functioning of nation-states. The Industrial Revolution had a direct impact on the development of science and their status in society. Technological advances have become associated with the level of development of society, and the development of technology has stimulated the development of science.

The modern meaning of the concept of "science" appears in the 18th century thanks to the activities of the thinkers of the Enlightenment. Intellectuals of the 18th century understood science as a set of regular or methodical observations and suggestions about a particular subject or thought. In his book *From natural philosophy to the sciences: writing the history of nineteenth-century science* (2003) David Cahan expresses ideas about the history and status of science in the 19th century. He claims: "By the early 1700s, when the Scientific Revolution had largely run its course, 'science' still meant natural philosophy taking that term, as does this volume's title, to include natural history. Natural philosophy had by then shed its Aristotelian metaphysics, rejected occult qualities in explanation, adopted new standards of evidence and experiment, created entirely new sorts of instrumentation, and generally incorporated new concepts and results" [5]. The author mentions Aristotle, the ancient Greek philosopher, and the father of science. Aristotle divided the sciences into three kinds: productive, practical, and theoretical. The fact is that in the days of Antiquity, science, or what we understand by it, was associated with the technique. In the 17th century, a distinction arises that is usually understood between theoretical truth (epistemē) and methods for achieving practical results (tekhne). The technique was aimed at obtaining a new product, it could be the technique of making a bow or the technique of making an amphora, similarly, there were techniques for the emergence of new knowledge. "*teks-. Proto-Indo-European root meaning 'to weave,' also 'to fabricate,' especially with an ax, also 'to make wicker or wattle fabric for (mud-covered) house walls"' [7].

In the essay *The Question Concerning Technology* (*Die Frage Nach der Technik,* 1954), Martin Heidegger attempts to think through the essence of technology (tekhne). The German philosopher was the assertion that technology is a product of human activity. The use of technical means to achieve human goals, but Martin Heidegger does not stop at this instrumental definition, he claims that there is something else — also important. To understand the words of the German philosopher, pay attention to the phenomenological dimension of poiesis, which underlies the understanding of instrumentality. Poiesis does not just refer to handicraft production or artistic creation, it is the essence of self-emergence, "arising of something from out of itself" [8].

Despite the fact that Aristotle was the father of science, in his book *Metaphysics* he outlined an idea that could significantly affect the future fate of science. "Mathematical accuracy is not to be demanded in everything, but only in things which do not contain matter. Hence, this method is not that of natural science, because presumably all nature is concerned with matter. Hence we

should first inquire what nature is; for in this way it will become clear what the objects of natural science are [and whether it belongs to one science or more than one to study the causes [20] and principles of things]" [2].

The Italian scientist Galileo Galilei, after two millennia, changed the idea of nature, returning mathematics to science. He expressed himself poetically in his book The Assayer (1623), and these words have gone down in history. Edwin Arthur Burtt prints translation of the quote in the book *The Metaphysical Foundations of Modern Science* (2003). "Philosophy is written in that great book which ever lies before our eyes — I mean the universe — but we cannot understand it if we do not first learn the language and grasp the symbols, in which it is written. This book is written in the mathematical language, and the symbols are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth" [4].

If Aristotle believed that the application of mathematics to the changing and temporary things of the sensory world would not bring ideal knowledge, then there is no need to apply mathematical knowledge to natural history. What is the point of studying something that will soon either change or disappear, thereby changing the true status of knowledge? According to Aristotle, it is necessary to study something eternal. In many ways, his vision was ahead of its time, though there was an accompanying step back. Scientists are really looking for fundamental principles and laws that may turn out to be eternal. However, Galileo Galilei changed the concept of nature, thanks to his studies of the book of nature; the astronomer was able to prove the usefulness of using mathematics in natural research. Proof of this is the unique discoveries made by him with his own scientific instruments.

The famous philosophical book *Science of Logic* (*Wissenschaft der Logik*, 1816), first published in 1816, is the work of Georg Wilhelm Friedrich Hegel. German philosopher called his book that because he described in it the logic of a metaphysical system. It is an exposition of the movement of thought in pure categories of thought. If the philosophy of spirit and the philosophy of nature depict the movement of the Absolute Idea in its other existence, then in logic the Absolute Idea is within itself. There are two words "logic" and "science" in the title. The concept of "Wissenschaft" comes from the combination of the two words "wissen" ("knowledge") and "-schaft" ("-ship; making"). This term "wissen" in turn comes from the Proto-Indo-European word *weyd which meant "to see" [6]. Thus, we can conclude that in the English translation of the title of the book *Science of Logic* there is some change in meaning. All because of the difference in the semantics of the words "science" and "wissenschaft". If "science" requires a person to take actions aimed at finding new knowledge, then "wissenschaft" provides for the vision and understanding of the process.

Dynamic processes in science in the 19^{th} — 20^{th} century determined the further fate of this human activity. The vision of science at the time of its active development caused conflicting feelings, some predicted an optimistic future, the development of science and technology, and the subordination of the forces of nature by man. "...mathematicians and scientists optimistically aimed to establish conceptual foundations and empirical knowledge for a rational, rigorous scientific understanding that is accurate, dependable, and universal.

These scientists criticized, enlarged, and transformed what they already knew, and they expected their successors to do the same. Most mathematicians and scientists still adhere to these traditional aims and expectations and to the optimism identified with modern science" [11].

Other historians of science have assessed the state of science through the prism of postmodernism and postpositivism. They argued that after the Enlightenment and until the 19th century, science developed as the positive science of Auguste Comte [9]. However, its further development showed that there is no main narrative for history as the history of progress. The idea that history has meaning inevitably became obsolete along with the teachings of the idealists. Nevertheless, in science, the process of development manifested itself in the improvement of scientific methods and theories.

The history of science has become a separate science that studies the main stages in the development of scientific knowledge, and the history of the emergence of paradigms. It is worth recalling famous historians of science; these are Charles Coulston Gillispie (1918–2015), Thomas Samuel Kuhn (1922–1996), Charles Joseph Singer (1876–1960), Lynn Thorndike (1882–1965), and others. The author of *The Birth of Modern Science* provides an interesting perspective on the world of science, describing the concepts and tools that underlie modern science and its history. Paolo Rossi pays special attention to early modern science, considering it very complex and fascinating [14]. In modern times, science is associated with the natural and physical sciences, science is usually limited to the study of the phenomena of the material universe and its laws.

3 Prospects for the development of transdisciplinarity in the science of the 20th century

In 1998, UNESCO officially recognized the importance of addressing the issue of transdisciplinarity. On the eve of this conference, in May 1998, a symposium on transdisciplinarity was held under the auspices of UNESCO at Royaumont Abbey, Paris, France: "The notion of 'integration' was clearly set as the scope of this Symposium, where the concept of 'trans-disciplinarity' was seen as the 'path back from the chaos', the 'antidote to fragmentation of knowledge', the way 'towards integrative processes and integrated knowledge'. It was particularly identified that 'problems are such because they are addressed too narrowly'. Indeed, the means to address global and complex issues do not lie in interdisciplinary approaches, in which different disciplines are converging but not interacting" [17]. At the symposium, the problems of science were considered, and the concept of "transdisciplinarity" was seen as an attempt to expand the human understanding of reality. A new understanding of the nature of knowledge as an integrated knowledge indicates a change in the vision of the overall picture of the world. It is a mistake to assume that the solution to problems is provided by a narrow idea of its nature, while it is necessary to consider the problem in a complex way. Transdisciplinarity was originally conceived as a general methodology, therefore, the transdisciplinary approach takes as an object precisely those different methods of various disciplines, which means that interdisciplinarity lies at the core.

In the 20th century, scientific and technological progress has changed the way of life of society, science and technology have firmly entered human life,

and they have become an important component of economic prosperity and security. In 2013, in the United States, under the auspices of the American Academy of Science and Culture, the ARISE-2 Report was published, which testified to the need to make a transition in American science from interdisciplinarity to transdisciplinarity. Advances in science in the United States and around the world have led to the need for collaboration not just between disciplines, but also between different perspectives, to provide comprehensive knowledge. Scientists from different fields of science: mathematicians, biologists, physicists, engineers, and programmers — recognize the importance of cooperation. This cooperation, from a pragmatic point of view, will lead to new results. A transdisciplinary approach is able to provide the potential for scientific discoveries, and the creation of new high technologies, which will directly affect the market and create a competitive environment: "The promise of interdisciplinary approaches has been noted for many years, and both universities and funding agencies have invested considerable effort into fostering such collaborations. However, both universities and funding agencies continue to be characterized by inflexible disciplinary and mission boundaries. Even the term interdisciplinary, which implies a space between disciplines, fails to convey the potential for integration across PSE and LSM. Perhaps transdisciplinary better captures the extent of integration required: it is the dismantling of disciplinary boundaries, rather than ad hoc collaborations, that could transform the scientific enterprise and deliver the potential to address previously intractable problems" [1].

Therefore, for example, bioethics, as a field of interdisciplinary research, was formed in the middle of the 20^{th} century at the intersection of ethics, philosophy, law, and the natural sciences. Ethics is responsible for the moral component of the question, philosophy is concerned with the imperative and the concepts of values, law is concerned with human rights, and the natural sciences are represented mainly by biology — the science of life. Taken together, bioethics concerns the moral aspect of human activity in medicine and biology. This is an excellent example of the usefulness of not just an interdisciplinary approach, but it may also indicate the possibility of applying a transdisciplinary approach, in the sense that the phenomenon of life has not been fully studied either by biology or by philosophy.

The French philosopher Henri Bergson asserted a true and original reality of life, which, being in certain integrity, differs from matter and spirit. Therefore, if it differed from any part of the presented dualism, it is possible to study this binarity exclusively simultaneously. This is how his concept "Élan vital" appears, along with Duration and intuition, shows the whole versatility of the concept of life. Life as an extension can only be conceived in the end, but the impulse of life still lasts. Bioethics is an actively developing scientific branch that has many directions. These are environmental bioethics, medical bioethics, and clinical bioethics. All these disciplines are different in their methods and tools, but the subject of research unites them. The American biochemist Van Rensselaer Potter II first used the term "bioethics" in relation to a new branch of science.

4 Social turbulence of the 21st century as a factor of transdisciplinarity

In the 20th century, interdisciplinarity was originally applied in education, but in the 21st century, interdisciplinarity is used much more widely. The productivity of interdisciplinarity has been proven by practice, but more and more specialists are speculating on the fashion of such research. This fact eliminates due attention to promising areas of research. However, interdisciplinarity no longer satisfies its productivity, it is an intermediate solution to the disciplinary limitations that arose as a result of the excessive specialization of scientific disciplines. Interdisciplinarity is a kind of synthesis of theory and practice, knowledge and technology; in this sense, modern biotechnologies and nanotechnologies are interdisciplinary. Thanks to the prefix "trans", which means going beyond, transdisciplinarity characterizes such research that goes beyond the boundaries of disciplines, thereby overcoming interdisciplinarity.

Edgar Morin in his book *Head well done. Rethinking reform, reform of thought* (*La tête bien faite: repenser la réforme, réformer la pensée*, 1999) talks about multidisciplinary, interdisciplinary and transdisciplinary research. He distinguishes between the concepts of "interdisciplinarity" and "transdisciplinarity", arguing that interdisciplinarity means involving different disciplines in research, but transdisciplinarity is able to bypass the last barriers to more reliable and productive knowledge. "With regard to transdisciplinarity, we are often talking about cognitive schemas that can move from one discipline to another, sometimes so abruptly that the disciplines are immersed in a trance state. In fact, it is the inter-, poly- and transdisciplinary complexes of knowledge that work and play a fruitful role in the history of science" [10].

The 21st century is characterized by the predominance of dynamic processes in all spheres of human existence. Social turbulence and political turbulence have a special impact on the modern world, together they form societies of rapid change. Social turbulence is a state of extremely turbulent society, general system, and point of view. Scientists Eric Trist and Frederick Emery developed the theory of "social turbulence". Because of industry and labor research in the UK, a theory was created that challenged the dominant technological superiority over man, where a man was perceived as an addition to the machine. The new view already saw people as a resource to be developed, encouraging cooperation [16]. Transdisciplinarity is a research strategy that aims to break through the boundaries of research strategies of interdisciplinarity in the context of postmodern discourse. In this context, transdisciplinarity is able to overcome holism, the notion of the relationship between the part and the whole, when the whole is preferred in science in relation to the parts. Actually, the holistic principle says that the whole is always greater than its component parts. This epistemological principle has been popular since the time of Georg Hegel, who was known to be a holist.

5 Conclusions

As a result, it became obvious that science within certain branches cannot respond to the answers of modernity, especially in the social sciences. Social

turbulence and the lack of new research tools to meet the challenges testified to the obsolescence and inability of the old-fashioned sciences to provide modern society with reliable research. Transdisciplinarity becomes a kind of source for the generation of new canons in philosophy, and the philosophy of science, thanks to transdisciplinarity, new methodologies are developed for a new society. The opinion regarding the importance of transdisciplinarity is almost unanimous; its potential is extremely high, especially in the socially turbulent conditions of our time.

Thus, transdisciplinarity is a theoretical attempt to "transcend" disciplines, seeking to overcome the growth of fragmentation and fragmentation of knowledge. The mutual intersection of disciplines and areas of knowledge that go beyond the boundaries of sciences forms a new scientific space. This space requires a special state of disciplines, namely, openness to new methods and cognitive schemes, but at the same time, closeness — in order to preserve the scientific character and the subject of research. A comprehensive consideration of the problem is necessary, and attention to social and cultural conditions and other factors is necessary. If science, as was shown etymologically, was engaged in the division of problems for the purpose of subsequent analysis, then in modern times it became necessary to go beyond the old paradigm, in other words, to transcend. For modern science, it will be productive not to divide, but to link and intersect methods and knowledge that have heuristic potential. The subject of transdisciplinary research may shift over time, but the essence of the transdisciplinary structure itself, based on the study of nonlinearity, complexity, and self-organization of various methods of various disciplines, apparently remains unchanged.

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