Prospects of Integrating Transdisciplinarity and Systems Thinking in the Historical Framework of Various Socio-Cultural Contexts

Vladimir Mokiy[1*]***, Tatiana Lukyanova***[2]

[1]Institute of Transdisciplinary Technologies, 360024, Nalchik, Russian Federation, Email: vmokiy@yandex.com

[2]Center for Sustainable Development, Kabardino-Balkarian State University, 360004, Nalchik, Russian Federation.

[*]Correspondence should be addressed to Vladimir Mokiy, Email: vmokiy@yandex.com

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During the 20th century, science generally advanced within a dual ideological context of capitalism and socialism. In capitalism, development of science has been of an evolutionary nature. However, it had been developing according to a revolutionary pattern within the framework of socialism. These two opposing ideologies were expected to achieve different scientific developments. By the early 21st century, however, it was clear that these ideological differences did not significantly influence the overall evolution of science. Moreover, modern science continues to advance steadily toward greater development of general systems theory and transdisciplinarity. By integrating these ideas into one meta-discipline (systems transdisciplinarity) it is possible to finalize the unification and generalization of disciplinary knowledge and scientific worldviews. Consequently, systems transdisciplinarity that seamlessly combines the advantages of academic and systems approaches has every chance of becoming an effective tool to address today's wicked problems.

Keywords: Transdisciplinarity, transdisciplinary approach, disciplinary approaches, systems approach, General systems theory transdisciplinary research.

1 Introduction

A. Whitehead, a British scholar, said that the progress of civilization does not necessarily involve a straight-line progression to a better world. However, it is possible to discern general patterns within this process by viewing it from a broad perspective (Whitehead, 1990). This perspective is offered by science. Nevertheless, science does not represent the entire human culture since it constitutes only one of the spheres that interrelate with other spheres of human creative and cognitive activities: philosophical, artistic, empirical, religious, mythological, ideological, and others. Therefore, it is rather difficult to explicate the specific characteristics of science as its identifying attributes and definitions (Simonov & Goldberg, 2021). Modern science has been around for roughly 300 years. For this reason, the German scientist M. Weber suggested that the object of science was impossible to determine until it could reach a certain stage of development. He was convinced that different branches of science emerged due to people's ability to connect various problems in their minds rather than makings factual connections. Therefore, science will only define its object when the problems that science is able to resolve are considered together. This would require the interrelation of the basic explanatory principles of science (Weber, 1990).

During the 20^{th} century, science generally advanced within a dual ideological context of capitalism and socialism. Regardless of a global social upheaval in the early 20th century, capitalist science continued to evolve. This development pattern preserved previously formed ideological positions, scientific principles, and cultural frameworks. In the meantime, society and science have been developing within the revolutionary framework of socialism in some parts of the world. Consequently, previously held ideological positions, scientific objectives, and cultural frameworks had been altered. According to Marxist ideology, these changes were supposed to ensure the creation of a "new ideal citizen." Needless to say that in people's societies divided by opposing ideologies, there should have also been different scientific procedures and developments. Once the socialist era ended in the late 20th century, it became apparent that the two opposing ideologies did not change the overall process of the development of science. Therefore, this chapter will present evidence that the overall development of capitalist and socialist sciences, particularly in Russia, is inextricably linked.

The phenomenon of multiple independent discoveries is one of the well-known attributes of general societal and scientific development. This phenomenon is associated with repeated cases of identical scientific discoveries. Such discoveries are almost simultaneously made by different scientists working independently of each other all over the world. Interestingly enough, scientific discoveries are almost inevitable when the necessary knowledge and research tools become available to the entire human society, especially when many researchers focus their attention on particular phenomena as a result of arising societal needs (Merton, 1963). This particular pattern was fully evident when the theoretical framework of systems thinking, general systems theory, and transdisciplinarity was established. Therefore, this chapter will focus on the differences between the interpretations of these theories adopted in Russia and English-speaking countries. It will also provide a rationale behind the assumption that general systems theory and transdisciplinarity will naturally merge into a specialized meta-discipline (systems transdisciplinarity). In the nearest future, this meta-discipline based on the generalization of diverse disciplinary knowledge, academic and systems approaches is expected to play a major role in overcoming a disparity of ideologies, cultures, knowledge, methodologies, and technologies because this obstacle is standing in the way of resolving today's wicked problems.

2 Methodology

The article is an innovative perspective on the development of transdisciplinarity and systems thinking. Innovation is not just any innovation, but only one that seriously increases the effectiveness of the current system of views. Therefore, out of many publications, we have used only those that, in our opinion, represent this innovation. In our case, we tried to focus on the phenomenon of multiple independent discoveries. It was this phenomenon that made it possible to preserve the overall development of science in the changing socio-cultural contexts of the leading Western countries and Russia. In conclusion, we have shown real prospects for combining the potentials of transdisciplinarity and systems thinking in systems transdisciplinarity. The results of such a generalization of information about systems thinking and transdisciplinarity will be useful, first of all, to students. It is important for students to learn the general trends in the joint development of systems thinking and transdisciplinarity. If necessary, students will be able to obtain detailed information from their teachers.

2.1 Evolutionary development of science. General Systems Theory and Transdisciplinarity

In the 20^{th} century, capitalism pursued further scientific and societal progress according to an evolutionary pattern. However, this development pattern faced some distinctive challenges:

- Challenges in the philosophy of science, namely the crisis of the mechanistic worldview. These challenges emerged due to a conflict between mechanicism (atomism, materialism, and physicalism) and organicism (emergent evolutionary theory, Gestalt psychology, holism, and organic indeterminism);
- Challenges in education, including those related to the disciplinary division of knowledge. In 1951, Mather suggested that the quality of university education might deteriorate to superficial learning so that students would simply present everything they had learned over a semester or a year. Therefore, it is more important to find basic concepts and underlying principles that can be applied to the whole body of knowledge (Mather, 1951).
- Challenges in forecasting and management, namely crisis management of complex systems. In 1968, those attending the Working Symposium on Long-Range Forecasting and Planning (Bellagio, Italy), stated that modern science needed to do more than simply study, interpret, and describe things as they are. They also believed that it should effectively address real-life challenges (Jantsch, 1969).

The advances of natural sciences in the 19th and 20^{th} centuries undermined the mechanistic worldview but did not dismiss the laws of physics. Consequently, there was an urgent need for a new approach to dialectical materialism to explain both natural and social processes, creating a new and generalized view of non-biological and biological objects. This generalizing aspect was represented by the concept of the system. This particular concept provided opportunities to examine the system as the sum of its parts to determine how its elements are interrelated. Thus, it initially predetermined the origin of general systems theory.

In the early 20^{th} century, the evolutionary development of science in the West advanced scientific discoveries that preceded this theory. W. Kohler put forward the hypothesis of the systems theory, suggesting studying the general characteristics of inorganic systems in comparison with organic ones (Kohler, 1927). Lotka (Lotka, 1925) proposed treating the general notion of the system beyond simply focusing on physical systems. At the same time, A. Whitehead (Whitehead, 1925) formulated the organic mechanism theory, etc. Therefore, similar ideas were indicative of a new systems theory. This theory was reflected in a philosophy that adopted the assumption that it was important to study organizations as systems, which led almost inevitably to the discussion on the general theory of systems (Scott, 1963).

L. Bertalanffy, one of the founders of general systems theory, considered it of paramount importance to investigate the structural similarity of the regularities identified in different disciplines so as to isolate system-wide regularities on this basis. L. Bertalanffy suggested that a unified world concept could be based on the isomorphism of laws in different domains, rather than on the far-fetched hope that all levels of reality would finally be reduced to physics. Materially speaking, this means that the world, as a set of observable events, demonstrates a structural uniformity evident in isomorphic patterns of order at different levels and in different domains. At the same time, the scientific community focused on such issues as order, organization, integrity, and teleology that had been clearly excluded from the mechanistic science agenda. Therefore, this was the basic idea behind general systems theory (Bertalanffy, 1968).

Some critics argued that general systems theory was trivial because isomorphisms were simply truisms, indicating that mathematics could be applied to literally any kind of object. Others deemed it erroneous because of its superficial analogies such as comparing society to an actual living organism. These analogies masked real differences and, therefore, led to incorrect and ultimately unethical conclusions. Finally, it was found to be philosophically and methodologically unfounded because of the irreducibility of higher levels of explanation to lower ones (Bertalanffy, 1969). Other academics believed that only an interdisciplinary field that organically combined the complexity of different approaches to the system could be the universal framework of the systems movement. R. Ackoff argued that the tendency to consider the system as a whole rather than as a cluster of its different parts coincided with the modern scientific trend to no longer isolate the phenomena under study in a strictly limited context, but instead to primarily investigate interactions and a greater variety of natural phenomena (Ackoff, 1959). Along with general systems theory, other similar areas of scientific research were being developed: Wiener's cybernetics (Wiener, 1948), Shannon's and Weaver's information theory (Shannon & Weaver, 1949), and Neumann's and Morgenstern's game theory (Neumann & Morgenstern, 1944). The fact that these scientific discoveries appeared almost simultaneously in different countries provides a striking example of the multiple discovery phenomenon, stating that these developments can occur when similar ideas are conceived by like-minded thinkers.

2.2 Current State of Systems Thinking. Obstacles to Establishing General Systems Theory in Evolutionary Science

The scientific community had become less interested in general systems research and systems philosophy in the second half of the 20^{th} century. Since then, there have been some considerable doubts in the philosophy of science as to whether it is possible to unify scientific knowledge and whether science can asymptotically reveal "better" worldviews (Rousseau, n. d.). Many experts believe that systems thinking possesses some major flaws. In certain cases, it is ambiguous and rather amorphous because the systems thinking approach is still in its formative stage, thus systems science is represented by a variety of disciplines and a highly fragmented understanding of the world as a whole (Warfield, 2003). In this context, it is important to note that there are a number of reasons for these limitations: the overwhelming diversity of definitions of what the term "system" means; slow progress in the development of general systems theory; the variety of terms used within systems science disciplines; failure to provide a model for identifying the object of systems science that could become the academic discipline that the founders of the systems movement imagined it to be (Rousseau, Billingham, & Calvo-Amodio, 2018). This is why it is now urgent to appeal to certain members of the scientific community who have included systems research in their scope of interest so that they could join their efforts in developing the concept and research methodology applicable to general systems theory as a distinct scientific discipline (Rousseau et al., 2016).

Russian practitioners of systems thinking have noted more profound obstacles to establishing overall systems theory as a rigorous scientific theory:

- There is no developed systems worldview based on appropriate ontological and epistemological foundations;
- There is no appropriate categorical basis for the systems worldview, thus systems research is forced to primarily apply outdated scientific concepts, which threaten to complicate the systems science agenda;
- There is no common concept as to what comprehensive scientific content should be included in the principles of the systems approach to studying different objects in order to determine their place in the system of modern scientific knowledge;
- There is no supporting rationale for the principles of isomorphism and the laws of perspectivism (Bertalanffy's interdisciplinary synthesis). Moreover, there is no systems understanding of scientific research to fully address the unity of science (Ackoff's interdisciplinary research approach) (Blauberg, Sadovsky, & Yudin, 1969). In order to overcome these obstacles, it is necessary to make a definite effort to rethink some of the tenets of the existing scientific worldview.

3 Transdisciplinarity in the Evolutionary Development of Science

It is essential to note the role of the Organization for Economic Cooperation and Development (OECD) in promoting systems thinking and transdisciplinarity. The OECD, founded in 1961, provided a platform for comparing various policy experiences, finding solutions to common problems, identifying best practices, and coordinating national and international policies among member states (Brief history of OECD, n.d.). In 1970, the OECD supported the idea of establishing the Club of Rome to develop ways of practicing the systems approach to effectively address society's wicked problems (History of the Club of Rome, n.d.). The same year, the seminar on interdisciplinarity in universities was held in France, which was organized by the OECD. It presented two main branches of transdisciplinarity (Apostel, 1972). The first transdisciplinary branch was developed by Jantsch. According to him, transdisciplinarity should be a meta-discipline that represents generalized axiomatic and epistemological regularities (Jantsch, 1972). He was convinced that the transdisciplinary approach should be based on the systems approach (Jantsch, 1970). The second transdisciplinary branch was defined by Piaget. He was intrigued by the natural integration of a variety of disciplines, but he never showed any interest in how they could be coordinated externally. Piaget thus associated transdisciplinarity with a high degree of integration: an effective method for the profound synthesis of disciplinary knowledge (Piaget, 1972).

3.1 Major Obstacles for Transdisciplinarity in the Evolutionary Development of Science

In the 20^{th} century, the development of transdisciplinarity was significantly influenced by the views of philosophers E. Morin and P. Feyerabend. Morin noted that systems thinking in the 20^{th}th century developed as if it were caught between different disciplinary domains. By covering these gaps, complex thinking became truly interdisciplinary. However, it became transdisciplinary when it started exploring the meta-scientific level. Morin argued that transdisciplinary integration of knowledge would not welcome its reduction to the object of any particular science. Therefore, transdisciplinarity should only encourage the development of the entire spectrum of interdisciplinary interactions in scientific research (Morin, 1999). On the other hand, Feyerabend argued that despite the importance of this scientific method, it cannot be reduced to a set of rigid, invariable, and obligatory principles of scientific investigation. It is unacceptable when any scientific method is declared to be the only true and universal one (Feyerabend, 1986). As a result, the Charter of the First World Congress of Transdisciplinarity (Convento da Arrábida, Portugal, November 2-6, 1994) stated that transdisciplinarity is neither a new religion, nor a new philosophy, nor a new metaphysics, nor a science of sciences (Nicolescu, 1994). In this regard, transdisciplinarity has been far from being academically recognized. For one reason, there is still no generally accepted definition of transdisciplinarity. Consequently, there are no widely accepted quality standards that would equally guide researchers, program managers, and funders. In this way, it threatens to marginalize those who are seriously committed to the integration efforts necessary for creative collaboration (Jahn, Bergmann, & Keil, 2012).

3.2 Revolutionary Development of Science. Bogadanov's Tectology. And Anokhin's Theory of Functional Systems

Ever since the Soviet Union was established, it had set an ambitious goal to catch up with and then surpass the capitalist countries in terms of economic development. Therefore, socialist science had been developing according to a revolutionary pattern. The USSR needed to organize and implement a cultural revolution, industrialization, and collectivization in a short period of time. In this context, Bogdanov's tectology was a notable scientific development in the USSR when it was actively seeking solutions to the threefold task of fundamentally reshaping its society.

3.2.1 Bogadanov's Tectology

Many scientists and practitioners fully accepted tectology because it was based on mathematics and did not address the philosophical issues that were sensitive to the socialists. A. Bogdanov opened his discussion on tectology with the obvious assertion that all human activities – technological, social, cognitive, and creative ones – can be viewed as some organizational experience and examined from an organizational point of view (Bogdanov, 1925). Bogdanov argued since various changing elements interact with one another, the observer can distinguish some types of "complexes," differing in their degree of organization. An organized complex is defined according to the principle that "the whole is greater than the sum of its parts." In this case, the more the whole differs from the sum of its parts, the more it is organized. In disorganized complexes, the whole is less than the sum of its parts. Finally, the whole is equal to the sum of its parts within neutral complexes. The laws of systems organization are the same for any object, while the most heterogeneous phenomena are united by common structural links and regularities. This allowed Bogdanov to argue that structural relations can be generalized to the same degree of formal schemes similar to the relations of magnitudes in mathematics so that organizational problems can then be solved similarly to mathematical problems. In this case, quantitative relations can be viewed as a special category of structural relations while mathematics can be considered a branch of the general organizational science (Bogdanov, 1928).

Western scientists recognized tectology's high research potential. For example, R. Mattessich, a Canadian scientist, in his *Instrumental reasoning and systems methodology*, expressed extreme bewilderment as to why Bertalanffy had missed the German edition of Bogdanov's Tectology published in 1926. Thus, Bertalanffy never once mentioned Bogdanov's name in his numerous studies when he was working on the theory of systems thinking back in the 1920s (Mattessich, 1978).

3.3 Anokhin's Theory of Functional Systems

In addition to Bogdanov's tectology, Anokhin's theory of functional systems held a special place in the development of systems thinking in the USSR. The theory of functional systems was formulated by a Soviet physiologist, P. Anokhin, in 1935. This theory considered the future (the result), instead of the past (the stimulus), as the determinant of behavior (Redko, Prokhorov, & Burtsev, 2004). Anokhin would often argue that one of the main goals of systems research was its ability to explain and contextualize the findings that had been generated and obtained by the researcher without any systems approach. He insisted that the systems approach produced some curious challenges. On the one hand, there was no supporting evidence from biological and physiological sciences as a result of discovering certain, system-specific mechanisms. On the other hand, there was an exorbitant amount of theoretical studies and speculations, which were supplemented with extensive mathematical calculations. In this regard, Anokhin believed that in order to develop various aspects of systems theory relating to the interests of many proponents of the systems movement, it was crucial to find and formulate a system-forming factor. This key point defines both the concept of the system itself and the whole strategy behind its application to research. Anokhin argued that the role of the system-forming factor is played by the purpose of the system (Anokhin, 1975).

3.4 Major Obstacles for Transdisciplinarity in the Revolutionary Development of Science

Authoritarianism dominated every domain of science in the USSR. Thus, the revolutionary pattern of development rejected any initiative from individual scientists. These initiatives, notably in the humanities and social sciences, could have shaken the Marxist-Leninist worldview, underpinning the Soviet Union's official ideology. For this reason, Kruglyakov, chairman of the Commission on Pseudoscience and Falsification of Scientific Research of the Russian Academy of Sciences, officially condemned transdisciplinarity as pseudoscience in 2008 (Kruglyakov, 2008). Consequently, the Russian Academy of Sciences published its first monograph dedicated to transdisciplinary research only in 2015, which was entitled "*Transdisciplinarity in philosophy and science: Approaches, problems, and prospects*" (Institute of Philosophy RAS, 2015). What makes this monograph special is that it features many articles written by foreign researchers who set the course for the discussion of transdisciplinarity. It is worth mentioning such researchers as Klein (Klein, 2015), Nicolescu (Nicolescu, 2015), and Scholz (Scholz et al, 2015) since they contributed to this publication the most.

In this context, Russian academics preferred to focus on synthesizing the existing Western knowledge of systems, the systems approach, and transdisciplinarity, instead of creating their comparable counterparts. Soviet philosophers Blauberg and Yudin argued that the systems approach involved an in-depth focus on developing its own distinctive research methodology. This naturally implied that the systems approach was fundamentally interdisciplinary, meaning that it was possible to introduce laws and concepts from one domain of knowledge to another. Therefore, they suggested that the systems approach was a general scientific research principle. This fact raised an important question of the relationship between the systems approach and philosophy, which was incorrectly posed by the conservative critics of the systems approach (Blauberg & Yudin, 1973).

3.5 Unicentrism and Systems Transdisciplinarity. General Classification of Academic and Systems Approaches

In the 1990s, the Russian School of Transdisciplinarity emerged due to the progress achieved during the Perestroika period in the USSR. In 1996, autonomous non-profit organizations were introduced into the structure of Russian science and tertiary education (Federal Law, 1996). Without experiencing ideological pressure from the state and academia, the Russian School of Transdisciplinarity has managed to achieve significant theoretical, methodological, and technological results.

Recent developments accompanying the progress of the Russian school of transdisciplinarity provide further evidence of the multiple discovery phenomenon (Brief History, 2021). For example, the first international symposium that linked transdisciplinarity with general systems theory was held in France, in May 1998. The Final Symposium Report states that transdisciplinarity is conceived as "meta-methodology": a transdisciplinary approach takes as its object precisely the different methodologies of the various disciplines, in order to "transform" and to "transcend" them. Transcending and transforming are seen here not as vague procedures to replace disciplinary methodologies with global, fuzzy, problem-solving techniques. On the contrary, they are conceived as rigorous processes of abstraction, inasmuch as a transdisciplinary approach, intended to tackle global problems, needs to be general (Kim, 1998). At the same time, there was a book on the Russian interpretations of systems theory and transdisciplinarity (Mokiy, Zhamborova, & Shegai, 1999). In 2008, the Institute of Transdisciplinary Technology was established in Russia. By accumulating the theoretical and practical experience of the Russian School of Transdisciplinarity, the Institute has become the only autonomous nonprofit organization in Russia devoted to developing the theory and practices of transdisciplinarity. In 2013, representatives of 23 leading U.S. universities, including the Massachusetts Institute of Technology (MIT) and Harvard University, released their report on Advancing research in science and engineering, ARISE 2. The report's authors stated that transdisciplinary implied an integration-driven emergence of new disciplines, not just ad hoc collaborations (American Academy of Arts and Sciences, 2013). In 2017, the first university textbook on systems transdisciplinarity was published in Russia (Mokiy & Lukyanova, 2017a). Finally, there was an international presentation on systems transdisciplinarity in October 2020 (Mokiy, Oktober, 2020).

Systems transdisciplinarity as a meta-discipline has basic attributes: meta-theory and meta-narrative. Within the framework of this metatheory and metanarrative, there is an integration of systemic and academic thinking and worldview.

Meta-theory is a description of the general representation of the fundamental features of the world order and the forms of their manifestation, which form the basis of the entire system of human knowledge about the surrounding reality. The set of initial systemic and academic worldview reference points and the main philosophical categories within the framework of the meta-theory of systems transdisciplinarity undergoes certain intellectual processing – rethinking, ordering, and generalization. The purpose of the meta-theory of systems transdisciplinarity is to create a picture of the one and only world. Disciplinary (local) pictures of the world, in this case, are considered abstract models of certain areas (fragments) of the one and only world. As a result, the meta-theory of systems transdisciplinarity appears to be a scheme that defines the way and context of building scientific models of the researched areas (fragments) of reality. Such a scheme, because of its abstract nature, provides a systems transdisciplinary interpretation of the results of modeling the fragments of reality within the framework of different disciplinary and interdisciplinary approaches.

Meta-narrative is a universal system of notions, signs, symbols, and models, which aims to create a single type of description of objects and the presentation of interrelated events in the picture of the one and only world. This meta-narrative summarizes the knowledge and languages of scientific disciplines, as well as cultural and semantic discourses (areas of interaction). Meta-narrative is formed in the process of philosophical rethinking of general concepts and categories (space, time, information, system), which are necessary and sufficient to describe the picture of the one and only world (Mokiy & Lukianova, 2016).

The systems transdisciplinary approach is based on the philosophic principles of unicentrism, which is developed by the Russian philosopher, Vladimir Mokiy. Also, he introduced the term “unicentrism” in 2009. In a broad sense, unicentrism is a position in philosophy and in science that is based on the problem of the correlation between the unity and its fragments. This position is founded on the isomorphism (similarity) of the general order structure of different fragments of reality, the attributes of information, and the periods of time that can describe the one and only world. Any objects at all levels of the reality of the one and only world are its natural elements and fragments. Therefore, the main condition for the existence of the one and only world is the existence of the general order in it (transdisciplinary system). It implies following that this order must manifest itself everywhere: in every element and fragment of this world and in every interaction of these elements and fragments at every level of reality. In the end, the same order must ensure that the goals and results of all these elements and fragments are achieved. In addition, it should synchronize these goals and results. For this reason, the one and only world is One Orderly Medium (Mokiy, 2019a). Therefore, the order determining unity is not revealed in the course of complex systems transdisciplinary research. It is not formed subjectively as it is done in other types of systems approaches. It is postulated through systems transdisciplinary models of the spatial (Mokiy, 2020), informational (Mokiy, 2021a), and temporal (Mokiy, 2021b) units of order. The model of the spatial unit of order provides grounds for the physical or logical object boundaries and the nature of relations between elements within these boundaries. The model of the informational unit of order provides grounds for the necessary and sufficient amount of information on the object. The model of the temporal unit of order shows the organization that converts the internal potency of the object from the original volume to the results that will be used in the subsequent processes of its conversion (Mokiy, 2019b).

3.6 General Classification of Academic and Systems Approaches by the Russian School of Transdisciplinarity

According to the Soviet philosopher Sadovsky, the present-day cognitive tools were primarily developed within the framework of classical science (academic approaches). Therefore, these tools have a distinctly analytical nature that makes them unsuitable for analyzing the integrity, hierarchy, and organization inherent in the system. However, systems thinking can be developed by modifying the existing cognitive tools (Sadovsky, 1974). This transformation is to ensure the following: (1) transitioning from the differentiation of scientific knowledge to its systems integration and generalization; (2) stepping away from the linear logic of academic science approaches to the contextual logic of systems and transdisciplinary approaches that can integrate both the knowledge of science itself and the complementary knowledge of myth, philosophy, and religion.

By rethinking the stereotypes of transdisciplinarity found in international science, we were able to provide a generalized definition of transdisciplinarity. Transdisciplinarity as an approach aims to intensify intellectual activity in the context of interdisciplinary interactions that contribute to broadening the scope of the scientific worldview to the greatest extent possible (Mokiy & Lukyanova, 2021). This definition of transdisciplinarity implies having all the necessary tools to broaden the scope of science. Such tools in the context of interdisciplinary interactions include the spatial, temporal, and informational unit models of the general order. In this case, it is about the general order that the founders of the systems approach and transdisciplinarity had been searching for.

In 2017, Russian school of transdisciplinarity experts generalized the identifying attributes and characteristics of academic and systems approaches, including transdisciplinary approaches (Mokiy, & Lukyanova, 2017b). As a result, each approach was given its own definition while all these approaches were combined into a generalized classification (see Table 1).

Table 1: General classification of classical scientific approaches and their respective systems counterparts

№	Generalized classification of classical approaches	№	Generalized classification of systems approaches
1	Disciplinary approach is a method of establishing a scientific worldview within the framework of a local picture of the world, methodology and language adequate in its explanatory capabilities. This method forming the foundations of moral responsibility for the results and consequences of theoretical research and professional activity	1	Systems disciplinary approach is the method of correct distinguishing and modeling the object or a problem based on the image of the local system, allowing the application systemic disciplinary methodology to their study and solution
2	Interdisciplinary approach is a method to enhance the scientific worldview towards the enrichment of knowledge, methodology and language of one scientific discipline in favor of knowledge, methodology and language of another scientific discipline. This method forms the moral responsibility for results and consequences of research and professional activity, which is defined by the collaborative framework of interdisciplinary disciplines	2	Systems interdisciplinary approach is a method of correct distinguishing and modeling the object or problem based on a local interdisciplinary system allowing the application of complementary systems disciplinary methods and means to their study and solution
3	Multidisciplinary approach is a method to enhance the scientific worldview towards a holistic image of the object of research. This method forms the moral responsibility for results and consequences of research and professional activity, the level of which is determined by the framework of existing scientific paradigm	3	Systems multidisciplinary approach is a method to correctly isolate and model the complex object or a complex problem within a holistic multidisciplinary system allowing the application of the corresponding set of systems disciplinary methodologies to their research and solution
4	Transdisciplinary approach is a way to enhance the scientific worldview towards a holistic image of the object of research, using not only scientific, but also non-scientific knowledge for this	4	Systems transdisciplinary approach is a method to correctly isolate and model the complex object or a complex problem within a vertical or horizontal functional ensemble allowing the application of the universal systems transdisciplinary methodology to their research and solution

It is worth noting that systems disciplinary and systems interdisciplinary approaches are less dependent on the general concept of the scientific worldview. Thus, it can be replaced by local scientific worldviews. However, they largely depend on the empirical presentation of systems research procedures along with how to model the research object and its areas in the framework of the system, which is supported by a rigorous mathematical expression of the research object. On the contrary, systems multidisciplinary and systems transdisciplinary approaches are more dependent on the existing general philosophical approaches and on natural and philosophical worldviews, influencing the essence of the ontological and epistemological aspects of systems research. They also affect the perspectives and main development trends of systems research. For example, the systems multidisciplinary approach offers the opportunity to apply an appropriate set of systems disciplinary methods when studying the research object or a complex problem. The integrity of the research object and problem involves finding common ground and consistency between similar and dissimilar research areas.

The systems transdisciplinary approach provides a universal transdisciplinary methodology to studying the research object or a complex problem. The status of “a single object” indicates the necessity to generalize (place directly) knowledge, similar and dissimilar research areas in accordance with the structure and principles predetermined by the general order (transdisciplinary system). The order determining unity is neither revealed in systems research nor subjectively constructed as is done in systems multidisciplinary approaches. It is postulated through the models of the transdisciplinary general order unit. These models allow the researcher to operate beyond the existing knowledge of similar and dissimilar research areas along with their interactions, thus they can initially determine their number and types as well as the nature and consequences of these interactions. In this case, it is possible to explain the parameters of the system-forming factor of each object at each level of reality (objective goal) and its objective regulatory quantitative and qualitative parameters.

In this way, the transdisciplinary system can act as the universal model of the system. Within this system, disciplinary knowledge about the world, the object of research, similar and dissimilar research areas are arranged without strict boundaries between different disciplines, but in accordance with objective truth, which follows the way things should be so that it is possible to ensure the unity of objects along with the unity of their diverse relations. In this capacity, the systems transdisciplinary approach acts more like a general systems theory or an academic discipline (metascience), providing opportunities to bring together all of humankind’s knowledge into one integrated and consistent science, with a common set of concepts expressed in a metalanguage.

To illustrate the consistent expansion of the scope of the scientific worldview through academic and systems approaches, we use a Gaussian model (Weisstein, n.d.) (see Figure 1).

Academic approaches are to the left of the median. This field is formed by five different approaches, ranging from pseudoscientific approaches to transdisciplinary approaches. As a consequence of the overall predominance of disciplinary knowledge and disciplinary methods in this field, the transdisciplinary approach fails to establish any general theoretical structure in the classification of academic approaches. In this sense, transdisciplinarity calls for greater reflexivity, “humility,” and openness to interacting with other methodologies and practices so that one is willing to consider other approaches if they are more appropriate to meet present-day challenges. This transdisciplinarity appears to be “weak.” Thus, its methodology, in fact, has become similar to the one used in multidisciplinary scientific research (Max-Neef, 2005). However, “weak” transdisciplinarity has certain strong characteristics that are shaped by an increasing degree of integration and synthesis of disciplinary knowledge, moving from interdisciplinary approaches to transdisciplinary approaches. As a rule, this knowledge is already systematized within the respective discipline. Normative quantitative and qualitative characteristics in their numerical or logical values have been established for scientific knowledge within these disciplines. However, disciplinary knowledge itself remains indifferent in its classification. They remain indifferent to the process of integration within the integrated model of the ideal object.

Systems approaches are to the right of the Gaussian. This field is also formed by five different approaches, ranging from pseudoscientific approaches to transdisciplinary approaches. In contrast to academic approaches that use the apparent essence of the ideal object model, systems approaches make

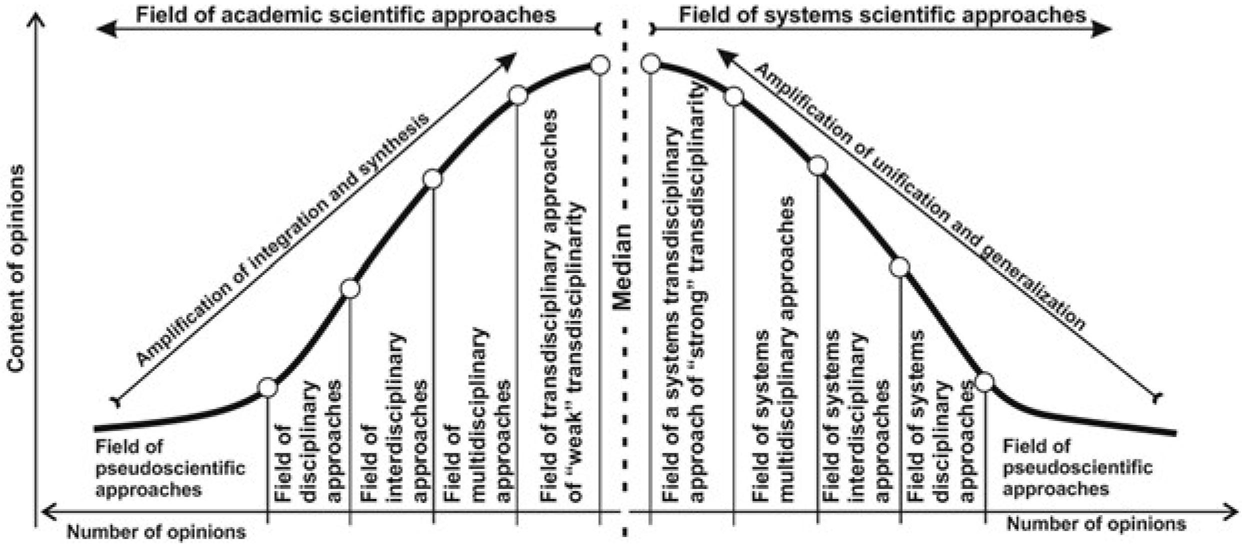

Figure 1: *Gaussian distribution of academic and systems approaches in the environment of interdisciplinary interactions.*

use of the objective essence of the object, presenting it as the system. Moreover, in order to validate this objective essence, systems multidisciplinary and systems transdisciplinary approaches employ particular philosophical foundations such as holism and unicentrism (Mokiy, 2019c). The systems approaches of the right Gaussian field are characterized by an increasing degree of unification and generalization of disciplinary knowledge. Unification describes the process of bringing disciplinary knowledge classifications of different disciplines into a single systems transdisciplinary classification. Once unified, disciplinary knowledge emerges as an active participant in the systems transdisciplinary solution of today's wicked problems. Generalization provides a method to orderly fill a systems transdisciplinary model of order units with necessary and sufficient disciplinary knowledge that accurately describes the objective essence of the object or problem. It is critical to note that systems transdisciplinary unification and generalization do not undermine disciplinary classifications of knowledge or eliminate their disciplinary criteria, indicators, and parameters. It attempts to interpret these criteria, indicators, and parameters from the perspective of the order that determines the integrity of the natural environment, as well as the objects and processes that belong to it. At the same time, it preserves the relevance, reliability, scientific rigor, and effectiveness of the disciplinary research tools and methods involved in systems transdisciplinary research.

The systems transdisciplinary unification and generalization with respect to disciplinary knowledge results in the following advantages:

- Different disciplinary scholars do not need to find compromise solutions with other disciplinary scholars;
- Transdisciplinary experts can focus on their professional expertise: (1) providing all the necessary disciplinary insights; (2) organizing and conducting the required experiments; and (3) supervising and providing commentary on how disciplinary knowledge is generalized toward finding solutions to today's wicked problems;
- It makes it possible to substantiate the choice of disciplinary scholars and disciplinary knowledge that will be involved in systems transdisciplinary research;
- It promotes a universal research method and a universal way to assess the risks of implementing a particular research project;

- It reduces the role of facilitators in transdisciplinary teams of disciplinary experts;
- It helps to avoid difficulties with self-referencing because transdisciplinary experts use objective and clearly definable philosophical, conceptual, and methodological criteria.

4 Conclusions

20^{th}-century history proved that new ideas and concepts were formed regardless of whether science was developing according to an evolutionary or revolutionary pattern. New scientific discoveries and inventions are always made when humankind accumulates all the necessary knowledge and tools to concentrate the scientific community's attention on addressing the most pressing problems of today's world. Merging and developing the ideas of general systems theory and transdisciplinary within the framework of meta-discipline (systems transdisciplinarity) are a vivid example of this impending reality.

The problem – is the distortion of the image of reality near the horizon of the existing scientific worldview. The transition from one approach to another in the classification of academic and systems approaches can be compared to a consistent broadening of the horizon of the scientific worldview. Mundane problems of society are low-threshold problems (disciplinary and interdisciplinary) problems. For that reason, they can be addressed by the bulk of professionals who have a bachelor's degree. Philosophical knowledge does not play a decisive role in the worldview of such professionals. Medium-threshold problems (multidisciplinary) issues arise in non-standard situations, such as space exploration, environmental preservation, industrial technology advancement, etc. The philosophical concept of holism is indispensable when dealing with these problems. The centripetal vector of holism allows for focusing and structuring disciplinary knowledge, thus isolating the object and the problem from its surroundings. Medium-threshold problem experts are usually trained in master's degree programs or graduate schools. In the early 21st century, high-threshold problems have taken center stage. These problems include (1) designing appropriate solutions for a new model of world socio-economic order, (2) promoting social sustainability, (3) preventing climate change, and (4) dealing with the consequences of global pandemics and natural disasters. It is impossible to tackle these problems without the philosophical paradigm of unicentrism. In contrast to holism, unicentrism has a centrifugal vector that guides its development to help the scientific community to focus and organize disciplinary knowledge in the context of objective goals of planetary nature (the objective system-forming factor). Simply put, a new model world socio-economic order represents the relationship of various people and nations as essential elements of nature that purposefully transform the matter of the planet. Therefore, the purpose of these relations should be determined by the objective content of the necessity and purpose of man and society as part of planetary nature rather than by subjective state ideologies. In addition, the result of this interaction must be synchronized in space and time with the objective goals and results of other biological and non-biological objects (elements) of planetary nature.

When we talk about a new horizon of scientific worldviews, we do not mean that many professionals should immediately change the worldviews they acquired in universities. However, we argue that high-threshold problems are challenging the coexisting disciplinary structure of universities. In this case, the inability to solve a high threshold problem is not due to the lack of necessary approaches, tools, and technologies. It stems from the fact that there are no university departments that can train top scientific minds among a certain group of students. These departments are required to train students so that they master the necessary systems approaches, transdisciplinary approaches, and practical skills involved in applying appropriate transdisciplinary and systems transdisciplinary approaches.

The history of science has demonstrated that new approaches, methods, and technology are primarily used in defense ministries rather than in universities. Therefore, each novel approach and technology cannot be left at the disposal of a single state. It is of great importance that there is an international standard of transdisciplinary education and transdisciplinary competence in order to prepare future professionals capable of tackling high-threshold problems. All issues related to adapting systems transdisciplinarity in the disciplinary curriculum of universities should be resolved through international cooperation, for example, in the framework of international center for innovation in education. These efforts will be of critical importance in promoting the overall development of science and society. This development will no longer depend on the individual opinions of politicians who possess different scientific worldviews. Therefore, further scientific advancement will be the main responsibility of an international team of experts who possess the appropriate level of scientific expertise and practical experience when it comes to dealing with high-threshold problems and challenges faced by modern society.

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About the Authors

Vladimir Mokiy (https://orcid.org/0000-0002-7107-8089) is the Head of the Russian School of Transdisciplinarity (http://td-science.ru); Head of the Scientific Research Laboratory of Transdisciplinary Planning and Forecasting in Kabardino-Balkarsky State University, Russia (from 1996 to 2003); Director of Institute of Transdisciplinary Technologies, Russia (from 2007 to present); Member of the Russian Philosophical Society (from 2015 to present); Member of the Society of Architects of Russia (from 2013 to present); Member of the International Academy of Organizational Sciences, Russia (from 2016 to present); and Member of the Research Group Systems Science and Philosophy of the Bertalanffy Center for the Study of Systems Science (BCSSS), Austria (from 2017 to present); Individual Founding Members of the Global Alliance for Inter- and Transdisciplinarity (from 2022 to present). A complete bibliography of Dr. Vladimir Mokiy can be found by following this link: http://td-science.ru/index.php/kabinet-direktora/26-eng/473-curriculum-vitae

Tatiana Lukyanova (https://orcid.org/0000-0002-7634-303X) is the leading expert of the Russian School Transdisciplinarity (http://td-science.ru); Project manager for the protection of biological resources in government agencies, Russia (from 1998 to 2007); Leading specialist of Institute of Transdisciplinary Technologies, Russia (from 2007 to present). Specialist of the Center for Sustainable Development, Kabardino-Balkar State University, Russia (from 2020 to present); Individual Founding Members of the Global Alliance for Inter- and Transdisciplinarity