The Unity of Science and Transdisciplinarity: A new Agenda to Face Civilizational Problems

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Abstract

The text's objective is to show that the Western scientific tradition, since the pre-Socratics, has as one of its traits the search for a unitary and universal system of knowledge. Since the modern age, many attempts have been directed toward the search for the unification of science, culminating in Neurath's analytical philosophy and efforts in cybernetics. These efforts reflected an epistemological expectation for the unity of science, seeking methods and languages that would allow such an achievement. But such an expectation has not yet satisfied the hopes of the monists. The diversification of science deepened and, at the same time, the problems faced by humanity increased the need for science to offer answers to solve the great global problems. The planet and humanity are under severe pressure in many ways. Pollution and depletion of water resources, threats of mass extinction of biodiversity, deforestation, desertification, global climate change, persistent poverty for large contingents of the world's population, attacks on democratic systems and values in many countries, and, at this moment, a pandemic of great proportions. In short, a threat to the sustainability of the planet and civilization as such.

The paper goes through Mode 1 of knowledge production, showing that this Model is limited and insufficient to solve the problems humanity is facing. Model 2 of knowledge production is suggested as the immediate perspective to support the cope with humanity´s global problems. This Agenda presupposes a new way to unify science, which transdisciplinarity can bring. Therefore, the unity of science wouldn´t be through reductionism or the unification of language, but through the new *modus operandi* of transdisciplinary practice.

Keywords

Unity of Science, Transdisciplinarity, Mode 1 and Mode 2 of Knowledge Production

I. Introduction

The Greek world is the main source of knowledge and also the ideal of unitarian and universal thought. Even today, Greek classical philosophy mobilizes a huge number of researchers seeking to understand and update the knowledge they produced. Congresses, specialized periodicals, published books, defended theses, and exegesis of old manuscripts mobilize universities and research centers all over the world.

The search for the ultimate explanation of life, society, and natural systems, mobilized the pre-Socratic philosophers and those who followed them for two millennia. Even today, there are those who think that this is a challenge still to be tackled and that an epistemological reductionism could redeem us from the multiplicity of knowledge branches we live with. After all, reality is one and our Mind should be able to apprehend it in its unity. Complexity, theory of everything, unified theory of science and cybernetics are some of the labels that the unifying efforts have acquired over time. The substrate that permeated all these attempts was, however, that of interdisciplinarity, meaning, the search of a unified theory that can be understood as a meta-theory of different disciplines and, therefore, an "Interdisciplinary theory". It would be a theory that could express different disciplines in a single theoretical body, in a single paradigm, to use Kuhnian language.

There are many thinkers who, in one way or another throughout history, have addressed the issue related to the unity of science. In this short essay, we will mention some of them, those who left a mark on this trajectory. Our aim is not to consider these efforts for themselves, but to show that current times demand a new conception of scientific unity. Not the one derived, eventually, from the cognitive symbiosis between theories, or even from the efforts of epistemological reductionism, which for a long time guided the movement for the unification of science. We need another type of unity of science, the one that embraces civilizational problem-solving perspective as the central preoccupation of our time.

II. On the unity of science.

Within the Western philosophical tradition, the pre-Socratics were the first to bequeath to us a set of conceptions about the world and the place occupied by men on it. As we know, the works produced by pre-Socratics did not survive in its entireness. In many cases, only a few fragments survived. Therefore, an overview of their conceptions is based on work done by philologists and philosophers who meticulously organized those fragments (Hermman Diels (1879) by quotations made by Aristotle, Theophrastus, Plutarch, and others, and by scholars who spent decades studying the documents.

Among the many contributions of the pre-Socratics, we mention the attempt to formulate a cosmological view of nature whose basis is linked to the search for the constituent element or elements of matter. In the search for the ultimate constituent of nature's materiality, they left us surprising cosmic visions, visions that have the format of "all is one", meaning that the world is subsumed under an element such as water, as postulated by Thales of Miletus, or the "everything is air" according to Anaximenes, or even "everything is fire" according to Heraclitus. Democritus believed that atoms were the substance and origin of everything, and Pythagoras attributed the very existence of the universe to a harmonious confluence of numbers and geometric figures. In short, these philosophers believed in a single cause for the world's existence. The conception of "all is one" was later introduced by Christian Wolff (1679 – 1754) who named it as ***monism***.

Plato's cave myth (428 BC - 348 BC) synthesizes his philosophical system, where true knowledge transcends the sensory world, the ephemeral appearance of sensible objects and focuses on the world of eternal forms. Knowledge results from the distancing of the intellect from the sensory world. Everything is unified in the perfect world of forms, which are captured by the philosopher's mind, or rather, are revealed by the philosopher's mind that rediscovers something he already knew, because knowledge is pre-existing, and forms are eternal.

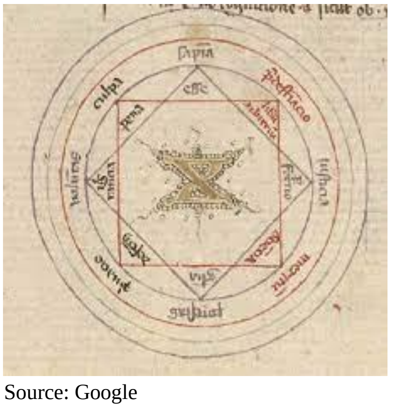
A few decades after Plato's death, Euclid (325 BC – 265 BC) of Megara `treatises began to appear, and were fully completed after his death, thanks to a group of mathematicians who worked after him in Alexandria. *The Elements* are a monumental and precise work that inspired philosophers for centuries, including Galileo, who almost one thousand and five hundred years later, in the same vein, would say that “the very great book (of nature) is written in mathematical language and the characters are triangles, circles and other geometric figures (...) without which one will be wandering in vain through an obscure labyrinth”.

Among the philosophers of classical Greece, Aristotle (384 BC – 322 BC) left the greatest legacy that we have access to. It was dedicated to various disciplines, and knowledge was divided into 3 parts: i) productive knowledge that deals with useful things; ii) practical knowledge that deals with ethics and politics and, iii) theoretical knowledge, which deals with science, and with the essence of things. This last type of knowledge is the noblest of all and only it can explain the laws that govern the world. Theoretical knowledge and the truths derived from it are acquired by contemplation, which means to some extent that it depends on the contemplator. As Barnes mentions, “*The Aristotelian contemplator is a man who has already acquired knowledge; and what he is contemplating is precisely the knowledge already present in his mind ... the contemplator is engaged in orderly inspection of the truths he already possesses; his task is to bring out the recesses of your mind and arrange them appropriately in the full light of consciousness”* (Barnes, 1976, 3). The unity of knowledge is found in the philosopher-contemplator. Truths can be externalized, but they are first in the philosopher-contemplator´s mind.

Aristotelianism influenced Western thought for almost 2000 years, becoming the basis of scholastic thought that prevailed for about 500 years, approximately from the year 1100 to the year 1600. Scholasticism fundamentally sought to establish a unique and guiding philosophical system of religious life and revealed truths, its greatest expression being Saint Thomas Aquinas (1225-1274). As Biener mentions, “*Scholastic-Aristotelianism in its many varieties encompassed all that was thought to be known and did so through a highly articulated conceptual scheme that mirrored the highly organized character of reality…. In the scope of scholasticism-Aristotelianism, its influence extended far beyond the realm of philosophical ideas to the constitution of teaching curricula, social institutions, and even theological doctrine. In a sense, Aristotelian-scholasticism had been woven into the very structure of society's life in the late Middle Ages, in the Renaissance until the beginning of modernity in Europe*”. (Biener, 2008, 4)

The means by which the intellectual dominance of scholasticism was exercised were the monasteries and their libraries. Later, universities, founded initially in the monasteries themselves, were the centers of knowledge creation until the Renaissance. The influence of scholasticism in social life and to ensure power structures were based on the unitary vision provided by the church. The importance of unity in the philosophical system was so important that the Catholic church started unifying the catholic doctrine long before the establishment of scholastic-Aristotelianism, through the organization of Councils aimed to overcoming interpretative differences. The best example is the first Catholic Council, held in Nicaea in the year 325 AD.

A thousand years after the Council of Nicaea, in the 13th century, Ramon Llull (1232 - 1316) dedicated himself, among many other things, to designing a logical machine, which he called *Ars Generalis Ultima*, whose main characteristic was the unification of religious doctrines. For him philosophy, theology and mysticism were not separate or contradictory sources of truth. Rather, they were different aspects of the same knowledge process (Priani, 2021). Llull hoped that "*through this machine, representatives of Judaism, Christianism and Islamism would be able to reasoning together and clearly delineate the enlightened nature of God, and the perfection of nature found in God's creation*" (Metcalfe, see reference).



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The Llull machine was conceived to answer questions, and the answers had to fit within a conception previously defined by the inventor, where the truth had to agree with the divine truth and this one should also be in agreement with the conception of its inventor. It is an early example of how logic and language can shape reality and give it a sense of unity. Llull uses geometric shapes, like Pythagoras, to represent the concepts that would serve as the basis for finding the expected answers. The blue triangle, for example, represented God, Unity and Essence and the red triangle represented Beginning, Time, Quantity and Cause.

Gottfried Leibniz (1646 – 1726) published his first book in 1666 entitled "*Dissertatio De Arte Combinatoria*", proposing the creation of a thinking machine, along the same lines as Ramon Llull. This machine would have the ability to reproduce the entire universe within a single science. In a letter addressed to the Duke of Hannover in 1679, he expresses the following: "My invention contains the application of all reason, a judgment in every controversy, an analysis of all notions, an assessment of probability, a compass for navigating the ocean from our experiences, an inventory of all things, a table of all thoughts, a microscope to prove the phenomena of the present and a telescope to predict those of the future, a general possibility of calculating everything. My invention is an innocent magic, a non-chimeric Kabbalah, a writing that everyone can read and that everyone can easily learn…". (History of Computing, see reference). This mechanism of "reasoning", using a previously defined language, he called "*Characteristica Universalis*", where all knowledge, all truths could be demonstrated by calculation, without any extra effort of mind or imagination.

Source:Google

Scholasticism was long-lived. More than a thousand years of prevalence, where the terrestrial and celestial worldview were well established and connected in the geocentric conception of the universe. The combined conceptions of Aristotle and Ptolemy (100 AD – 170 AD) sustained the geocentric paradigm in Middle Ages, leaded by the Christian Church in Rome. Physics and metaphysics united by the same universal force deified by Christianity. But during the fifteenth century, the rupture of Aristotelian-Scholastic-Ptolemaic stability has begun. Nicolaus Copernicus (1473 – 1543) and his heliocentric model brought up to light a new cosmovision, reversing the previous paradigm and placing the men in a new order in universe. This movement was deepened by Johannes Kepler (1571 – 1630) and his elliptical heliocentric model, striking even more the idea of a circular and perfect universe, with the Earth at the center of the system, as recommended by the Church and the Aristotelian-Scholastic model.

Deep epistemological discussions within the Church, where the idea of a model was opposed to the idea of reality. The church could live with the idea of an explanatory model aiming to "facilitate" mathematical calculations about the movement of the planets, but never a representative model of reality, ontologically constituted. We know the result of some decades of discussion and the death of Giordano Bruno (1548 – 1600) due to the defense of the many possible worlds: it was the famous "*Eppur si muove*" said by Galileo (1564 – 1642), who at the end of the prosecution abandoned the ontological status of heliocentrism to survive. This period of instability and questioning should, however, be replaced by a new cosmology and a new philosophical system. This is what Biener (2008) sustains, adding to the factors mentioned above, the analytic geometry, invented and used by Descartes (1596 – 1650), the development of mathematical calculus, carried out by Leibniz, and, finally, the pearl of the scientific development, the publication of the *Philosophia Naturalis Principia Mathematica* in 1687 by Isaac Newton (1642 – 1627).

The intellectual environment in seventeenth century in Europe prefigured the paths that science and philosophy would take for the next 100 years. The massive development of natural sciences and their progressive separation from philosophical thought. The development of mathematics and physics were, without a doubt, the elements that enabled the "philosophers-mathematicians-physicists" (as was the case of Descartes) to make incursions in the search for comprehensive and unifying philosophical systems. For him, the unification of the *res extensa* and the *res cogitans* would be made by mathematics.

It was also the case of Immanuel Kant (1724 – 1804), opening a whole tradition of thought, reinforcing the a-priori principles of thought over empirical reality, to the point that Kant claims that *"the unity of science is not the reflection of a unity found in nature, or even less assumed in a real world behind apparent phenomena. Rather, it has its foundations in the a priori unifying character or function of concepts, principles and of Reason itself. Nature is precisely our experience of the world under universal laws that include some of these concepts. And science, as a system of knowledge, is "a whole of cognition ordered according to principles" and the principles on which proper science is based are a priori*" (Kant, 1786). The unifying dimensions in Kant´s works are the notion that fundamental ideas constructed by the mind are the basis for the organization of reality and the classification of sciences as well.

Newtonian physics contributed greatly to a scientific worldview, the view that the new physics could provide certainty about a world, or more precisely, about the universe as understood at the time and of which Kant was an enthusiast. The book *Philosophiæ naturalis principia mathematica* opened a new chapter in the search for unitarian science, where Newtonian physics was a great protagonist (Oliveira Barra, 2004).

Going through August Comte (1798 – 1857) and his social physics, Max Planck (1858 – 1947) and Ernst Mach (1838 – 1916) with the idea of unity as the regulating principle of reason until the declaration made by Wilhelm Ostwald (1853 – 1932) that the 20th century would be the *"monistic century"*, the efforts to maintain science as an indivisible whole, became something increasingly difficult to sustain given the growing diversification of knowledge into disciplines and the increasingly difficulties to find a common research method for social and natural sciences. Stuart Mill (1806 - 1873) had already noted these difficulties since the 1850s through empiricist positivism. We also mention Otto Neurath's efforts to maintain the ideals of a unitarian science with the creation, in 1937, of the International Institute for the Unity of Science after organizing a series of international conferences on the same theme in previous years.

It is worth mentioning the creation of the International Encyclopedia of Unified Science, edited by Otto Neurath, Rudolf Carnap and Charles Morris (Neurath et al. 1938), with the objective to supporting the movement led by the International Institute for the Unity of Science mentioned above. As Neurath stated in the introduction to the Encyclopedia, *"This new version of the idea of unified science will be created by the confluence of divergent intellectual currents. The empirical works of scientists used to be antagonistic to the logical constructions of an a priori rationalism generated by philosophical-religious systems; therefore, "empiricalization" and "logicization" were considered to be mainly in opposition. The two have now become a synthesis for the first time in history*" (Neurath et al, 1938). A monumental project, from which important works emerged, including Thomas Kuhn´s 1958 book, as well as the logical empiricism.

The idea of a unified science did not mean a single knowledge system uniting physical, social and life systems. It was more in the line of eighteenth-century encyclopedists, more like a mosaic (Neurath et al., 1938) of knowledge that could come together into one big picture, giving meaning to the world. In Neurath's words, it would be like an encyclopedia.

In this context, Cybernetics emerges as a wide-ranging and universalist undertaking, with the objective of understanding the behavior of systems, of "real machines", as Ashby (1957) would say, whether they were mechanical machines, neurons, or the economy. Cybernetics as a theory was inaugurated with the book *Cybernetics: Or Control and Communication in the animal and the Machine*, published by Norbert Wiener in 1948. It includes the best-known definition of cybernetics. The "science of control and communication in animals and machines". The discussion focuses on the control of information flows for systems feedback. Thus, intentional systems "whether mechanical, biological or social, are like an arrow with a specific direction in the flow of time, not a line segment facing both directions, which we can regard as guiding one and the other" (Wiener, 1948). That is, organisms incorporate information and change behavior based on that information. This is called learning. Organisms of any kind that receive information and modify behavior accordingly are called cybernetic organisms, whether they are human, biological, or mechanical. In Wiener words, systems are not automatons that repeat behaviors, but "*creatures that (...) advance from a known past to an unknown future, and this future is not interchangeable with that past*". In short: for Wiener, the fundamental task of cybernetics is to carry out comparative analysis and discover the general laws that govern the processes of information transformation in natural and artificial systems, transformations based on information and learning.

The most important proponent of systems theory was Ludwig von Bertalanffy, who began his thinking on the subject in the 1920s, as mentioned in his book *General System Theory* (Bertalanffy, 1968). A few years later, in 1937, in a conference given in Chicago, he mentioned for the first time the expression *General Systemology*, (the study of systems) according to David Pouvreau (2014). Except for some reference regarding the low acceptance of this new perspective, there is no news of a specific text on the subject at that time.

The project of a General Systemology was made public in 1947, in a conference entitled *Unity of Science and Principles of a General Systemology* (Pouvreau, 2014). As Pouvreau (2007) mentions, Bertalanffy's main objective was to *"generate a new type of unity of science: not a unity based on the reduction of concepts, methods or even laws of all sciences or of a single science considered more essential; but rather a formal unity based on the generality and ubiquity of the concept of system and on the isomorphisms it induces* *between sciences whose logical and methodological autonomy is guaranteed*". In this sense, Bertalanffy had some resistance with the term "theory" since this term has a disciplinary connotation. He preferred the term "*Systemology*" because he wanted something "upper level" that applied to all systems and theories. Based on this approach, Cybernetics aimed to describe/study systems beyond disciplinarity.

Finally, we mention the quest for a *cybernetic unity of the world* through the work of Valentin Turchin and his attempt to rewrite the evolution of the universe in cybernetic terms. Turchin presented in *The Phenomenon of Science* (Turchin, 1977) a scheme of the evolution of the universe, starting at the level of individual atoms and molecules, continuing through the origin of life and the development of plants and animals, culminating with man and self-awareness, society, and the development of man's intellectual creations, particularly the scientific knowledge. A complete evolutionary view of the universe through cybernetics.

III. The operative mechanism to unify science.

In the previous section, we briefly mentioned some of the efforts under the scope of a quest for the unity of knowledge and science. The outcomes of each of the previous philosophical attempts did not succeed in the search for the unity of knowledge and science, but they are important chapters in the history of scientific and philosophical thought.

In a classic text regarding the unit of science, Paul Oppenheim and Hilary Putnan (1958) mentioned 3 possibilities to operate the unification of science: i) Unity of science in its weak sense, ii) Unity of science in a strong sense, and, iii) Unity of science in a very strong sense. The first of them, unity in the weak sense, the unity would occur through the reduction of the language of one discipline to the language of another discipline. In these cases, the more mature discipline would rewrite the less mature discipline, as might happen, for example, with chemistry being rewritten by physics, or sociology being rewritten by psychology. This reduction would occur bilaterally, discipline by discipline. For this to be feasible, however, some conditions must be present. If we take two theories T1 and T2, where T2 will be reduced to T1, then:

a) The vocabulary of T2 contains terms that are not part of the vocabulary of T1;
b) Any observational data explained by T2 must be equally explained by T1;
c) The systematization of T1 must be greater than or equal to the systematization of T2.

These conditions can occur in the reduction of two theories, for example, molecular biology being reduced to chemistry, or chemical bonds being explained by physics, or sociology being reduced to psychology, as discussed by Hummel & Opp (1968). This was also Neurath's purpose, as mentioned in the introduction to the International Encyclopedia of Unified Science: *"The unification of scientific language is one of the purposes of the unity of science movement. It is a question of how far such unification can be promoted. One can perhaps reduce all scientific terms to a kind of term by means of a special logical technique"* (Neurath at al, 1938).

The second meaning of unity of science, in its strong sense, implies not only the rewriting of the language of a T2 theory in terms of T1 theory, but also the absorption of the laws of T2 theory by the laws of T1 theory. In both situations, weak and strong reduction, the operation that is practiced is epistemological and semantic in nature, as it would be operating the semantic reduction of observational language (selective semantics) and the reduction of explanatory laws, as observed by Tuomas E. Tahko (2021). Neurath also mentions this type of reductionism in the introduction to the Encyclopedia (Neurath, 1938).

The literature also mentions another type of reduction, that is, ontological reductionism. In the history of philosophy there have been many ontological reductions as mentioned in section II. The “everything is....” type, as we have shown. This type of reduction aims to transform something (abstract or material) into something else apparently simpler, a substance or an element. The pre-Socratic philosophy was relatively prolific in the exercise of reduction. More recently we have the conception that “everything is energy” or “everything is information” or even the proposal to reduce psychology or problems related to the mind to chemistry or other material things. These types of reductions have been rejected and do not seem to offer positive prospects for going down this path. We must ask: does it make sense to continue seeking the unity of science, at a time of extreme diversification of knowledge? In addition, as we can infer from the epistemological discussion about the truth or adequacy of theories to reality, whether in the Popperian (2004) or Kuhnian (1958) perspective or in the interpretations of Nagel (1979) and Hempel (1966), theories are always an approximation to the reality, to the truth. The implication of this is that theories are provisional and will be eventually falsified and replaced. What is, therefore, the point in reducing theories or seeking scientific unity if theories are necessarily going to be falsified?

In addition to the debate on the concrete possibilities of epistemological, methodological, or ontological unification of science, the current requirements related to the unification demand a new standpoint in face of the challenges that lie ahead. A new type of unification is needed, not the unification dreamed of by "physicalists" or "formalists" trying to reduce natural sciences to physics or logic, but a unity that links nature, life, and sociocultural systems in a unifying model oriented to problem-solving. The question that arises is whether the development of a “knowledge system” that consider nature, life, and socio-cultural environments would be viable and how they would operate. Let us see what these challenges might be and how science can respond to them.

IV. Some Challenges Ahead of Humanity

We have seen previously how the ideals of unity of science have remained alive in Western thought since antiquity, even with the separation and development of scientific disciplines since the 16th century. Philosophy of science has been trying to analyze each new language, each new concept, each new theory, in all its details, in order to improve our description and explanation of the external world. But we have found limitations. Scientific disciplines encounter epistemological barriers to understand the reality in its entireness. Additionally, the institutionalization of science established administrative barriers that become limiting factors due to the compartmentalization of knowledge and hindering its integration, requiring efforts and additional energy expenditure to overcome sectorial barriers (Brewer,1999)

We discussed some of the efforts made throughout history regarding the unification of science. But now we are going to discuss the unity of science in another terms. Let us move momentarily away from the epistemological discussion of reductionism to enter to the problem-solving arena, where a new kind of unity is needed. I would say that the 21st century is the century of great civilizational challenges. Humanity is facing great challenges and I would dare to say that the entire planet is at risk. United Nations as well as many scientists have been alerting and raising awareness about the status of global problems. Some of these threats are, of course, not new and have been identified since long time ago. Since Thomas Malthus and his *Essay on the Principle of Population* published in 1798 and later in the 1960s with the publication of *The Population Bomb* by Paul Ehrlich, culminating finally with the warning issued in 1969 by the UN Secretary General U Thant are examples of that (Secretary General of United Nations U Thang said: *“I do not wish to sound too dramatic, but I can only conclude from the information that is available to me as Secretary General, that the members of the United Nations have perhaps ten years to subordinate their former* *grievances and launch a global partnership to contain the arms race, improve the human environment, counteract the population explosion, and provide the necessary impetus for development efforts. If this global partnership is not formed in the next decade, I am very much afraid that the problems I mentioned will have reached such staggering proportions that they will be beyond our ability to control"* (Meadows, 1972)). This warning foreshadowed the release of the Club of Rome report *The Limits to Growth* (Meadows, 1972), which clearly foresaw a breakdown of the capitalist system due to the depletion of natural resources.

From this alert on, the international community, through its institutions, began a process of reflection that culminated in events, reports, scientific publications and international agreements aimed at producing significant changes in development patterns, as well as on how to tackle the challenges and crossroads humanity has been facing. The main challenges humanity has ahead can be summarized as follows:

a) Environmental Degradation: Deforestation, pollution, habitat destruction, and unsustainable resource consumption have negative impacts on ecosystems, biodiversity, and human livelihoods. Climate Change poses significant threats, including rising temperatures, extreme weather events, and sea-level rise;
b) Global Poverty and Inequality: Millions of people worldwide continue to live in poverty, lacking access to basic necessities such as clean water, food, healthcare, and education.
c) Technological Disruption: Rapid advances in technology, including artificial intelligence, automation, and robotics, bring both opportunities and challenges.
d) Overpopulation and Urbanization: The world's population continues to grow, leading to increased demands for resources, urbanization, and strain on infrastructure;

e) Governance and Corruption: Effective governance, transparency, and combating corruption are essential for economic development, social stability, and trust in institutions. Strengthening democratic processes, promoting accountability, and reducing corruption are ongoing challenges.
f) Technological Divide: While technology has the potential to improve lives, the digital divide remains a significant challenge. Bridging the gap in access to technology, digital literacy, and internet connectivity is crucial to ensure equal opportunities and empower individuals worldwide.

It's important to note that these challenges are interconnected and often require collaborative efforts from governments, organizations, and individuals across the globe to find effective and sustainable solutions.

Ulrich Beck (2014) published an interesting book called *Risk Society* showing that modern social development based on science and technology is putting our society at risk. And the risk was reached after 2 centuries of scientific development and now science must dedicate itself to investigate and, eventually, solve the side effects caused by itself. In the same line of reasoning, Maxwell (2012) stated that humanity is currently facing a situation in which disciplinary science is no longer able to respond to the challenges of global problems. More than that, science can be considered a risk factor for humanity if it does not submit itself to a new civilizational paradigm, because the science we want to solve the humanity´s problems is the same that produces the technological innovation and economic development that created these problems. As a result, universities around the world, which constitute the privileged locus of scientific production, are also responsible for creating a new paradigm, combining knowledge and problem-solving methods. The author then makes a strong appeal to the need for an "intellectual revolution in universities and other educational institutions" so that we cannot only understand the world around us, but essentially learn how to promote the progress towards a better world through transdisciplinarity (Maxwell, 2012, 2).

V. Science: from Mode 1 to Mode 2 of knowledge production

We are in a moment where it is needed a new scientific approach that would be able to unify the natural and social sciences for the solution of civilizational problems. This new approach should unite knowledge coming from the systems of nature, life, and society/culture, to create alternatives and choices for society. Traditional disciplinary scientists might object that it is not the role of science to engage in such a salvationist program and that science would only be tasked with investigating and explaining nature, life, and sociocultural systems as objectively as possible. But is disciplinary knowledge able to respond adequately to the challenges of our time? It seems that it is not.

It is no longer enough to verticalize (albeit necessary) knowledge or the search for a unified language for science, which could eventually work well in "hard sciences" such as physics, and chemistry, but would not work very well for humanities, either by the origin and differentiated characteristics of the objects of investigation, or by the structural differences in the construction of the scientific explanation (Matallo Junior, 2021). In fact, when we mention the different types of objects, we are referring to 3 systems: natural, life, and sociocultural systems. We can eventually look for a theoretical and cognitive unification among these systems, but what drives us in these times is really a new pattern of knowledge production. We need a definite transition from the Mode 1 to the Mode 2 in knowledge production.

In the 1970s, a group of authors led by Gernot Bohme published for the first time a paper entitled “Finalization of Science” (Böhme, 1976), showing how the external orientation of knowledge gained importance for the development of science. A few years later, the book *Finalization in Science: The Social Orientation of Scientific Progres* (Böhme et al., 1983) was published highlighting the new orientations of the dynamics of knowledge production. This dynamic points to the need to produce knowledge for solving problems through technological innovation (Bohme et al, 1983), based on the emergence of the concept of “Sustainable Development”. This means that science has become an agent of change, in addition of being a particular model of cognition.

Gibbons et al. (2002) also shows us how society has witnessed a qualitative and methodological change in the production of knowledge since the end of the 20th century. We went from Mode 1 of doing science to Mode 2 as Gibbons explains in the following way: *“Mode 1 is identical to what is meant by science. Their cognitive and social norms determine what should be considered a significant problem, who should be allowed to practice science, and what constitutes good science. Practices that adhere to these rules are, by definition, scientific, while those that violate them are not. These are the reasons why it is conventional to talk about science and scientists in Mode 1, but it was necessary to use the more general terms of knowledge and professionals when describing Mode 2”* (Gibbons, 2002, 3). The author continues by mentioning that *“The knowledge of Mode 2 is carried out in an application context. Mode I is disciplinary, while Mode 2 is transdisciplinary. Mode 1 is characterized by homogeneity. Method 2 by heterogeneity. Organizationally Mode 1 is hierarchical and tends to preserve its shape, while Mode 2 is more heteroarchical and transitory. Each employs a different type of quality control. Compared to Mode 1, Mode 2 is more socially responsible and reflective*. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localised context.*”* (Gibbons, 2002, 3).

The work of Gibbons and his associates also shows us the existence of a market demand for Mode 2 of knowledge production, whether in the private sector or in the national and international public sector. From our point of view, what interests us most, and has been the focus of our concerns, is related to the production of knowledge in the public sector, which comprises universities, research centers, national governments, or international institutions, since the solution of a large part of the problems at any level requires regulatory policies and these must be materialized based on socially validated science and knowledge. We should pay attention to global problems, which need long-term commitments and high adaptive capacity of groups and communities.

In summary, Mode 1 of knowledge production in insufficient to promote what humanity requires nowadays. It doesn´t mean that Mode 1 is not relevant and will eventually disappear. Mode 1 is essential and is in the nature of science. Specialization is part of the dynamics of disciplinary knowledge production as well as for technological development. However, the humanity needs more. It needs a combination in a proper way of different kinds of knowledge to solve the complexes problems it has been facing (some of them created by the same science!). This is something that Mode 1 of knowledge production cannot offer. Instead, Mode 2 will be society-oriented and its nature is essentially different of Mode 1 as we will see next.

VI. Inter and transdisciplinary knowledge.

The discussion in the previous section immediately takes us to the new forms of knowledge production: the interdisciplinary and transdisciplinary knowledge. The production of knowledge in the world moves a complex and expensive machinery (Strevens, 2020), requiring specialized institutions to manage this complex system. Universities, as traditional institutions in the production of knowledge, are organized by disciplines and departments and are responsible for funding a series of other institutions and companies around them. Funding bodies, specialized magazines in different disciplines, companies that produce equipment for laboratories and committees for evaluating publications are some of the elements that are part of this machinery.

Among companies and governments, the concepts and practice of inter and transdisciplinarity has increasingly been used as the solution for improving efficiency in problem-solving. In 2008, the New Zealand's Ministry of Research, Science and Technology commissioned Dr Karen Cronin to provide a consultancy report outlining ways to incorporate sustainable development issues into the ministry's policy formulation and implementation. The report was entitled *Transdisciplinary Research (TDR) and Sustainability*, and I think it is a good example on how to use the concepts of inter and transdisciplinarity in problem-solving. In this report, these concepts were defined as follows:

Interdisciplinary studies: various unrelated academic disciplines (contrasting research paradigms, for example the differences between qualitative and quantitative approaches or between analytical and interpretive approaches that bring together humanities and natural sciences disciplines) involved in such a way as to force them to cross the boundaries of subject to create knowledge and theories and solve a common research objective.

Transdisciplinary Studies: projects that researchers and academics from different independent disciplines and non-academic participants, such as land stewards and the general public, investigate with a common goal of creating knowledge and theory. Transdisciplinarity combines interdisciplinarity with a participatory approach. Transdisciplinary research involves a range of approaches that can lead to the breaking of disciplinary boundaries, the merging of existing disciplines, and the introduction of non-disciplinary knowledge from external stakeholders. It also has the potential to create a framework of knowledge and a comprehensive synthesis from diverse perspectives in the research environment" (Cronin, 2008).

In the above-mentioned formulation, what differentiates the two concepts is the participatory approach. It means that depending on the circumstances, one can move from interdisciplinary to transdisciplinary environment. In general, universities and research centers do not use the participatory approach in academic work. Participatory processes in universities and research centers take place through seminars and conferences between peers. It is a evaluation mechanism, but not a knowledge production system. Another aspect to consider is that generally the issues they are concerned with are, primarily, of academic nature and the result of the interdisciplinary exercise is the technical-scientific report, the article or book to be published.

The concept of transdisciplinarity has a different nature and requires the external participation of various stakeholders potentially involved with the issue, and the result of the exercise is not the scientific article to be published, but an action program, a product, a technology, a set of recommendations or a proposal for policy to be institutionalized.

> Science has become an agent of change, in addition of being a particular model of cognition

There are also two important aspects to be considered: governance and operativity in transdisciplinary activities. The management problem is perhaps the most important component for a successful functioning of inter and transdisciplinary projects in both, public and private sectors.

The success or even the existence of such projects depend on the organizational and management aspects. In the case of formal groups, the project design, the material resources needed, the assignment and calendar of responsibilities, and the timing to come up with outcomes are of fundamental importance. In companies, these requirements are taken seriously, as the delay in presenting results due to poor management or inadequate dimensioning of the resources necessary for the execution of the project can cause irreparable losses for the company. In public institutions, the governance problem is, for the most part, formally resolved. Projects follow existing hierarchies. However, the problem lies in the allocation of resources, the complexity of the project, political will and the time foreseen for its implementation, that is, it depends on the effectiveness of the teams' leadership and the adequate allocation of resources.

In the case of informal groups, the commitment of participants with the subject matter and the perspective of results is a relevant aspect. However, the aspect regarding personalism and leadership are constant threats to the project. In general, informal groups do not have adequate economic and administrative infrastructure and the leadership style can put the entire project at risk.

Some requirements for the success of inter and transdisciplinary projects, whether formal or informal can be summed up as follows (Pinto & Slevin, 1987; Müller & Turner, 2007; Beleiu & Crisan & Nistor, (2013):

- the project design, definition of objectives, results to be achieved and expertise required for the project.
- Selection of professionals according to the required specialties and assignment of responsibilities.
- material resources needed, calendar of activities and time for the presentation of results specified
- Governance/Management/leadership.

As mentioned earlier, formal and informal groups may have difficulties due to potential conflicts generated by the leadership style. These leads, among other things, to a greater possibility of disagreement about the validity of knowledge and can result in conflict. Thus, while heterogeneity is a central feature of inter- and transdisciplinary teams, it simultaneously represents their greatest threat. The theme of leadership in formal and informal interdisciplinary teams, academic, public, or private organizations, has been the object of discussion since at least 1938, through the work of Chester Barnard (1938). There is an extensive literature (Dudovskiy, 2013) on the subject given the importance of motivational leadership for inter- and transdisciplinary projects and the observed failure rate.

Additionally, it is considered that interdisciplinary research is a necessity derived from the nature of current problems, but it can also incur high costs due to the need to invest time and other resources to build solid collaborative relationships, for the development of a shared language as well as in enhancing a common perspective for different points of view (Bromham & Dinnage & Hua, 2016).

VII. Our Common Future: A paradigmatic Example of Transdisciplinarity to Address a Civilizational Problem

The *"Our Common Future"* is a seminal report published by the United Nations World Commission on Environment and Development in 1987 (UNCED, 1987). It emphasized the need for global cooperation and sustainable development to address pressing environmental and social challenges facing humanity.

The report aimed to go beyond the boundaries of individual academic disciplines and incorporate diverse perspectives and knowledge domains. It recognized that solving complex global issues required collaboration and integration of insights from various fields such as science, economics, sociology, and politics in line with we mentioned in previous session (Cronin, 2008). The report is under Mode 2 as explained, since it adopts a transdisciplinary approach, bridging the gap between different knowledge systems and foster a more holistic understanding of sustainable development. It acknowledged the interconnections between environmental issues, economic development, poverty eradication, social equity, and technological progress. The report's transdisciplinary approach was instrumental in raising global awareness about the interrelated challenges of environmental degradation, poverty, and inequality. It called for policy changes, international cooperation, and the integration of sustainability principles into decision-making processes at all levels. Since its publication, "Our Common Future" has had a profound influence on global discussions and actions related to sustainable development. It helped shape the agenda for subsequent international agreements, such as the Rio Declaration on Environment and Development and the United Nations Sustainable Development Goals (SDGs).

The president of the World Commission on Environment and Development, the Prime Minister of Norway Gro Harlem Brundtland (1987) puts in this way the work of the Commission: *"due to the scope of our work and the need to have a broad perspective, I realized perfectly that I should create a highly qualified and influential political and scientific team in order to constitute a Commission. truly independent. This was paramount if we were to succeed. Together we should embrace the planet and unite to formulate an integrated and interdisciplinary approach to our common concerns and future. We needed broad participation and a majority of members from developing countries in order to reflect the realities of the world. We needed people with broad experience, from all political backgrounds, not only related to the environment or development and other political disciplines, but also from all sectors where vital political decisions are taken that influence economic and social progress, in the national and international levels*" (UNCED, 1987). Actually, when she mentioned that the interdisciplinary work was discussed by different stakeholders at different levels, she was actually taking a step forward in the direction of transdisciplinarity.

It is worth to mention the document *Our Common Future,* which takes into consideration political, economic, and sociocultural systems, albeit in an unconventional way when compared to academic practices. As Cronin (2008) says, "sustainability management is now an important and growing field of research, reflecting the principles and practices of Transdisciplinarity and sustainability research is seen as a social process involving natural and social science disciplines, specialists and non-specialists, and cooperation between institutions". In fact, we have already been experiencing transdisciplinarity related to multilateral international negotiations, in national governments, particularly for the elaboration of public policies and, also, in the private sector.

I think that the previous paragraph summarizes the transdisciplinary work mentioned by Cronin (2008) and Nowotni et al (2001) as well as the views expressed by Bohme and associates (Bohme et al, 1983) when they presented their conception of "Finalization of Science". The work done by UNCED defined the concept of sustainability through the interdisciplinary commission of scientists and politicians. This is an important issue in the process, meaning that the concept arose from political negotiation with a broadly participatory approach, generating enormous practical effects such as the broad action programme crystallized in the Agenda 21 and, later, in the Millennium Goals and the 2030 Agenda. These documents are helping the humanity to change course in development paths. The concept of *sustainable development* is an example whereby transdisciplinarity was instrumental for developing a civilizational concept aimed to providing a new way for humanity.

VIII. Conclusion

The subject we have been considering is based on the expectations of humanity, since ancient times, to achieve the unity of knowledge to explain the whole natural and social systems through one single theoretical knowledge system. Many attempts have been made to unify science around a grand theory aimed to describe nature, life, and society altogether. We briefly showed some of these attempts.

Modern society has been defined as the knowledge society, where science plays a changing role, transforming knowledge into technology and, thus, modifying patterns of economic, cultural, and social relations. Scientific disciplines were the engine of this development until the end of the 19th century, when a new and more efficient way of producing knowledge began to take hold, albeit slowly. We moved from Mode 1 of knowledge production to Mode 2, as Gibbons (2002) showed. More recently, it has been shown that Mode 2 of knowledge production, with its matrix of transdisciplinarity, is in accordance with the very nature of modern societies and with the patterns of economic production and social complexity.

At the same time, the levels of development experienced by humanity brought up new challenges to be resolved. Humanity finds itself at a crossroad. Development, technology, and integration have created challenges that were previously unknown. New threats to natural resources are questioning the paths to be followed by humanity. These are what we call civilizational challenges. Many warnings have been given about the risks we are subject to, as mentioned in section *IV Some Challenges Ahead of Humanity*.

Despite the investments in knowledge production, the alerts that have been made by the scientific community, and the numerous reports presented by international institutions, humanity resists to change its behavior, consumption patterns and change of attitudes towards natural resources and the environment. The result of development, as the *Our Common*

Future report warned, is a global threat to the civilization. We need science more than ever. We need transdisciplinary science to mediate conflicts, solve problems, stimulate awareness, and generate new paths of sustainability, as recommended by the *Our Common Future* report.

We live in an integrated and overly complex world. The reality we live in is challenging our capacity to solve the global problems created by ourselves. Humanity is not subject to natural cycles as the rest of nature. Economic and social dynamics are not in correspondence with natural cycles. Using a mathematical analogy, the relationship humanity has with nature is non-harmonic, subject to non-linear parameters. Therefore, the science we need refers to the ability for solving the problems emerged from the globalization and from our interference on environment. Complexity of social systems and its relationship with life and natural systems requires a complex approach to be understood as a theoretical subject and, most importantly, requires the transdisciplinary approach to solve the problems we are currently facing. Transdisciplinary approach is the only viable response to understand and to act for solving the current level of global problems. Mode 1 of disciplinary knowledge production will certainly continue its verticalization. However, Mode 2 of knowledge production needs to be disseminated and assumed by responsible institutions at all levels, local, national, and international. Transdisciplinarity as a shared method for solving civilizational problems is, as far as one can see, the path that leads to a sustainable Common Future.

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