



Evolution and Characteristics of the Transdisciplinary Perspective in the Research: a Literature Review

C. Hernández-Aguilar^{1,*}, F. A. Domínguez Pacheco¹, Efraín J. Martínez Ortiz¹, Rumen Ivanov², José Luis López Bonilla¹, Alfredo Cruz Orea³, Jose Ordonez Miranda⁴

¹Programa en Ingeniería de Sistemas-SBAAM, SEPI-ESIME, Instituto Politécnico Nacional-ESIME Zacatenco, Col. Lindavista. 07738, Ciudad de México, México.

²Unidad Académica de Física, Universidad Autónoma de Zacatecas, A.P. 580, Zacatecas, México.

³Departamento de Física, CINVESTAV-IPN, A. P. 14-740. 07360, Ciudad de México, México.

⁴Institut Pprime, CNRS, Université de Poitiers, ISAE-ENSMA, Futuroscope, 86962 Chasseneuil, France

*e-mail: e-mail: clauhaj@yahoo.com, clhernandeza@ipn.mx

Received 18 May, 2020; **Revised** August 25, 2020; **Accepted** 29 August, 2020

Available online 29 August, 2020 at www.atlas-journal.org, doi: 10.22545/2020/00140

In this documentary investigation, we review literature about the transdisciplinary (TD) perspective to generate knowledge, locating its origin, evolution and characteristic features. It is found that: i) This origin is located in France and the United States, although some characteristic features related to self-knowledge, participatory research and the unity of knowledge, were proposed before the creation of this TD term introduced in 1970. ii) The concept of transdisciplinarity has evolved over time involving a transition of vision towards the application of perspective to investigate. Switzerland was the first country to apply the transdisciplinarity in research in the 1990s. iii) The key world events that gave impetus to the transdisciplinarity are the world (1994) and Zurich (2000) congresses, as well as the special edition entitled “the foundation of Academy of Transdisciplinary Learning of Advanced Studies (ATLAS)” of the Journal “Futures” (2004) and the Transdisciplinarity Journal of Engineering & Science (TJES) in 2010. iv) the main features of transdisciplinary research are: a) research for society and with society, i.e. participatory research, b) scientific research under systemic thinking, c) communication of results to the scientific community and disseminated to non-scientific population. v). The number of transdisciplinary research publications have increased over time, along with the quantity of authors per publication and citations thereof. Some contributions from the 90s were the most impactful due to the number of cites today. The transdisciplinary approach could be the best pathway to develop research in Latin American countries and the world, for solving the diverse problems of society.

Keywords: Research process, Transdisciplinarity, definitions, characteristics.

1 Introduction

Relevant problems of our era, such as food and water security, health (obesity, cancer, malnutrition, mental illness as depression etc.), poverty and hunger, inequality, climate change, natural resources, environment, disaster risks, epidemics, pandemics, etc. (Hernández et al., 2010, 2016; Thompson et al., 2017; Hernández and Dominguez, 2020) [1-4], cataloged as complex problems, require a change of perspective to generate knowledge and develop research processes. Since these problems cannot be solved from a discipline and likewise without interacting with the empirical and/or problem actors, and without getting involved with the decision makers. A worldwide proposal in the scientific community that has evolved and has been accepted by different research groups is to carry out the research process, under a transdisciplinary vision. One of the characteristics for the generation of knowledge in the mode “two”, published in 1994 by Gibbons et al. [5]; establishing a contract between Science and Society, proposing “socially robust” knowledge (Gibbons, 1999) [6]. This research mode is characterized by its orientation towards contextualized problems and results (Gibbons et al., 1997) [7], being a thoughtful and conscious way to rethink science; on the part of the investigators and the leaders of the investigation of the countries.

Rethinking science and its role in society has been repeatedly proposed, to take on the problems of humanity. Einstein, among other scientists, at the end of the Second World War, with the launch of atomic bombs (a result of the Manhattan project), rethought the role of scientists in society [8, 9]. In this sense, Einstein (1946) [10] establishes a campaign to renew the way of thinking after of the disaster of the War: “The world that we have created today as a result of our thinking has problems; which cannot be solved by thinking in the same way what we thought when we created them”.

In this way, the Atomic Scientists Emergency Committee (generally called the Einstein Committee) is formed: Albert Einstein (1879-1955), Harold Urey (1893-1981), Linus Pauling (1901-1994), among others participated in the committee [11]. It is an organization that has within its objectives to educate the American people about the nature of nuclear weapons and nuclear war. The educational campaign in society was carried out for five years. In this way for a long period of time, “Peace was an important agenda for many scientists”. “Einstein before his death in 1955; signs the Russell-Einstein Manifesto, a call by scientists (including Linus Pauling) for world peace and the abolition of war [12, 13]”. At the death of Einstein, Ludwig Philipp Albert Schweitzer (1875-1965), continued this call against arms and nuclear tests by giving lectures on it. He said: “Man has lost his ability to foresee and anticipate, he will end up destroying the earth”. However, atomic experiments were resumed in 1962, again insisting in the scientific community a call to the conscience of men of good will that there was no justification for maintaining radioactive contamination on Earth [14,15]. Among others, Schweitzer, Bertrand Russel, Martín Niemöller, Robert Jung, prominent scientists and humanists, write the manifesto entitled “Atomic experiments do not contribute to peace” [16].

At this time in the post-war science another problem arises due to the use of DDT first synthesized by Othmar Zeidler (1850-1911) [Gamboa, 2014] [17,18] and patented in 1939 by Paul Hermann Müller (1899-1965), who was even awarded the Nobel Prize latter in 1948 (Escobar, 2008; Extremera, 2018) [19, 20]. At the beginning of the discovery and its application in World War II to protect the military troops in the Philippines, Japan and Italy from attack by insects [17], it achieved great global impact. In 1944, in Naples it was possible to control a typhus epidemic caused by pediculosis, also in 1945 in Japan. Moreover, also, by the DDT, it was possible to end with lice transmitting typhoid fever and it was also used to control malaria, yellow fever, etc. (Raju, 1999) [21]. Many years it was commercialized and enjoyed its benefits, mainly for productivity in agriculture and to foresee diseases such as malaria [Torres and López, 2007] [22]. However, in the 1960s, Rachel Carson (1907-1964) observed a phenomenon what others did not see to date, since DDT had a negative impact on the environment. What had been considered a safe and effective low-toxic pesticide had an unwanted side effect: “it killed birds” (Carson, 1962) [23]. The modern environmental movement begins with her, in fact, she considers herself the mother of this movement. DDT has a great environmental impact also on people, even studies by Cohn et al (2007) [24] have confirmed in recent years the relationship between DDT and different types of cancer, such as breast cancer, from which Carson died in 1964 (Seager, 2003) [25].

Other scientists in this postwar era addressed societal problems, such as cancer disease. Otto Heinrich Warburg (1883-1970) discovered the cause and prevention of this disease, attributing its existence to acid and without oxygenation environments (Warburg, 1969; Leandro, 2019) [26, 27]. Joanna Budwig (1908-2003) studies the positive effects of omega 3 fatty acids, finding that they could limit cancer, not just dementia and depression (Budwig, 1992;1996) [28, 29]. Linus Pauling linked prevention of the cancer and heavy doses of vitamin C; he was convinced that the correct administration of vitamin C in the population would decrease the incidence of diseases of any etiology by at least 50%, since its deficiency is the one that causes greater pathologies on the human organism (Pauling, 1971) [30]. Other scientists have investigated more about cancer, such as Max Gerson (1881 - 1959), who proposed the cure of cancer could be through nutrition and detoxification (Gerson, 1958; 1978) [31, 32], and Catherine Kousmine (1904-1992) who affirmed that after the second world war food changed from being agro-livestock to industrial; with the respective great degenerative consequences of civilization, among others cancer (Kousmine, 1959) [33]. Although it is true in her time the proposals were not materialized, over time information has been generated where most of them have been demonstrated; being clear the vision and observation of geniuses of that post-war era, as well as their interest in studying the problems of humanity, in this case in various diseases.

On the other hand, to mention some other scientists of the time, there are the cases of those who dedicated themselves to proposing solutions to the food problem: production and nutrition. Norman Ernest Borlaug (1914-2009), known as “the man who saved a billion lives”, proposed the use of hybrid seeds to increase agricultural production in poor countries and he succeeded among others in Mexico, India, Pakistan, Turkey, and Africa [34, 35]. This led to self-sufficiency in wheat production in Mexico in 1956. Another scientist sought a peace centered on the idea of “freeing himself from need”: pointing out the importance of the population having their food, this being the priority need. John Boyd Orr (1880-1971) emphasized the importance of children’s growing nutrition and health [36, 37]. Before and now it is still a problem for many of the countries, the quantity and quality of foods [38] that in excess produce diverse diseases such as obesity and diabetes, or in deficiency produce malnutrition or anemia, among other diseases. These are the problem problems of our times, marking the need for research that contemplates educating society and adapts to its contextual characteristics. A solution for the world problems, many times cannot be generalized, so it must be adapted to the context of the application. These and other problems, such as climate change that was mentioned in the 1960s and is associated with human activities in 1970 [39, 40], are evidence of the need to investigate closer to society. All these disciplines reported added to an incredible increase in disciplines and sub-disciplines educative/scientific in the year 1250, there were 7, in 1950 there were 54 disciplines. But for 1975 - Higher education statistics Agency of UK-registry 1845 disciplines and 10 years ago (2010) the National Science Foundation archives of the USA pointed out the existence of more than 8000 scientific disciplines and sub-disciplines [41]. It causes an increasingly fragmentation of science, which in turn also leads to a greater need to complement knowledge of some disciplines with others, to propose solutions to contextualized problems, since in isolation it is impossible. The scientific community faces the need to propose systemic solution proposals for sustainable development to the world’s problems, i.e. a type of development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Komiya and Takeuchi, 2006) [42]. So, today’s researchers cannot stay permanently in laboratories or cubicles: it is necessary to study the problems of the world, leave laboratories, get closer to society, know the problems and after, return to their workplace. It is necessary to know the problems and propose solutions. For his part, Karl R. Popper (1902-1994), the philosopher of science, was convinced that “We do not study issues, but problems; and problems can cross the boundaries of any object of study or discipline. We are students of problems, not disciplines” [43, 44]. The problems are studied, the origin, their causes, the problems are looked for and the solutions are proposed, the way to know them better, is get closer to them. This implies the paradigm shift of doing science in decision makers of institutes, research centers, governments, and current and future researchers themselves.

In this sense, Funtowicz and Jerry Ravetz (1991) [45] pointed out the need for a science in the context of complexity, a new scientific methodology to tackle global environmental problems. Where the task is from an extended community, not individual experts. Turning the scientific system into inputs for new

ways of deciding politics and governance (Funtowicz and Ravetz, 1996) [46]. Then, the science would be support to decision making where the uncertainties of the systems and the risks of the decisions are considered. This implies a change in the scientific paradigm; for which today it is even more understood in the face of the challenging and complex problems of our times by having a globalized world.

In this way, despite the increasing awareness of how favorable a Transdisciplinary approach can be, as stated by Gaihre et al., 2019) [47] and demonstrated by the increase in studies reported in the scientific literature introducing this perspective in the research process [48]. It is still necessary to learn from this vision and train new researchers fulfilling the characteristic features of this perspective. And not only to researchers in training, research institutions and governments, society, civil, etc.

Thus, the objective of the present document is to share a literature review about, the evolution of term and characteristic features of transdisciplinarity; as it could be the way to investigate in the near future in Latin American countries or between countries of different regions of the world; with societies characterized by their respective contexts: social, economic, educational, health, age, physical, climatic variables, ecological, geographic location, cultural, political, etc.

2 Pre-Transdisciplinarity

The term transdisciplinarity, for some authors, was introduced in 1970 [49-53], although the notion of the term was found earlier according to Ramadier (2004) [50]. The various benefits that science could have towards society, was glimpsed by various scientists such as Bacon, Bernard, Einstein and Bohr among many others. Einstein already expressed concern that man would evolve towards different holistic levels and feel compassion for others and the other (beings and nature). Bacon defended the collaboration between scientists for the progress of science and its orientation in a good to society, according cited by Hadorn et al. (2008) [54]. Bohr, dedicated part of his life to convince to his colleagues of the need to use the findings of nuclear physics for useful and beneficial purposes to man; the latter scientist was recognized as the one who had the notion of transdisciplinarity before the term Ramadier appeared (2004) [50].

One of the main characteristics of transdisciplinarity is to investigate for and with the communities, but this vision is found before the appearance of the term. Kurt Lewin (1890-1947), the father of action-research (A-R), since he started this type of investigation in 1944, although some authors indicate that it began 10 years before (Lewin, 1944;1946; Miguélez et al., 2000) [55-57]. Regarding this research mode, close to the community, two aspects were identified: the sociological dimension, represented by Lewin and the educational dimension by Paulo Freire (1921-1997), where the problematic actors became participants and co-responsible in solving their own problems. Sol Tax (1907-1995) was another promoter of this type of action research (Rahman and Borda, 1992) [58]. In this sense, research for society and with society (Scholz, 2000a; 2020) [59-60], is practiced since before the introduction of the term. The problems to be tackled were born from the community that lives them. Likewise, the researchers had to propose dialogue strategies with the community, where changes in society and academia are required.

The changes in people, their transformation, which is another characteristic of transdisciplinarity, has also been proposed for many years, before Christ and after Christ. In the 19th century, various thinkers, mystics, spirituals, alchemists proposed walking towards the self-observation, the reflection, the internalization of man, self-inquiry, self-knowledge, etc. [61-64]; in general, to lead to the knowledge of man for the evolution and their transformation. It is worth mentioning the famous aphorism of the Greek sages in the time before Christ: "Know thyself". Marco Aurelio (121-180 AD), stoic philosopher [65]: he reflected on the matter of "Looking within oneself". Since inside is the source of good, and it will come back, if you keep digging. In addition, for expanding the mind, he stressed the importance of systematically and really investigating everything that is observable in life. Polymaths like Leonardo Da Vinci (1452-1519) - (Scientist, painter, mechanical engineer, sculptor, thinker, city planner, storyteller, musician, architect) [66] claimed to transform oneself to transform, obstinate rigor. Some spoke of transformation towards virtue, e.g. Newton (1642-1727) recognized the virtue of having patience more than other talent for the development of his discoveries. In the case of Benjamin Franklin (1706-1790), visualized cultivate virtues, proposing the

development of thirteen virtues, among which are: silence, order, determination, temperance, tranquility, humility, etc. Goethe pointed-out that science involves capacities of observation and thought, but also human faculties that can resonate with the spiritual dimension (Max-Neef, 2016) [67]. The empathy that must exist in research is highlighted by Claude Bernard who rejects research without feeling; as well as proposing that study the phenomena of life in the context in which they develop (De Romo, 2007) [68]. In this sense, from before the origin of the term there was already talked about contextualizing the research, i.e., having a problem or a need focused on space and place and putting it in relation to its environment and at different holistic levels and different dimensions and behavior over time; visualizing the problem in its multivariable dimension. On the one hand and on the other the importance of knowing the himself and the researcher's need to develop virtues.

Many other characteristics have been reflected on and sought throughout the history of the production of knowledge, e.g. the unity of science. It is worth mentioning a world-famous phrase from Plato (427-347 b.c), in the Phaedrus dialogue (cited in Miguélez, 2011) [69]: *"If I find someone capable of seeing things in their multiplicity and, at the same time, in their unity, that is the man I look for as a god"*. The unity that implies reconciling and yielding, which then implies humility and many times accepting one's ignorance in certain knowledge, is a process to live, to learn to integrate as an act to unite and link parts that form a whole, one of the bases of transdisciplinarity.

This is clearly reflected in the Systems General Theory (SGT), in the 50's years, which since its creation promotes the integration of disciplines (Bertalanffy, 1986) [70]. With the creation of the "Society for Systems General Theory" (Bertalanffy, 1954; see Cuadrado, 1995) [71], a research program is established, which within its principles was "to promote the unity of science by improving communication between specialists". It is one of the challenges of transdisciplinarity today. Where the language that is used is relevant, such as behaving with the other, with a different culture, a different country, a different level of knowledge, different interests, etc. So, a change in attitude of the scientist (now more commonly called researcher) was established. Schrödinger (1887-1961) [72] stressed that the scientific attitude must be rebuilt; science must be redone again.

In the 1960s, at the beginning, the United Nations for Development reflected on the development process, stating "development not only refers to the material needs of man but to the improvement of social living conditions and to his noblest aspirations. Development is not only economic growth; it is growth added to evolution" (ONU, 1960) [73]. A possible evolution of the man who was, is and will be necessary for his own survival.

3 Origin and 1st Stage of Development

For Miller (2008) [74], the origin of transdisciplinarity goes back to the 50s, after the 2nd. World War at the same time as the SGT. Others like Groß y Stauffacher (2014) [75] indicated the beginnings of the TD debate in 1969, when the UNESCO meeting was held in Genova, Italy. The vast majority of authors point, in general, to 1970 as the year in which the term is introduced in France (Ramadier, 2004; McGregor, 2007; Jahn, 2008; Cronin, 2008; Basarab, 2010;2014; Sholz and Steiner, 2015a) [50,51, 76-80] and there is talk about it in the United States (Bernstein, 2015) [52]. Coinciding precisely with the international year of education (Maheu, 1970) [81]. On the one hand, in Nice, France is recognized to Jean Piaget (1896-1980) as who introduced the term during the Conference titled "interdisciplinarity, problems of teaching and education in universities" (Jahn, 2012) [82].

André Lichnerowicz (1915-1998) and Jantsch (1929-1980), French mathematician and Austrian astrophysicist, respectively; related the term with the logic and set theory and education and planning issues. Jantsch defines it as the synthesis of disciplines, overcoming the multidisciplinary and interdisciplinarity (Miller, 2008; Nicolescu, 2010) [74, 78]. Jantsch (1970) [83] visualized social need as the creative force to direct, shape and organize education and research. He suggested a transdisciplinary university including systems design laboratories powered by disciplines, and departments oriented to build capacity for self-renewal of societies (Jantsch, 1970; 1972; Sholz and Steiner, 2015b; Osborne, 2015) [83-86]. In this way

initially, some associate the term of transdisciplinarity with the application of SGT in the educational policy (Osborne, 2015) [86].

On the other hand, in the same year of 1970, as reported by Bernstein (2015) [52], in the United States, Jack Lee Mahan (1970) discuss about TD, incorporating ethical and humanistic considerations in this transdisciplinary approach to research. Highlighting the “reverence for life, man and the human condition”. He proposes transdisciplinary research would be characterized among other aspects by a) the transcendence of disciplinary limits, b) attention to the context of the research, c) respect to the life and dignity of the human being, and d) applying knowledge to the improvement of society. In this sense, the origin of the term transdisciplinarity is found in Europe and America. It is worth mentioning that at the same time of the 70s, when the processes of environmental deterioration and degradation of the Earth become evident, Gaylord Nelson, (1970) [87], calls for awareness to protect the Earth and the life that the habitat, a message that transcended the ONU worldwide, an organization that, in 1971, decrees World Earth Day and begins a series of actions in this same consciousness.

At the end of the 70s, Kockelmans (1979a;1979b) [88, 89], distinguished the transdisciplinary approach as the unit of science. The author proposes to be continually “provoked” through reflection, where it is required to do the task for everyone, not only for disciplinary philosophers, in a critical attitude. A critical attitude that implies participation, this is various actions on everyone’s part. It is necessary to integrate in the research process scientists representing various disciplines, as well as other representatives outside the scientific field, the users or actors of the problem. Transdisciplinarity could then be a scientific and non-scientific work, with the intention of overcoming the negative effects of specialization. In education and research, it would be a matter of both being relevant to society.

Mittelstrass (2011) [90], self-recognizes who introduced the concept into philosophy in 1987; same year in which the CIRET (International Center for Transdisciplinary Studies) opens in Paris, France. Already previously in 1973 another Center for trans-disciplinary studies had been opened, the first of its kind, directed among others by Edgar Morín (Ramadier, 2004) [50].

4 Transdisciplinarity in the Decade of the 90s

Despite the date on which the term TD is introduced, and it reflects on the need for another way to investigate to participate in the world’s problems. It is in the 90s; after the environmental crisis started in the 70s and later aggravated in the 80s added to other world crises. Almost 25 years after those initial ideas of TD (Scholz and Steiner, 2015b) [85], when the approach to research is resumed and it could be considered it begins to take impulse; it could be said that a first evolution of the term begins to take place to produce knowledge and mainly it is moved towards its application.

In 1991, the Swiss Environmental Priority Program began, and projects were asked to go under transdisciplinary research (Scholz, 2020) [60]. In 1992, Mittelstraß [91], asked the scientific community to reconnect research with real-world problems, transcending disciplinary limits (Hoffmann et al., 2017) [92]. It is even necessary to reconnect different disciplines, different knowledge (scientific and empirical), etc. Even within the same discipline, within the same institute, “stop rowing” each one on their own. Focus everyone in the same direction to get ahead, in the face of problems that sometimes they are even survival. Paraphrasing Brewer (1999) [52-93], “The world has problems, but universities have departments” (Cronin, 2008; Pohl, 2011) [77, 94]. Department sometimes without orientation, each walking in unknown directions, even the researchers that make up each department. For this reason, is primordial the oriented research. Where the institutes have the country’s problems, in common agreement with the governments; so each one is assigned complementary tasks according to their specialties, but integrating and complementing each other, to this way redirect the course of the investigation. This process is based on current and future anticipated needs in the real world. According to the literature review and the context of the time, it was apparently the great impetus given to this vision with the contribution published in 1994 by Gibbons et al. [5], whose contribution allowed them to rethink how to do science. It should be noted that it is the document from the introduction of the term of transdisciplinarity to date (within which they provide

definitions and characteristics), with the highest number of citations (according to Google academic, more than 10,000). Along with the contributions of Gibbons et al. (1994; 1997) [5,7] an important event is also highlighted, the World Congress of transdisciplinarity celebrated in a region of Portugal: Arrábida. According to McGregor (2015a) [95], in this event there were diverse assistants such as the president of the country, civil society, representatives of industry, government and academics; among which were Freitas, René Berger, Ubiratan D'ambrosio, Roberto Juarroz, Edgar Morín and Nicolescu Basarab, etc. who collaborated in the writing of the transdisciplinarity charter that was one of the results of this meeting (Anes et al., 1994) [96].

Basarab Nicolescu defines transdisciplinarity as a generalized transgression that opens a space for freedom, knowledge and love (Basarab, 1996) [97]. On the other hand, Julie Klein (1996) [98] defines transdisciplinarity as the perfect interdiscipline. In this decade begins to be mentioned, the need for a language and attitude of transdisciplinary [99]. The latter term being introduced by Roberto Juarroz, recognized by Basarab (Ramadier, 2004) [50].

The TD language allows a researcher to communicate with another of his own discipline, with another of a different discipline and with the problem actor, where a reflective thought of the investigator-subject is relevant. Subsequently, Gibbons (1997;1999) [6,7] in the second quinquennium of the 90s, continues to publish about Mode 2 to produce knowledge, where his article of 1999 stands out, at the journal "Nature", where it is incorporated the term "socially robust knowledge". He also proposes the need for science to establish a contract with society. Meanwhile, Basarab (1997) [100], proposes self-transformation, based on self-knowledge, for a new way of living. In this same year, was celebrated the International Congress in Locarno, Switzerland entitled: "The transdisciplinary evolution in the University", same that was organized by CIRET and UNESCO deriving from that event, Locarno's statement. An aspects established was the emergence of a new tolerance to achieve the exchange of knowledge. A new tolerance that allows the acceptance of differences, the acceptance of ignorance, the acceptance of the new and unknown, etc. The investigator would have to learn to deal tactfully to other disciplinary and non-disciplinary. Paraphrasing Newton: (1643–1727). "the tact is the ability to get to a point without making an enemy"

The following decade, from the year 2000, is marked by another trascendental event: The Transdisciplinarity Conference held in Zurich, where that conference could be considered another relevant event related to the evolution of the TD perspective.

5 Transdisciplinarity from 2000

Transdisciplinarity, at a conference held in Zurich was defined as: a manner of learning and solving problems with the cooperation of society and academy to face the challenges of the societies. According to Klein et al. (2001a) [49], some participants who stand out in this event are Michael Gibbons, Helga Nowotny, Rudolf Hiiberli, Charles Kleiber, Rita Colwell, Thomas von Waldkirch, Roland Sholz, David Marks, Perrig-Chiello, Richard Ernst, Thomas Jahn, Christian Pohl and Julie Klein; the latter being the one who led the edition of the Event Report, entitled: "Transdisciplinarity: Joint solution of problems between science, technology and society. An effective way to manage complexity".

It should be noted that there were more than 220 contributions from various participants from different parts of the world such as India, Denmark, Nigeria, Holland, Spain, Indonesia, Germany, Russia, Italy, Austria, United States, Portugal, United Kingdom, Sweden, Belgium, Brazil, Ukraine, France, Bulgaria, Greece, Croatia, Ethiopia, Japan, China, Colombia, Slovenia, Israel and Switzerland, among others. In this way, the transdisciplinarity perspective in research is increased. At the initiative of the Swiss academies of arts and sciences, the "Network for transdisciplinary research (td-net)" was opened at congress of Zurich (Td-net, 2020) [101].

In the year 2000 the Academy of Transdisciplinary Learning & Advanced Studies (ATLAS) was created by Dr. Atila Ertas, to serve universities around the world. Dr. Atila Ertas, Dr. George Kozmetsky and Dr. Raymond T. Yeh were the co-founders of ATLAS (ATLAS, 2020) [102]. Association affiliated to the Transdisciplinarity Journal of Engineering & Science (TJES), which is dedicated to Professor John Nelson

Warfield (father of systems science) by his transdisciplinary knowledge and culture of peace. It should be noted that the first article written by Julie Klein (2010) [103] in the (TJES) [104] is dedicated to Professor John Nelson Warfield memory. The journal's edition has represented another boost in the growing adoption of perspective to investigate in the world's universities. It started with 10 articles published and last year it reached double (20 articles), having a multiplier effect through its more than 350 cite and 122 articles to the current date. Researchers from various countries have published in this journal.

Contributions by Christian Pohl (2010) [105] and Lawrence (2010) [106], have been the most cited in the TJES with 81 and 76 citations, respectively. Pohl, among other aspects, reaffirms the characteristics and challenges of transdisciplinarity and Lawrence revises the ambiguity of the term, synthesizing some characteristics which some authors have given. Furthermore, publications by Dr. Basarab Nicolescu, author of the Transdisciplinary methodology, stand out (2010; 2011;2012;2016) [78, 107-109].

Basarab (2010) [78] defends within the etymological meaning of transdisciplinarity the “beyond the disciplines”, where the social field introduces that dimension, but the individual human being and his spiritual dimension should not be left aside. As well as, the scientific spirit, which is the center of TD; the transdisciplinary methodology and the scientific method complement each other.

In the interview with Basarab (2011) [107] by Professor Augusta Thereza de Alvarenga (University of Sao Paulo, Brazil), Basarab highlighted the importance of the various international conferences: previous (Conference of Venice “Science and the Boundaries of Knowledge”, in 1986; Congress “Science and tradition: Transdisciplinary Prospects for the 21st Century”, Paris, in 1991) and later (International Congress of Transdisciplinarity “Which University for tomorrow?”, Locarno in 1997, Second World Congress of transdisciplinarity, Vitória, Brazil, in 2005), to the first world congress in 1994; because these have contributed to the emergence of transdisciplinarity, from the emergence of a community until the already formed community, and have subsequently contributed to the training of educators and students.

These events and contributions from the beginning of the decade of 2000s and the end of the 90s, perhaps have been, among others, the most relevant for the creation of a transdisciplinary culture in the world. Adding to the passage of time more researchers convinced of the paradigm shift to investigate.

Of this manner, in a review by Kueffer et al. (2007) [110] in the “web of science”, indicate that the quantity of articles with the word transdisciplinarity has increased over time. The authors analyzed articles from 1970-2000; where the number of publications per year was increasing over time. They reported a significant increase since 2000; highlighting the publications in the years 2004 and 2005, where 60 and 70 articles published were reached, respectively. Some of the journals that have published transdisciplinary research particularly in the area of environmental sciences, according to the authors are: *Communication, Cooperation, Participation; EcoHealth, Ecological Economics, Ecology and Society, Society Futures, Nature + Culture, International Journal of Transdisciplinary Research, Journal of Transdisciplinary Environmental Studies, Ecology and Society, Environmental Sciences: Journal of Integrative Environmental Research, Bulletin Interactif du CIRET, co-design*, etc. Zscheischler and Rogga (2015) [48] in another literature review consulting the databases of “ISI Web of Knowledge” and “Scopus” they also point to the increase in publications in the area of sustainability with a transdisciplinary approach since 2000. The acceptance of the scientific community in this area is appreciated in this article, mentioning 217 different provenances which carried out a TD-RP. Presenting a great evolution of the Transdisciplinary perspective towards its application. Other relevant events are included in the year 2004; the special publication of the subject about transdisciplinarity in the English Journal “Futures” with a total of eight publications by different authors and nationalities: Lawrence and Després (Switzerland and Canada), Balsiger (Germany), Ramadier (France), Jones and Sime (United Kingdom and United States), Bruce et al., (United Kingdom), Pinson (France) and ending with Klein (United States).

In this sense, the transdisciplinarity, has undergone an increasingly integrative practical evolution (Espina et al., 2004) [111], increasingly systemic thought, which do see to the world of a different way (Max-Neef, 2005) [112]. Among other requirements for a TD-RP is the collaboration between disciplines and participatory research (Pohl and Hadorn, 2007) [113]. For this there are among others, some requirements such as a transdisciplinary training of new researchers and therefore transdisciplinary trainers of future researchers are necessary. In the declaration of the 2nd World Congress of Transdisciplinarity held in

Vitória, Brazil (2005); it is pointed out that the action TD, articulates the relationship with the world (eco-formation), the relationship with the other (hetero and co-formation), the relationship with oneself (self-formation) and relationships with the being (onto-formation) (Espinosa, 2005) [114]: being one of the urgent actions proposed by Nicolescu: Transdisciplinary education, i.e. influence the training of transdisciplinary researchers; representing this one of the great current and future challenges.

Complying with the characteristic features requires knowing-self-investigating and self-transforming. In this sense, Jahn et al. (2012) [82] points out others characteristic features in the research TD, this is: a) critical, b) self-reflective, and c) relates society and scientific problems. Transdisciplinary approaches for Méndez (2013) [115], could include academic scientific disciplines, as well as different knowledge systems (e.g. empirical experience, local knowledge, indigenous knowledge, etc.) aimed at solving problems. Groß and Stauffacher (2014) [75] reported that the type of knowledge generated not only discovers laws, but also is to provide solutions to socially relevant problems. For this, heterogeneous groups are formed to produce scientific knowledge.

Then it leads to solving problems present in the real world. For which, as Miller (2008) [74] mentions, transdisciplinary research requires a social responsibility. Social responsibility implies an important individual and introspective work because it implies being responsible for the other. Paraphrasing Emmanuel Lévinas (1905- 1995) “When I see you, I feel intrinsically responsible for you”, implying seeing beyond ourselves (Jiménez, 2017; Martos, 2011) [116, 117]. Therefore, as McGregor (2004) [118] indicates, whoever wants to adopt a TD approach should consider profound internal changes which could lead to, according to Max-Neef (2005) [67], to a different way of seeing the world that could represent a challenge as pointed out by Pohl (2010) [105].

Pohl (2010) [105] distinguishes mainly three challenges: 1) Structuring the problem together, 2) integration of participants group and 3) intervention in society. Structuring the problem together is one of the challenges, using methods that allow having the different views of the problem of the different participants of the research project, who will act, interrelationships between the participants, dialogue methods, the joint formulation of hypotheses, etc. They are aspects considered and carrying it out represents a challenge in the practice of transdisciplinarity. Another challenge that he analyzes is the integration, how to reconcile points of view between scientists and non-scientists, that is a real challenge, to establish the problem together, to define the hypothesis, from different value systems and ideas and beliefs, to reach integrate and reconcile academic research and experience. The third challenge of Transdisciplinarity is to successfully carry out the results, which implies reaching intervention in society. Projects could then take years to reach implementation. The stages of the project are to communicate results to civil society, the private and public sectors, but now it is to implement the solution proposal. Then you enter a cybernetic, recursive process, planning research, establishing it, developing solutions, implementing, verifying the impact on society, learning, analyzing, reformulating problems, new research questions, etc. and so on, a process that can take years, even decades.

It is for this reason that to overcome the challenges in the practice of transdisciplinary research, a different intelligence is proposed by the participants and constant introspective work, for strengthen the spiritual dimension.

Ubitaran D’Ambrosio who participated in the elaboration of the transdisciplinarity charter (1996) [119] notes that to face the complexity of the world and its self-destruction of the species, an intelligence is required that visualizes the planetary dimension, among others. Additionally, it mentions that an ethic is required where to change is necessary: from competition to cooperation, from separation to human interconnection, from dependence to human interdependence, from fear to love and from individualism to altruism (D’Ambrosio, 2014) [120]. In this way, there is a need for deep transformations in the investigator subject that longs to be a TD researcher, requiring in it, a training that allows to become aware of that need for self-investigation for its self-transformation, where critical Self-knowledge is essential. From where knowledge could be co-constructed as co-creators of transdisciplinary knowledge (Iván Illich, 1976; see, Vargas, 2015) [121]. The leaders of transdisciplinary research have to develop certain capabilities noted Hoffmann et al. (2017) [92]. Among which stand out: a) integrative vision, b) skills for intellectual between-disciplinary exchange between disciplinary, c) project planning, evaluate, monitoring, etc., d)

reconcile multiple interests and possible conflicts, etc. In such a way, the role of the scientist takes wide relevance and transcendence. Wiek (2007) [122] reflects that the role of the scientist as an epistemological mediator between science and practice must be reconfigured. As well as reconsidering the role of the scientist as a figure to create a culture of peace, which for D'Ambrosio (2011) [123] covers four dimensions: military, environmental, social and individual peace, this being the most universal problem facing humanity (De Holanda and Medeiros, 2014) [124].

Pohl (2010) [64] pointed out several characteristics of TD, among which he highlights: 1) develop knowledge and carry out practices for the common good, 2) adopt a comprehensive, multi-perspective approach, 3) tackle problems and solutions transgressing scientific disciplines, etc. Then, the spirit of transdisciplinarity is to develop research to serve society, i.e. with mainly social sense. The perspective of transdisciplinary research would be focused on the common good (Enengel, 2012) [125].

In this way, the borders of the researchers, of the disciplines and of the specific problems themselves are transcended, seeing a complex and interconnected whole, where the unity of sciences and consciences is invited. Stokols et al. (2003) [126] suggests caution in the use of terms: transdisciplinary collaboration and transdisciplinarity to do science (TD science), because they are not synonyms. Doing science under the transdisciplinary approach is not to form coalitions involving collaborations, whose mission is for example to promote improvements in health, educational or economic conditions. Transdisciplinary collaborations aim to generate intellectual results that are their hallmark; carry out scientific research activities and generate knowledge.

Transdisciplinarity according to Klein (2001b) [127] does not begin in a specific discipline. If not, it is based on a practical problem (Hult, 2010) [128], which seeks the generation of practice-oriented solutions and their dissemination among the target population (Bergmann et al., 2005) [129]. Others authors Jahn (2003) [130] retake what was pointed out by Krott (2002) [131], indicating that the specific added value of a research project TD does not stop with the explanation of the world, but even intervenes directly in the problem or situation. In order to persist, in the intervention of the problem situation, collaboration with different disciplines, collaboration with the different actors in the problem, etc., a constant openness to change is required. Then, it will be essential for researchers and participants to continually transition mutual and transformational learning, as recommended by Mitchell et al. (2015) [132]. One of the challenges that the Transdisciplinary group faces, among many others, is to stay in unity. Starting from the differences that may exist between everyone, maintain unity and learn to agree with the other, hence the importance of continuous self-transformation. To learn to listen and not impose, etc. The members of the research project (TD) from the beginning to enter of manner individual, must be aware that it must self-transgressed, causing continuous change through self-evaluation. On the other hand, research assessment permanently is also proposed by some authors for quality assurance in the RP-TD (Balsiger and Kötter, 2005) [133].

In summary, it is possible to observe in Table 1 (see Appendix), a list that integrates some definitions and characteristic features of transdisciplinarity. A perspective to address the research in these poly-critical times, where the challenges will be to make it operable according to the contexts of the various countries and consciences of scientists and extra-scientists involved.

The trainers of future generations have various challenges in the process of researchers training, which must be transformed in order to re-educate towards a transdisciplinary perspective. The trainer must live and teach to live alongside the research process, self-research, self-knowledge due to that is useful for self-transformation. Being this basic aspect in compliance with the characteristic features of a TD research process, as shown in Figure 1, column 2.

According to the reviewed literature, Figure 2 shows by decades the behavior of the number of authors, citations of contributions and number of papers in the last fifty years. It is possible to observe in Figure 2a, how the number of authors by paper in average has been increasing over time. Starting in the 70s and 80s with a single author and the average number of authors in the last decades has increased to almost three authors. It is worth mentioning that there were articles from this literature review with 20 and 14 authors such as Axelsson et al. (2013) [121] and Benesh et al. (2015) [125], being a trend of increasing number of authors in scientific contributions from a transdisciplinary perspective.

Regarding the number of citations of contributions per decade (Fig 2b), it was found that the decade

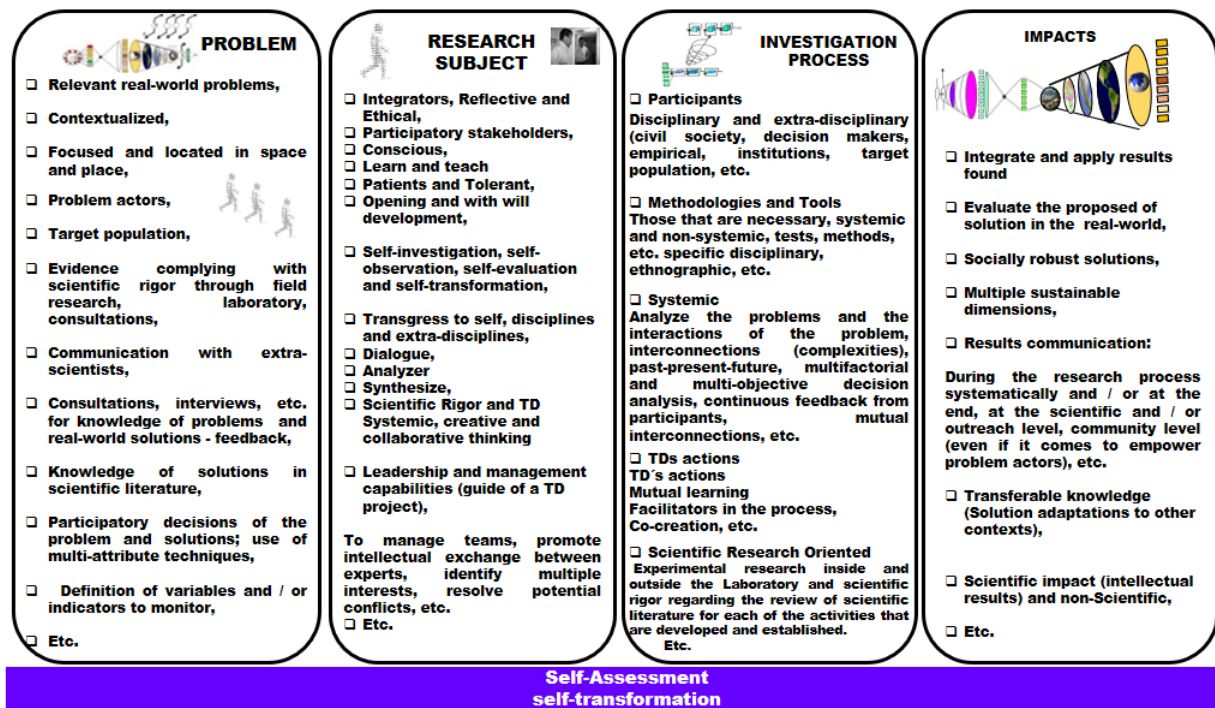


Figure 1: Characteristic features of transdisciplinarity.

of the 1990s had the greatest impact. This is also evidenced by the number of papers, which have been increasing from decade to decade, increasing by more than 100% with respect to the beginnings of transdisciplinarity (Figure 2c). Among the papers reviewed, the most cited by decade are observed in Table 2 (see in Appendix). It is possible to observe that since the appearance of the term transdisciplinarity until today, the ones that have been most cited are the contributions of Gibbons et al. (1994), Klein (1996), Gibbons (1999), Max-Neef (2005) and Hadorn et al. (2008) [5, 57, 6, 72, 54].

Figure 3a shows the number of authors from each country who have contributed to this perspective according to the literature review carried out. Finding that the countries with the highest number of authors who have researched and promoted this perspective are mainly Switzerland, USA, Germany, Austria, Sweden, France and UK.

The transdisciplinary perspective in these critical times of COVID-19, can be a support to approach the investigation, in diverse aspects, from the integration of diverse investigators coming from different disciplines, from the sustainable results that can be offered, from the participants and their spiritual dimension that they would have to work on and in this way decide in a transdisciplinary systemic way and especially today in training researchers (Figure 4).

In such, a way that addressing the problems that are experienced require the proposal of solutions from different scientists in collaboration with those who experience the problems; as the findings occur, sensitizing and re-educating the population is necessary. Hence, the importance of another perspective to investigate, where contemplating re-education and awareness of society would be relevant. It might be up to the scientific community, in part, to teach and work with society. This would be of great impact and would allow the transformation and evolution of societies and not involution.

Our students, and future Transdisciplinary researchers: The advantage they would have is that they could have developed the necessary resilience in these difficult times, which will help them not to fall into mental problems, to avoid problems of anguish, depression, loneliness, etc. These are difficult times, the transition to a new era, but you must maintain hope to be part of the reconstruction of a better world

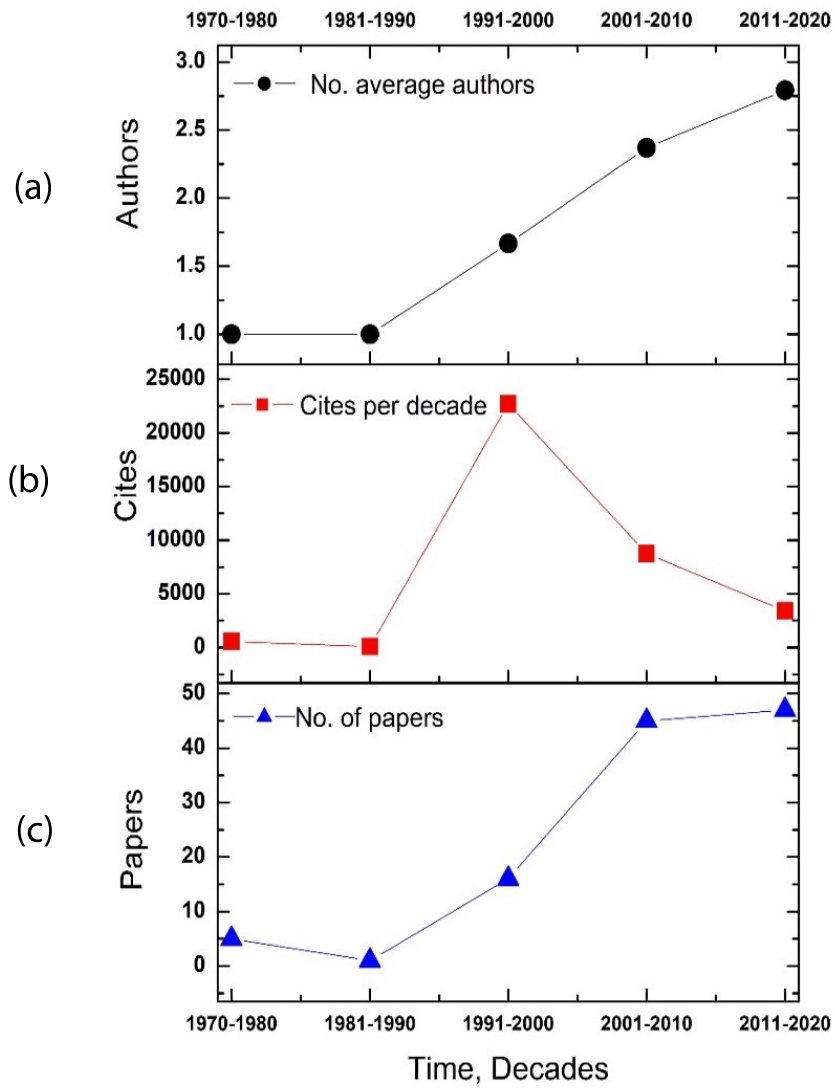


Figure 2: Contributions to the term and/or to characteristic features of Transdisciplinarity in the last 50 years (1970-2020), according to the literature review carried out: a) Average number of authors per paper, b) Total number of citations per decade c) Publications per decade.

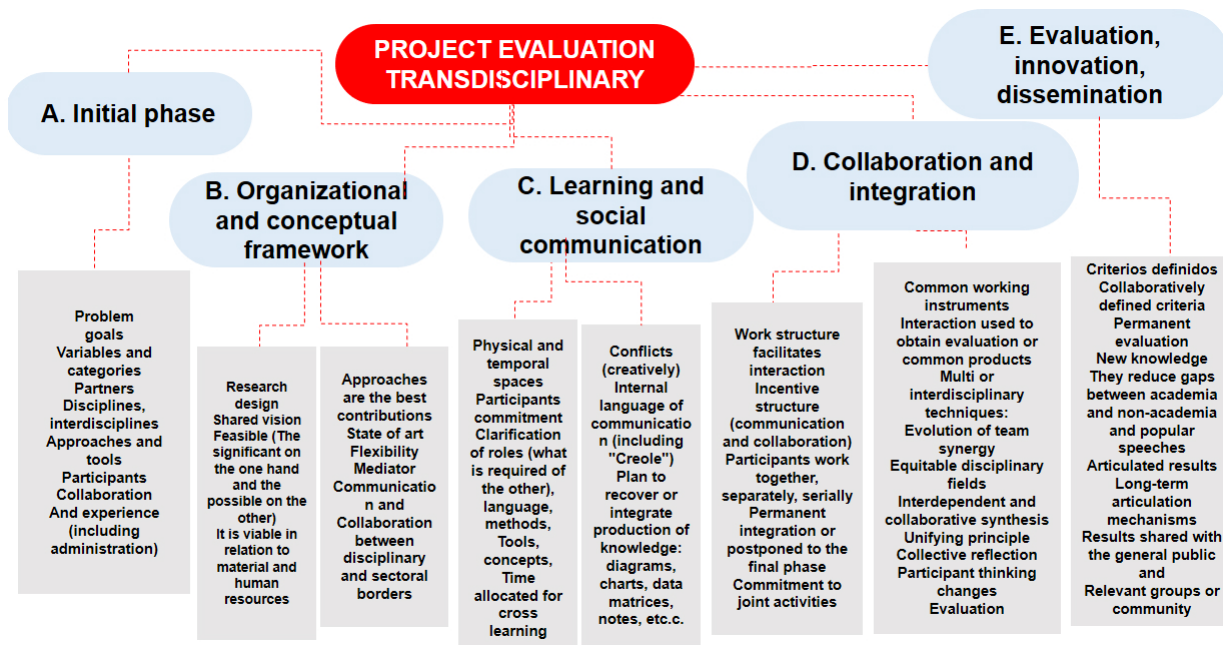


Figure 5: Transdisciplinary projects evaluation according to Klein (2004) [111].

and to reconstruct new ways of doing science and of being human in science and in the world. Adapting to the changes of the new life will be necessary, awakening consciousness and joining the actions aimed at reconstruction or resurrection. This will fulfill what Basarab (1996) [97] said: that Transdisciplinary researchers appear more and more as hope-makers.

As is known, evaluating a project is a strategy for continuous improvement. In this way, there are proposals to evaluate both the effectiveness of the collaborating team and the aspects to be covered in a transdisciplinary project [111, 184]. In the case of the evaluation of transdisciplinary projects, Klein (2004) [111] proposes a questionnaire of 47 questions divided into five categories: A) initial phase, B) organizational and conceptual framework, C) learning and social communication, D) collaboration and integration and E) evaluation, innovation and dissemination related to various aspects that can be observed in Figure 5.

Other basic guiding supports for the researcher are various methodologies that have been reported in the literature. Which are based on general phases to develop the research process (see, Table 3 in Appendix). Basically, they coincide in: 1) the need to collaboratively define and understand the problem (including its various actors), 2) the design and planning of the research process, with the participation of the actors in all phases and 3) Preparation of the research synthesis, conclusions, recommendations and communication of results in the scientific field and to the public.

Only one of the methodologies (Hernández, 2018) [177], addresses a phase to develop the self-investigation of the subjects who investigate that is necessary to carry out the research process and can serve to maintain integration and close collaboration. In addition to develop, among other dimensions, the spiritual one that is decisive in a research process of this type and finally achieve self-transformation as one progresses along the path of research, becoming more aware of oneself, the others and the other.

Finally we can say that knowing the history of transdisciplinarity, its evolution, its characteristic features, etc. could allow current and future generations to work to fulfill them and in this way co-participate in the survival of man and his world.

6 Conclusions

The transdisciplinary approach could represent the best pathway to develop research in Latin America countries to face the diverse problems of society. The main countries that have developed this approach and have marked some characteristic features are Switzerland, Germany, the United Kingdom, the United States, Canada, France, and some of Latin America such as Bolivia, Colombia, Brazil, Chile and Mexico; where they are performing Research under this perspective and move on in the fulfillment of characteristic features of it.

The approach is in evolution and as time passes, various characteristic features are added according to the experiences that researchers face in the practice of transdisciplinarity. It is a challenge for researchers today, above all to make individual changes that must be made that demand their self-investigation and self-transformation that allows their evolution as the research carried out evolves, also evolve each one of them.

There is increasing acceptance in the world scientific community, increasing the number of articles by more than 100% compared to the last century, but there must be a change in the policies of those responsible for making them, so that transdisciplinary research achieves its objective of intervene in systems and thus evolve societies and nations.

Transdisciplinarity presents an evolution that allows complementing its concept and its characteristic features over time.

Author Contributions: All authors contributed to this paper equally.

Funding: No funding was solicited for this research.

Conflicts of Interest: There are no conflicts of interest for this thought piece/research.

Acknowledgments

The authors are grateful for support from the IPN through the SIP, EDI and COFFA projects, and Conacyt. Hernández-Aguilar thanks students and postdoctoral students who have graduated from the research group (Sustainable biophysical systems applied to agriculture, food and medicine) for 13 years of walking through this perspective TD to investigate within the Graduate Program in Systems Engineering. In a special way, we thank the professors of the program in Systems Engineering (IPN-Mexico City): Efraín Martínez Ortiz, Ernesto Mercado Ramírez, Ignacio Peon Escalante, Luis Manuel Hernández Simon, etc. who have fought to preserve it and have allowed new generations find space to learn, develop and contribute. Special thanks also to the technical support in the various laboratories with which we have collaborated, mainly to Eng. Esther Ayala. Thank you all.

References

- [1] Hernández, A. C., Domínguez, P. A., Cruz O. A, Ivanov, R., Carballo, C. A., & Zepeda, B. R. (2010). Laser in agriculture. *Int. Agrophys*, 24(4), 407-422.
- [2] Hernández, A. C., Domínguez-Pacheco, A., Cruz-Orea, A., Podlešna, A., Ivanov, R., Carballo-Carballo, A., Pérez-Reyes, M. C., Sánchez-Hernández, G., Zepeda-Bautista, R., & López-Bonilla, J. L. (2016). Laser biostimulation in seeds and plants. *Gayana Botánica*, 73(1), 132-149.
- [3] Thompson, M. A., Owen, S., Lindsay, J. M., Leonard, G. S., & Cronin, S. J. (2017). Scientist and stakeholder perspectives of transdisciplinary research: Early attitudes, expectations, and tensions. *Environmental Science & Policy*, 74, 30-39.
- [4] Hernández-Aguilar, C., & Pacheco, F. D. (2020). Relationship of airports, population, competitiveness indexes and human development with confirmed and deceased cases by COVID-19: Need for transdisciplinary systemic decisions. *Transdisciplinary Journal of Engineering & Science*, (11) 91-102.

- [5] Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. Thousand Oaks, California: SAGE Publications,
- [6] Gibbons, M. (1999). Science's new social contract with society. *Nature*, (402), C81-C84.
- [7] Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1997). La nueva producción del conocimiento. *La dinámica de la ciencia y la investigación en las sociedades contemporáneas*. Ediciones pomares-corredor, Barcelona. ISBN:84-87682-28-6.
- [8] Einstein, A. (1941). The common language of science. *Advancement of Science* 2(5):109–110.
- [9] Bernstein, B. J. (1988). Four physicists and the bomb: The early years, 1945-1950. *Historical Studies in the Physical and Biological Sciences*, 18(2), 231-263.
- [10] Calaprice, A. (2010). *The Ultimate Quotable Einstein*, Edited by Alice Calaprice, Princeton University Press, Princeton, New Jersey.
- [11] Galison, P. L., Holton, G., & Schweber, S. S. (Eds.). (2018). *Einstein for the 21st century: His legacy in science, art, and modern culture*. Princeton University Press.
- [12] Ikeda, D. (2007). La restauración de las conexiones humanas: el primer paso hacia la paz global.
- [13] On, F. Y. (2012). The Russell-Einstein Manifesto.
- [14] Hahn, J. (1983). Albert Schweitzer O el respeto por la vida. *Huellas*, 10, 4-9.
- [15] Jack, H. A. (1988). Albert Schweitzer on nuclear war and peace.
- [16] Urdaneta-Carruyo, E. (2007). Albert Schweitzer. El hombre como símbolo. *Gaceta médica de México*, 143(2), 173-181.
- [17] Dash, A. P., Raghavendra, K., & Pillai, M. K. K. (2007). Resurrection of DDT: a critical appraisal. *Indian Journal of Medical Research*, 126(1), 1-4.
- [18] Gamboa, N. (2014). DDT, Una revisión histórica. *Revista de Química*, 28(1-2), 10-13.
- [19] Escobar, L. M. R. (2008). Nacimiento, vida y muerte del desarrollo: las semejanzas entre desarrollo y el DDT. In De la economía global al desarrollo local: El alcance de la intervención de los agentes de empleo y desarrollo local, 45-67. *Servei de Publicacions*.
- [20] Extremera, B. G. (2018). Alfred Nobel y la medicina. *Educación Médica*, 19, 211-219.
- [21] Raju, T. N. The Nobel chronicles. 1948: Paul Hermann Müller (1899-1965) [published correction appears in *Lancet* 1999 Jun 12;353(9169):2078]. *Lancet*. 1999;353(9159):1196.
- [22] Torres-Sánchez, L., & López-Carrillo, L. (2007). Efectos a la salud y exposición ap, p'-DDT yp, p'-DDE: el caso de México. *Ciencia & Saude Coletiva*, 12(1), 51-60.
- [23] Carson, R. "Silent Spring," *The New Yorker*, (June 30, 1962), 64.
- [24] Cohn, B. A., Wolff, M. S., Cirillo, P. M., & Sholtz, R. I. (2007). DDT and breast cancer in young women: new data on the significance of age at exposure. *Environmental health perspectives*, 115(10), 1406-1414.
- [25] Seager, J. (2003). Rachel Carson died of breast cancer: The coming of age of feminist environmentalism. *Signs: Journal of Women in Culture and Society*, 28(3), 945-972.
- [26] Warburg, O. H. (1969). The prime cause and prevention of cancer, 6-16. K. *Triltsch*.
- [27] Leandro, I. D. M. (2019). El Origen de las Enfermedades. *Revista Médica de Panamá-ISSN 2412-642X*, 38(2).
- [28] Budwig, D. (1992). Johanna. Flax Oil as a True Aid against Arthritis, Heart Infarction, Cancer and Other Diseases, *Vancouver, Canada: Apple Publishing*.
- [29] Budwig, J. (1996). Flax oil as a true aid against arthritis, heart infarction, cancer and other diseases. *Apple Publishing*.
- [30] Pauling, L. (1971). Vitamin C and the common cold. *Canadian Medical Association Journal*, 105(5), 448.
- [31] Gerson, M. (1958). A cancer therapy: results of fifty cases. Whittier Books.
- [32] Gerson, M. (1978). The cure of advanced cancer by diet therapy: a summary of 30 years of clinical experimentation. *Physiol Chem Phys*, 10(5), 449-464.

- [33] Kousmine, C., & Strojewski-Guex, M. A. U. R. I. C. E. (1959). Allergie et Cancer. *Allergy*, 14(3-4), 259-270.
- [34] Borlaug, N. E. (1968). Wheat breeding and its impact on world food supply. In *Third International Wheat Genetics Symposium* (pp. 1-36). CIMMYT.
- [35] Borlaug, N. E. (1971). *The green revolution, peace, and humanity* (No. B7615-R. CIMMYT).
- [36] Staples, A. L. (2003). To Win the Peace: The Food and Agriculture Organization, Sir John Boyd Orr, and the World Food Board Proposals. *Peace & Change*, 28(4), 495-523.
- [37] Orr, J. B. (1928). Milk Consumption And The Growth Of School-Children.: Preliminary Report on Tests to the Scottish Board of Health. *The Lancet*, 211(5448), 202-203.
- [38] Hernández-Aguilar, C., Domínguez-Pacheco, A., Cruz-Orea, A., & Ivanov, R. (2019). Photoacoustic spectroscopy in the optical characterization of foodstuff: A review. *Journal of Spectroscopy*, 1-34.
- [39] González Elizondo, M., Jurado Ybarra, E., González Elizondo, S., Aguirre Calderón, Ó. A., Jiménez Pérez, J., Cháidez, N., & de Jesús, J. (2003). Cambio climático mundial: origen y consecuencias. *Ciencia Uanl*, 6(3).
- [40] Martens, W. J. M., Slooff, R., & Jackson, E. K. (1998). El cambio climático, la salud humana y el desarrollo sostenible. *Revista Panamericana de Salud Pública*, 4, 100-105.
- [41] Mullally, G., Sage, C., & Byrne, E. (2016). Disciplines, perspectives and conversations. In *Transdisciplinary Perspectives on Transitions to Sustainability* (3-20). Routledge.
- [42] Komiyama, H., & Takeuchi, K. (2006). Sustainability science: building a new discipline.
- [43] Fernández-Ríos, L. (2010). Interdisciplinariedad en la construcción del conocimiento: Más allá de Bolonia. *Innovación educativa*, 20, 157-166.
- [44] Varela, L. A., Moreira, L. D. N., & Cruz, I. S. (2015). ¿Objeto y método de las Ciencias de la Información?: Algunos problemas de la cientificidad del campo.
- [45] Funtowicz, S. O., & Ravetz, J. R. (1991). A new scientific methodology for global environmental issues. *Ecological economics: The science and management of sustainability*, 10, 137.
- [46] Funtowicz, S., & Ravetz, J. (1996). La ciencia postnormal: la ciencia en el contexto de la complejidad. *Ecología política*, (12), 7-8.
- [47] Gaihre, S., Kyle, J., Semple, S., Smith, J., Marais, D., Subedi, M., & Morgan, H. (2019). Bridging barriers to advance multisector approaches to improve food security, nutrition and population health in Nepal: transdisciplinary perspectives. *BMC public health*, 19(1), 961.
- [48] Zscheischler, J., & Rogga, S. (2015). Transdisciplinarity in land use science—a review of concepts, empirical findings and current practices. *Futures*, 65, 28-44.
- [49] Klein, J. T., Grossenbacher-Mansuy, W., Häberli, R., Bill, A., Scholz, R.W., & Welti, M. (Eds.). (2001a). Transdisciplinarity: Joint problem solving among science, technology, and society: An effective way for managing complexity. *Birkhäuser*, Basel.
- [50] Ramadier, T. (2004). Transdisciplinarity and its challenges: the case of urban studies. *Futures*, 36(4), 423-439.
- [51] McGregor, S. L. (2007). Consumer scholarship and transdisciplinarity. *International Journal of Consumer Studies*, 31(5), 487-495.
- [52] Bernstein, J. H. (2015). Transdisciplinarity: A review of its origins, development, and current issues. *Journal of Research Practice*, 11(1), 1.
- [53] Scholz, R. W. (2017). The Normative Dimension in Transdisciplinarity, Transition Management, and Transformation Sciences: New Roles of Science and Universities in Sustainable Transitioning. *Sustainability*, 9(6), 991.
- [54] Hadorn, G. H., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., & Zemp, E. (2008). Handbook of transdisciplinary research. *Philadelphia: Springer*.
- [55] Lewin, K. (1944). The dynamics of group action. *Educational leadership*, 1(4), 195-200.
- [56] Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues* 2 (4), 34-46
- [57] Miguélez, M. M. (2000). La investigación-acción en el aula. *Agenda académica*, 7(1), 27-39.

- [58] Rahman, A., & Fals Borda, O. (1992). La situación actual y las perspectivas de la investigación-acción participativa en el mundo. *La investigación-acción participativa. Inicios y desarrollos*, 205-233.
- [59] Scholz, R. W. (2000a). Mutual learning as a basic principle of transdisciplinarity. Transdisciplinarity: Joint problem-solving among science, technology and society. *Workbook II: Mutual learning sessions*, 13-17.
- [60] Scholz, R. W. (2020). Transdisciplinarity: science for and with society in light of the university's roles and functions. *Sustainability Science*.
- [61] Krishnamurti, J. (1983a). Educando al educador. México: Editorial Orión (e.o.: 1953).
- [62] Krishnamurti, J. Clavier A (1983b). *Principios del aprender*. Edhasa.
- [63] Maharshi, R. (1998). Be as you are, Tiruvannamalai, South India. Sea lo que Usted Es. Las enseñanzas de Sri Ramana Maharshi. Versión electrónica disponible en: http://www.bibliotecaespiritual.com/pdf_obras/0Sea%20lo%20que%20usted%20es+.pdf
- [64] Ouspensky, P. D. (1978). Psicología de la posible evolución del hombre (9ª ed.). Argentina: Librería.
- [65] Muñoz-Sanz, A. (2012). Marco Aurelio Antonino (121-180 d. C.), filósofo y emperador de Roma, y la peste de Galeno. *Enfermedades Infecciosas y Microbiología Clínica*, 30(9), 552-559.
- [66] Da Vinci, L. (2012). The notebooks of Leonardo da Vinci (Vol. 1). Courier Corporation.
- [67] Max-Neef, M. A. (2016). Los cimientos de la transdisciplinaria Aportes teórico metodológicos para la sustentabilidad alimentaria y del desarrollo. Editores Freddy Delgado / Stephan Rist, 191-213.
- [68] De Romo, A. C. R. (2007). Claude Bernard, el hombre y el científico. *An Med (Mex)*, 52(2), 90-96.
- [69] Miguélez, M. M. (2011). Paradigmas emergentes y ciencias de la complicitad. *Opción: Revista de Ciencias Humanas y Sociales*, (65), 45-80.
- [70] Bertalanffy, L. (1986) Perspectivas en la teoría general de sistemas: estudios científico-filosóficos. *Madrid: Alianza*, 153-154.
- [71] Cuadrado, A. G. (1995). Notas sobre la teoría general de sistemas. *Revista general de información y documentación*, 5(1), 197.
- [72] Schrödinger, Erwin. 1967. What is the life? & Mind and mater. Cambridge University Press. Cambridge.
- [73] ONU (1960) <http://research.un.org/es/docs/dev/1960-1970>.
- [74] Miller, T. R., & Baird, T. D. (2008). Epistemological pluralism: reorganizing interdisciplinary research. *Ecology and Society* 13 (2).
- [75] Groß, M., & Stauffacher, M. (2014). Transdisciplinary environmental science: problem-oriented projects and strategic research programs. *Interdisciplinary science reviews*, 39(4), 299–306.
- [76] Jahn, T. (2008). Transdisciplinarity in the practice of research. *Transdisziplinäre Forschung: Integrative Forschungsprozesse verstehen und bewerten*. Campus Verlag, Frankfurt/Main, Germany, 21-37.
- [77] Cronin, K. (2008). Transdisciplinary research (TDR) and sustainability. Overview report prepared for the Ministry of Research, Science and Technology. Disponible en http://learningforsustainability.org/pubs/Transdisciplinary_Research_and_Sustainability.pdf
- [78] Nicolescu, B. (2010). Methodology of Transdisciplinarity—Levels of Reality, Logic of the Included Middle and Complexity. *Transdisciplinary Journal of Engineering & Science* 1(1), 17-32.
- [79] Nicolescu, B. (2014). Methodology of transdisciplinarity. *World Futures*, 70(3-4), 186-199.
- [80] Scholz, R. W., & Steiner, G. (2015a). The real type and ideal type of transdisciplinary processes: part II—what constraints and obstacles do we meet in practice?. *Sustainability Science*, 10(4), 653-671.
- [81] Maheu, R. (1970). Año Internacional de la Educación: mensaje del señor René Maheu Director General de la Unesco. *Revista de educación*, 206, 46-47. <http://www.educacionyfp.gob.es/revista-de-educacion/dam/jcr:7536856f-3d6b-44ef-9d08-87b99b7b2879/1969re206aniointernacional01-pdf.pdf>
- [82] Jahn, T., Bergmann, M., & Keil, F. (2012). Transdisciplinarity: Between mainstreaming and marginalization. *Ecological Economics*, 79, 1-10.
- [83] Jantsch, E. (1970). Inter-disciplinary and transdisciplinary university. Systems approach to education and innovation. *Policy Sci.* 1, 403–428.

- [84] Jantsch, E. (1972). Interdisciplinarity and transdisciplinarity in education and innovation. In *Interdisciplinarity: Problems of Teaching and Research in Universities; Organisation for Economic Co-Operation and Development (OECD) Paris, France*, 97–12.
- [85] Scholz, R.W., & Steiner, G. (2015b). The real type and ideal type of transdisciplinary processes: part I—theoretical foundations. *Sustainability Science*, 10(4), 527-544.
- [86] Osborne, P. (2015). Problematizing disciplinarity, transdisciplinary problematics. *Theory, culture and society*, 32(5-6), 3-35.
- [87] Nelson, G. (1970). Pollution and a Concerned Public. *Current History*, 59(347), 31.
- [88] Kockelmans, J. J. (1979a). Why interdisciplinarity? In J. J. Kockelmans (Ed.), *Interdisciplinarity and higher education (123-160)*. University Park, PA: Pennsylvania State University Press.
- [89] Kockelmans, J. J. (1979b). Science and discipline: Some historical and critical reflections. *Interdisciplinarity and higher education*, 11-45.
- [90] Mittelstrass, J. (2011). On transdisciplinarity. *Trames*, 15(4), 329-338.
- [91] Mittelstraß, J. (1992). Auf dem Weg zur Transdisziplinarität. *GAIA—Ecological Perspectives for Sci. Soc.* 1, 25
- [92] Hoffmann, S., Pohl, C., & Hering, J. G. (2017). Exploring transdisciplinary integration within a large research program: Empirical lessons from four thematic synthesis processes. *Research Policy*, 46(3), 678-692.
- [93] Brewer, G. D. (1999). The challenges of interdisciplinarity. *Policy Sci.* 32, 327–337.
- [94] Pohl, C. (2011). What is progress in transdisciplinary research? *Futures*, 43(6), 618-626.
- [95] McGregor, S. L. (2015a). The Nicolescuian and Zurich approaches to transdisciplinarity. *Integral Leadership Review*, 15(2).
- [96] <http://www.filosofia.org/cod/c1994tra.htm> (accessed July 15, 2017).
- [97] Basarab, N. (1996). *La transdisciplinarietà: manifesto*. Multiversidad Mundo Real Edgar Morin, AC.
- [98] Klein, J. T. (1996). *Crossing boundaries: Knowledge, disciplinarity, and interdisciplinarity*. Charlottesville: University Press of Virginia.
- [99] Juarroz, R. (1994). Algunas ideas sobre el lenguaje de la transdisciplinarietà. http://www.pensamientocomplejo.com.ar/docs/files/juarroz_el%20lenguaje%20de%20la%20transdisciplinarietà.pdf
- [100] Nicolescu, B. (1997). La transdisciplinarietà busca discípulos. *Le Monde de la Educación de la Cultura de la Formación*. N° 252.
- [101] Td-net: Network of Transdisciplinary Research. <http://www.transdisciplinarity.ch/en/td-net/Uebertd-net.html>, (accessed January 20, 2020).
- [102] ATLAS: *Academy of Transdisciplinary Learning and Advanced Studies* (2000). <http://www.theatlas.org/index.php/about-atlas>., (accessed January 20, 2020).
- [103] Klein, J. T. (2010). Remembering John Warfield. *Transdisciplinary Journal of Engineering & Science*, 2-4.
- [104] TJES: *Transdisciplinary Journal of Engineering & Science* (2010). <http://www.atlas-tjes.org/index.php/tjes>. (accessed January 20, 2020).
- [105] Pohl, C. (2010). From transdisciplinarity to transdisciplinary research. *Transdisciplinary Journal of Engineering & Science*, 65-73.
- [106] Lawrence, R. J. (2010). Deciphering interdisciplinary and transdisciplinary contributions. *Transdisciplinary journal of engineering & Science*, 111-116.
- [107] Nicolescu, B. (2011). International Congresses on Transdisciplinarity: Their importance for the emergence of a transdisciplinary methodology. *Transdisciplinary Journal of Engineering & Science*, 4-9.
- [108] Nicolescu, B. (2012). The need for transdisciplinarity in higher education in a globalized world. *Transdisciplinary Journal of Engineering & Science*, 11-18
- [109] Nicolescu, B. (2016). Technological Singularity – The Dark Side. *Transdisciplinary Journal of Engineering & Science*, 43-47.
- [110] Kueffer, C., Hadorn, G. H., Bammer, G., Van Kerkhoff, L., & Pohl, C. (2007). Towards a publication culture in transdisciplinary research. *Gaia*, 16(1), 22-26.

- [111] Espina, P. M., Klein, J. T., & Carrizo, L. (2004). Transdisciplinariedad y Complejidad en el análisis social, UNESCO. (accessed January 20, 2020).
- [112] Max-Neef, M. A. (2005). Foundations of transdisciplinarity. *Ecological economics*, 53(1), 5-16.
- [113] Pohl, C., & Hadorn, G. H. (2007). *Principles for designing transdisciplinary research*. Munich: Oekom.
- [114] Espinosa, M. A. C. (2005). II Congreso Mundial de Transdisciplinariedad. *Visión docente Con-Ciencia* 27. Disponible en http://www.ceuarkos.com/Vision_docente/revista27/t3.htm
- [115] Méndez, V. E., Bacon, C. M., & Cohen, R. (2013). La agroecología como un enfoque transdisciplinar, participativo y orientado a la acción. *Agroecología*, 8(2), 9-18.
- [116] Jiménez, P. G. Teoría ética de Lévinas. *Cuadernos de Materiales: Filosofía y Ciencias Humanas*, p. 1-6. (accessed January 20, 2017).
- [117] Martos, A. A., (Ed.) (2011). *Emmanuel Levinas: La filosofía como ética*. Universitat de Valencia.
- [118] McGregor, S. L. (2004). The nature of transdisciplinary research and practice. *Kappa Omicron Nu Human Sciences Working Paper Series*.
- [119] D'Ambrosio, U. (1996). Evaluación del rendimiento del alumno. investigación en la sala de clases: acciones pedagógicas complementarias. *Boletín 40: Proyecto principal de educación en América Latina y el Caribe*, 40, 55-61.
- [120] D'Ambrosio, U. (2014). Conocimiento y valores humanos, Capítulo 1 del libro: Transdisciplinariedad formación universitaria: Teorías y prácticas emergentes, *CEUARKOS*, ISBN: 978-607-9371-00-5, p. 30.
- [121] Vargas-Madrado, E. (2015). Desde la transdisciplinariedad hacia el auto-conocimiento y el diálogo comunitario de saberes: simplicidad ante la crisis. *Polis (Santiago)*, 14(42), 515-536.
- [122] Wiek, A. (2007). Challenges of transdisciplinary research as interactive knowledge generation—Experiences from transdisciplinary case study research. *GAIA-Ecological Perspectives for Science and Society*, 16(1), 52-57.
- [123] D'Ambrosio, U. (2011). A busca da paz como responsabilidade dos matemáticos. *Cuadernos de investigación y formación en educación matemática*, (7).
- [124] De Holanda, M. J. B., & de Medeiros, A. R. (2014). Uma educação para a paz: transdisciplinaridade e ampliação da consciência humana. *Revista Filosofia Capital-ISSN 1982-6613*, 9(16), 99-108.
- [125] Enengel, B., Muhar, A., Penker, M., Freyer, B., Drlik, S., & Ritter, F. (2012). Co-production of knowledge in transdisciplinary doctoral theses on landscape development—an analysis of actor roles and knowledge types in different research phases. *Landscape and Urban Planning*, 105(1), 106-117.
- [126] Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., Unger, J., Palmer, P. A., Clark, M., Colby, S. M., Morgan, G. & Trochim, W. (2003). Evaluating transdisciplinary science. *Nicotine y Tobacco Research*, 5(1), S21-S39.
- [127] Klein, J. T., (2001b). The discourse of transdisciplinarity: an expanding global field. In *Transdisciplinarity: Joint problem solving among science, technology, and society* (pp. 35-44). Birkhäuser, Basel.
- [128] Hult, F. M. (2010). Theme-based research in the transdisciplinary field of educational linguistics. In *Directions and prospects for educational linguistics* Springer Netherlands, (19-32).
- [129] Bergmann, M., Brohmann, B., Hoffmann, E., Loibl, M. C., Rehaag, R., Schramm, E., & Voß, J. P. (2005). Quality criteria of transdisciplinary research. *A guide for the formative evaluation of research projects. ISOE-Studientexte*, (13).
- [130] Jahn, T. (2003) (im Erscheinen): Sozial-ökologische Forschung – Ein neuer Forschungstyp in der Nachhaltigkeitsforschung. In: Linne, G.; Schwarz, M.: *Handbuch Nachhaltige Entwicklung. Wie ist nachhaltiges Wirtschaften machbar?* Opladen.
- [131] Krott, M. (2002). Evaluation of transdisciplinary research. *Encyclopedia of life support systems (EOLSS)*, 3.
- [132] Mitchell, C., Cordell, D., & Fam, D. (2015). Beginning at the end: The outcome spaces framework to guide purposive transdisciplinary research. *Futures*, 65, 86-96.
- [133] Balsiger, P. W. & Kötter, R. (2005). Permanent Evaluation: An important tool for a quality assurance in interdisciplinary research. In *Valuation and Conservation of Biodiversity: Interdisciplinary Perspectives on the Convention on Biological Diversity* Springer Science & Business Media, 421.

- [134] Carrizo, L., & Galliccio, E. (2006). Desarrollo local y Gobernanza. Centro Latinoamericano de Economía Humana. ISBN: 9974 -581-34 6.
- [135] Pohl, C. (2008). From science to policy through transdisciplinary research. *environmental science & policy*, 11(1), 46-53.
- [136] Scholz, R. W., Mieg, H. A., & Oswald, J. E. (2000b). Transdisciplinarity in groundwater management—towards mutual learning of science and society. *Water, Air, & Soil Pollution*, 123(1), 477-487.
- [137] Kim, Y. (ed.) (1998) Transdisciplinarity: 'Stimulating Synergies, Integrating Knowledges'. Paris: UNESCO.
- [138] Nicolescu, B. (1999). The transdisciplinary evolution of learning. In Symposium on Overcoming the Underdevelopment of Learning at the Annual Meeting of the American Educational Research Association, Montreal, Canada.
- [139] Montuori, A. (2013). The complexity of transdisciplinary literature reviews. *Complicity*, 10(1/2), 45.
- [140] Hadorn, G. H., Pohl, C., & Scheringer, M. (2002). Methodology of transdisciplinary research. *Unity of Knowledge in Transdisciplinary Research for Sustainability, in Encyclopedia of Life Support Systems (EOLSS), developed under the auspices of the UNESCO, Eolss Publishers, Oxford, UK.*
- [141] Hoffmann-Riem, H. (2002). Herausforderungen für die Umweltforschung. *GAIA-Ecological Perspectives for Science and Society*, 11(1), 49-52.
- [142] Cicovacki, P. (2003). Transdisciplinarity as an interactive method. TRANS: The Internet-Journal for Cultural Sciences, 15. http://www.inst.at/trans/15Nr/01_6/cicovacki15.htm26
- [143] Lawrence, R. J., & Després, C. (2004). Futures of transdisciplinarity. *Futures*, 397-405.
- [144] Balsiger, P. W. (2004) Supradisciplinary research practices: history, objectives and rationale. *Futures*, 36(4), 407-421.
- [145] Jones, H. T., & Sime, J. (2004). Living on the border: knowledge, risk and transdisciplinarity. *Futures*, 36(4), 441-456.
- [146] Bruce, A., Lyall, C., Tait, J., & Williams, R. (2004). Interdisciplinary integration in Europe: the case of the Fifth Framework programme. *Futures*, 36(4), 457-470.
- [147] Pinson, D. (2004). Urban planning: An undisciplined discipline?. *Futures*, 36(4), 503-513.
- [148] Klein, J. T. (2004). Prospects for transdisciplinarity. *Futures*, 36(4), 515-526
- [149] Pohl, C. (2005). Transdisciplinary collaboration in environmental research. *Futures*, 37(10), 1159-1178.
- [150] McGregor, S. L. (2005). Transdisciplinarity and a culture of peace. *Culture of Peace Online Journal*, 1(1), 1-12.
- [151] Casella, J., Espinosa, M. A. C., & Villarreal, S. O. (2009). Encuentro con Gaston Pineau Ceuarkos, *Revista Visión Docente Con-Ciencia* (48), 19-35.
- [152] Wickson, F., Carew, A. L., & Russell, A. W. (2006). Transdisciplinary research: characteristics, quandaries and quality. *Futures*, 38(9), 1046-1059.
- [153] Galvani, P. (2006). Transdisciplinarietà y Educación. *Visión docente Con-Ciencia*, V (30), 16-26.
- [154] Espinosa Martínez, A. C., & Galvani, P. (2014). Transdisciplinarietà y formación Universitaria Teorías prácticas emergentes *Ceuarkos* ISBN:978-607-9371-00-5.
- [155] Hadorn, G. H., Pohl, C., & Bammer, G. (2010). Solving problems through transdisciplinary research. *The Oxford handbook of interdisciplinarity. Oxford University Press, Oxford, United Kingdom*, 431-452.
- [156] Peón, E., & Hernández, A. C. (2009). Complex model of a transdisciplinary action-research program on the environment, through interinstitutional networks. Paper presented at The Brisbane, Australian in the 53rd Annual Meeting of the ISSS-2009.
- [157] Casella, J., Rodríguez, B., Costilla, R., & Espinosa, M. A. C. (2010). Experiencias en los talleres transdisciplinarios con estudiantes, *Revista Visión Docente Con-Ciencia* (55), 32-44.
- [158] Nuñez, M. C. (2011). Sustainability and spirituality: A transdisciplinary perspective. *Transdisciplinary Journal of Engineering & Science*, 2.

- [159] Nicolescu, B. (2013). La necesidad de la transdisciplinariedad en la educación superior. *Trans-pasando Fronteras*, (3), 23-30.
- [160] Andersson, K., Annerstedt, M., Axelsson, R., Elbakidze, M., Garrido, P., Grahn, P., K. Jönsson, I., Pedersen, S., Schlyter, P., Skärbäck, E., Smith, M., & Stjernquist, I. (2013). Solving problems in social-ecological systems: Definition, practice and barriers of transdisciplinary research. *Ambio*, 42(2), 254-265.
- [161] Axelsson R., Angelstam, P., Myhrman, L., Sädbom, S., Ivarsson, M., Elbakidze, M., Andersson, K., Cupa, P., Diry, C., Doyon, F., Drotz, M. K., Hjorth, A., Hermansson, J. O., Kullberg, T., Lickers, F. H., McTaggart, J., Olsson, A., Pautov, Y., Svensson, L., Törnblom, J. (2013). Evaluation of multi-level social learning for sustainable landscapes: Perspective of a development initiative in Bergslagen, Sweden.
- [162] Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., & Moore, H. (2013). Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability*, 5(3-4), 420-431.
- [163] Augsburg, T., (2014) Becoming transdisciplinary: The emergence of the transdisciplinary individual. *World Futures*, 70(3-4), 233-247.
- [164] Benesh, E. C., Lamb, L. E., Connors, S. K., Farmer, G. W., Fuh, K. C., Hunleth, J., Montgomery, K. L., Ramsey, A. T., Moley, K. H., Colditz, G. A., & Gehlert, S. J. (2015). A case study approach to train early-stage investigators in transdisciplinary research. *Transdisciplinary Journal of Engineering & Science*, 6.
- [165] Darbellay, F. (2015). Rethinking inter-and transdisciplinarity: Undisciplined knowledge and the emergence of a new thought style. *Futures*, 65, 163-174.
- [166] Brenner, J. E. (2015). Information and the Future of Transdisciplinarity. *Transdisciplinary Journal of Engineering & Science*, 6.
- [167] Vilsmaier, U., Engbers, M., Luthardt, P., Maas-Deipenbrock, R. M., Wunderlich, S., & Scholz, R. W. (2015). Case-based mutual learning sessions: knowledge integration and transfer in transdisciplinary processes. *Sustainability Science*, 10(4), 563-580.
- [168] Mateescu, B. N., Moraru, M., & Măruțelu, L. C. (2015). Transdisciplinary Education and Human Micro Universe Decipherment—the Key to Universal Knowledge. *Procedia-Social and Behavioral Sciences*, 180, 389-394.
- [169] Wiesmann, U., Biber-Klemm, S., Grossenbacher-Mansuy, W., Hirsch Hadorn, G., Hoffmann-Riem, H., Joye, D., Pohl, C., & Zemp, Elisabeth. (2016). Fortaleciendo la investigación transdisciplinaria: una síntesis en quince proposiciones. Ciencias, diálogo de saberes y transdisciplinariedad. Aportes teórico- Metodológicos para la sustentabilidad alimentaria y del desarrollo. Editores Freddy Delgado / Stephan Rist, 261-270.
- [170] Hurni, H., & Wiesmann, U. M. (2016). Hacia la transdisciplinariedad en la investigación para el desarrollo orientada hacia la sostenibilidad. Aportes teórico metodológicos para la sustentabilidad alimentaria y del desarrollo. Editores Freddy Delgado / Stephan Rist, 247-258.
- [171] McGregor, S. L. (2017b). Challenges of Transdisciplinary Collaboration: A Conceptual Literature Review. Disponible en <http://integralleadershipreview.com/15402-challenges-of-transdisciplinary-collaboration-a-conceptual-literature-review/>.
- [172] Pohl, C., Krütli, P., & Stauffacher, M. (2017). Ten Reflective Steps for Rendering Research Societally Relevant. *GAIA-Ecological Perspectives for Science and Society*, 26(1), 43-51.
- [173] Morin, J., (2017). Transición a una ciencia y cultura transdisciplinarias. *Revista de la Academia*, 24, 111-142.
- [174] Morales, M. M. (2017). Creating the transdisciplinary individual: Guiding principles rooted in studio pedagogy. *Journal of Interdisciplinary Studies in Education*, 6(1), 28-42.
- [175] Appel, J., & Kim-Appel, D. (2018). Towards a Transdisciplinary View: Innovations in Higher Education. *International Journal of Teaching and Education*, 6(2), 61-74.
- [176] Costley, C., and Pizzolato, N. (2018). Transdisciplinary qualities in practice doctorates. *Studies in Continuing Education*, 40(1), 30-45.
- [177] Hernandez-Aguilar, C. (2018). Transdisciplinary Methodological Option for Initial Research Process: Training of Researchers. *Transdisciplinary Journal of Engineering & Science*, 9, 157-180.
- [178] Fam, D., Neuhauser, L., & Gibbs, P. (2018). *Transdisciplinary theory, practice and education*. Springer International Publishing AG.

- [179] Scholz, R. W., Lang, D. J., Wiek, A., Walter, A. I., & Stauffacher, M. (2006). Transdisciplinary case studies as a means of sustainability learning: Historical framework and theory. *International Journal of Sustainability in Higher Education*, 7(3), 226-251.
- [180] Scholz, R.W., Stauffacher, M., Bösch, S., & Krütli, P. (Eds) (2003). Appenzell Ausserrhoden: Umwelt – Wirtschaft – Region, Rüegger und Pabst, Zurich
- [181] Enengel, B., Penker, M., & Muhar, A. (2014). Landscape co-management in Austria: The stakeholder's perspective on efforts, benefits and risks. *Journal of Rural Studies*, 34, 223-234.
- [182] Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C. J. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability science*, 7(1), 25-43.
- [183] Richter, C. H., Steele, J. A., Nguyen-Viet, H., Xu, J., & Wilcox, B. A. (2015). Toward operational criteria for ecosystem approaches to health. *Ecohealth*, 12(2), 220-226.
- [184] Miah, J. H., Griffiths, A., McNeill, R., Poonaji, I., Martin, R., Morse, S., Yang, A., & Sadhukhan, J. (2015). A small-scale transdisciplinary process to maximising the energy efficiency of food factories: insights and recommendations from the development of a novel heat integration framework. *Sustainability Science*, 10(4), 621-637.
- [185] Berger-González, M., Stauffacher, M., Zinsstag, J., Edwards, P., & Krütli, P. (2016). Transdisciplinary research on cancer-healing systems between biomedicine and the Maya of Guatemala: a tool for reciprocal reflexivity in a multi-epistemological setting. *Qualitative health research*, 26(1), 77-91.
- [186] Gebhardt, L., Brost, M., & König, A. (2019). An inter-and transdisciplinary approach to developing and testing a new sustainable mobility system. *Sustainability*, 11(24), 7223.



Copyright ©2019 by the authors. This is an open access article distributed under the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

About the Authors



Dr. C. Hernández-Aguilar, Professor-researcher of the National Polytechnic Institute, within the Graduate Program in Systems Engineering of ESIME Zacatenco. Member of the Mexican Academy of Sciences and the National System of Researchers (México). International distinction as member of the Editorial Committee of the journal: *International Agrophysics* (period:2012-present). Coordinator of the graduate programs in systems engineering (period 2012-2015). Creator and leader of the research group on Sustainable Biophysical Systems (SBS) for Agriculture, Food and Medicine with a Transdisciplinary approach. Main contributions related to methods for improvement and quality evaluation of agricultural seeds and food. Among others methods: laser radiation, electromagnetic field (fixed and variable), ultraviolet radiation (A-B-C), infrared, LED diodes, ozone, natural. Concerned and occupied in improving the quality of life of society. Trainer of researchers in the last 13 years, making a call to conscience, to rescue a human attitude in the research process and the impact obtained from it. Motto: Transform yourself, to transform your world.



Dr. Arturo Dominguez Pacheco, Doctorate in Systems Engineering with a postdoctoral degree in PHYSICS from Cinvestav, Mexico (two periods). Research Professor of the Postgraduate Program in Systems Engineering at ESIME-Zacatenco-IPN in the line of research in Engineering Systems. Member of the Research Group on Sustainable Biophysical Systems (SBS) for Agriculture, Food and Medicine. Main scientific contributions in the area of Characterization of Materials and Development of Irradiator Prototypes. Active collaborator and participant in research projects with the Cinvestav. Photothermal Techniques group, as well as Director of research projects at the IPN since 2010. Currently SNI level I of the area VI.



Master Efraín José Martínez Ortiz. Academic training. Bachelor of Education and Bachelor of Mathematics (Universidad Nacional Mayor de San Marcos Lima Peru), Master of Mathematics (CINVESTAV Mexico), Operations Research Specialization, Grenoble France. Teaching experience. National University of San Marcos. Lima Peru 1968-1970; National Autonomous University of Mexico 1975-1996, National Polytechnic Institute 1973 to date. Instructor in the training of human resources in SEP Special Projects and in different universities of the Mexican Republic. Academic and / or Administrative Function. Head of the Mathematics Department at FESC-Cuautitlán-UNAM, and Coordinator of the Master in Systems Engineering ESIME-IPN in two periods. Coordinator of the Master in Systems Engineering ESIME-IPN at the Virtual Polytechnic Campus. Publications. More than one hundred participations in Congresses in the educational field and in the Operations Research area at national and international level, with eighty-three theses directed at master's level, four published books and director of fifteen Research Projects at the IPN.



Dr. Rumén Ivanov Tsonchev completed his undergraduate studies at Sofia University “St. Kliment Ohridski” in 1977, with a specialty of radio-physics and electronics. His PhD degree was concluded at the “Bulgarian Academy of Sciences” in 1988. From 1977 to 1980 he worked in the machine building industry. From 1980 to 1998 he worked at the Medical University in the city Varna, Bulgaria. Since 1998 he works at the Physics Faculty of the Universidad Autonoma de Zacatecas, Mexico. He is author of more than 90 papers in prestigious scientific journals, he participated in more than 100 national and international conferences, he holds 5 patents and he is the author of 4 technological developments. He is a member of the Sistema Nacional de Investigadores since 2000, currently he has level II. Since 2013 he is a member of the Mexican Academy of Sciences, he is editor and referee in scientific journals. He has more than 1,200 citations from his articles (without self-citations). His scientific interests are in the field of material characterization (optical, thermal and electrical properties), he is currently working on the

application of active thermography in physical and engineering measurements.



José Luis López Bonilla Professor and Scientific Researcher at the Higher School of Mechanical and Electrical Engineering (ESIME) of the National Polytechnic Institute, Mexico. Specialist in Mathematical Methods Applied to Engineering and Theoretical Physics.



Dr. Alfredo Cruz Orea completed his undergraduate studies at Escuela Superior de Física y Matemáticas del Instituto Politécnico Nacional. His Master and PhD studies in Physics were carried out at Universidade Estadual de Campinas, Sao Paulo, Brazil. From March 1994 to March 1999, he was a researcher at Programa Multidisciplinario en Ciencia Aplicada y Tecnología Avanzada at Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV - IPN). Since April 1999 he is a researcher at the Physics Department in CINVESTAV - IPN. Dr. Cruz is member of the Mexican Academy of Sciences since 2004, also he is member of Sistema Nacional de Investigadores, level III since 2008. His research is focused on the study of optical and thermal properties of materials by using Photothermal techniques. Dr. Cruz has published more than 200 articles in indexed international journals, five chapters in books, and around 900 citations from his articles (without self-citations). He has directed and co-directed 11 PhD theses, 14 Master's theses and 7 Bachelor's theses. He has been visiting professor at the Katholieke Universiteit Leuven, Belgium. Dr. Cruz also has been invited to teach courses on Photothermal Techniques at Universidad de Concepción, Chile and Universidad Surcolombiana, Colombia.



Dr. Jose Ordonez-Miranda is a CNRS researcher at the Institute Pprime in Futuroscope, France. His research area is the transport of heat by phonons, photons, electrons, and polaritons propagating in nanomaterials with applications in thermotronics. The Boltzmann transport equation and Maxwell's equations of electromagnetism are his main tools of theoretical modelling. He obtained his bachelor degree in applied physics at the National University Jorge Basadre Grohmann (UNJBG) in Tacna, Peru and received his Master in Physics from CINVESTAV in Merida, Mexico. Jose holds a Ph. D. degree in physics granted by CINVESTAV in collaboration with the University of Colorado in Boulder, USA. He performed a postdoc in the laboratory EM2C at the Ecole Centrale Paris, and was recruited by the CNRS in October 2015, for which he currently works as a full researcher (CRCN). Jose was awarded the prize of outstanding young researcher granted by the International Photoacoustic and Photothermal Association (IPPA), in 2014, Shanghai, China. In addition, In 2018, Jose received the medal Jorge Basadre as a distinguished researcher graduated from the UNJBG, Peru

APPENDIX

Table 1a. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	DESCRIPTION	NATIONALITY AND / OR UNIVERSITIES
Edgar Morin (1988)	In TD, "the knowledge operator must at the same time become an object of knowledge" (see, Carrizo and Gallicio, 2006) [134].	Paris, France
Mittelstraß (1992)	Transdisciplinarity in the decade of the 90s. TD is a way of investigating that transcends disciplines to propose solutions to problems in the world of life, as quoted by Pohl (2008) [135].	Konstanz University, Germany
Arber (1993)	TD transfer concepts or methods from one discipline to another (see Scholz et al., 2000b) [136]	University of Basel, Switzerland
Kim (1998) [137]	TD is the "intellectual space" where problems are thought about, their alternative solutions and interrelationships are observed. "Co-operative work"= "sinergon"	UNESCO
Basarab (1999) [138]	Transdisciplinarity implies an ethical attitude of opening and dialog. Strengthens the physical, emotional and intellectual balance of the Subject. Who bridges with itself, with others and with the nature to reconstruct, from the honesty and the commitment those social, environmental, cultural and affective. Strengthens their integral formation.	French nationalized
TD Conference in Zurich in 2000 (Klein et al., 2001) [49]	Transdisciplinarity from 2000. Transdisciplinarity is a way of learning and solving problems through the participation of the academy and society. Facing the challenges of this last.	Zurich, Suiza
Flyvbjerg (2001)	TD is based on general theory of systems, complexity, contextualization, etc. Collect information from different disciplines to act wisely, etc. (Flyvbjerg, 2001; see, Montouri, 2013) [139].	Oxford University
Hadorn et al. (2002) [140]	Empirical and theoretical knowledge is necessary to know the system and its relationships. Noted another feature: mutual interdependencies	ETH Zurich, Switzerland
Hoffman-Riem (2002) [141]	Environmental research has to establish reliable knowledge that can be transformed into effective measures. This requires a combination of experiments and field observations based on different disciplinary perspectives.	Universität Bielefeld, Germany
Cicovacki (2003) [142]	Transdisciplinarity is a vision of humanity for the human knowledge and human relationships.	Department of Philosophy, Holy Cross College, Worcester, USA
Lawrence and Després (2004) [143]	TD challenges the fragmentation of knowledge. Characteristics: hybrid nature, nonlinearity, reflective, transcends disciplinary structure, accepts contexts of uncertainty, knowledge based on the specific context, collaboration in all phases of the research project, is usually oriented to action.	University of Geneva, Centre for Human Ecology and Environmental Sciences Université Laval, Quebec, Canada
Balsiger (2004) [144]	TD research is scientific research and scientific rules are followed. TD does not compete with disciplinary approaches.	Interdisciplinary Institute of Philosophy and History of Science University of Erlangen-Nuremberg, Germany
Jones and Sime (2004) [145]	Connections are made between disciplinary boundaries, between academic and experimental research. Border work is required	University School of Social Sciences, Cardiff Wales- United Kingdom University of Utah, Salt Lake City, USA
Bruce et al. (2004) [146]	"Expand the mind" through the participation of the potential user to know their needs.	Scottish Universities Policy Research and advice network Institute for the study of Science, Technology and innovation, University of Edinburgh, United Kingdom.
Pinson (2004) [147]	Requirement: Cooperation between identifiable disciplines, dialogue with other specialties, etc. This cooperation will be more effective as each discipline defines its specific contribution.	University of Droit, Marseilles, France
Klein (2004) [148]	TD has become an important imperative in all sectors or domains of society and knowledge, which makes it an essential way of thinking and action. Transdisciplinary attitude is required to cultivate.	Department of Interdisciplinary Studies (CULMA), Wayne State University, Detroit, USA.

Table 1b. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	DESCRIPTION	NATIONALITY AND / OR UNIVERSITIES
Pohl (2005) [149]	TD takes into account: a) the complexity of a topic that jointly explains the current state of the topic and its dynamics, b) the different perceptions of science and society, and c) the separation of the idealized context of science to produce knowledge practically relevant.	Federal Technological Institute, Switzerland
McGregor (2005) [150]	Participants in a TD research project could be: academics, civil society, government authorities, companies, artists, etc. They propose the TD as a process to achieve peace.	Universidad Mount Saint Vincent, Halifax, Canada
Vitória's statement (2005)	"Transdisciplinary action articulates relationship with the world (ecoformation), the relationship with the other (hetero and co-formation), the relationship with ourselves (self-training) and the relationships with being (onto-formation)" (Cetrans, 2005; see, Casella, 2009) [151].	Victoria, Brazil
Wickson <i>et al.</i> (2006) [152]	Researchers who operate regularly in a TD manner would encourage the development of the integrative and collaborative required in research. Features: 1) The TD integrates various methodologies, it is not one, 2) collaboration with actors of the problem (affected people).	Wollongong University, and University of Sydney, Australia
Galvani (2006) [153]	Transdiscipline must be understood as an attitude of intellectual rigor, which allows the researcher to be aware of their own limits and the limits of their discipline. "Being transdisciplinary" for this author means being aware that everything cannot be explained through the lens of our profession or particular area, but we must accept that we need other professions and fields of knowledge, to gather all or the greatest possible number of perspectives that allow us to form a more complete idea of reality. Demanding openness not only to other disciplines, but also to classical and popular knowledge, and to the cross-cultural, including art, philosophy, spirituality, science, etc.	
Congress in Barcelona (2007)	Pineau points out contributions in ecological training, contemplating respect for nature (ecology) and others (otherness) [154].	Barcelona, Spain Pineau of the Rabelais Tours University, France.
Hadorn <i>et al.</i> (2008; 2010) [54, 155]	Research that addresses issues in the world of life. Phases: 1) problem identification and structuring phase, 2) problem investigation and 3) outcome phases. Transdisciplinary have three types of knowledge: systems, objective, of transformation, and reflects the mutual dependence.	ETH Zurich, Switzerland
Peón and Hernández (2009) [156]	The transdisciplinary research process is service oriented, useful to share with others or others. It always implies universal values and ethics. In addition to observing the object studied, it requires self-observation. We work for tolerance between different ideas of disciplined experts and even beyond, we work to understand the undisciplined, the empirical, the common citizen, etc. Constant awareness of unity. Focused not only on doing but also on being (Hernández-Aguilar).	National Polytechnic Institute Mexico
Casella <i>et al.</i> (2010) [157]	TD is a way of conceiving, thinking and analyzing the reality that surrounds. Seeks to relate knowledge with life. Born for to meet the need to deal with the unprecedented challenges of the problematic world in which we live and require a multi-referential treatment because they are complex.	Arkos University Studies Center, Puerto Vallarta, Mexico
Pinson (2004) [147]	Requirement: Cooperation between identifiable disciplines, dialogue with other specialties, etc. This cooperation will be more effective as each discipline defines its specific contribution.	University of Droit, Marseilles, France
Klein (2004) [148]	TD has become an important imperative in all sectors or domains of society and knowledge, which makes it an essential way of thinking and action. Transdisciplinary attitude is required to cultivate.	Department of Interdisciplinary Studies (CULMA), Wayne State University, Detroit, USA
Pohl (2005) [149]	TD takes into account: a) the complexity of a topic that jointly explains the current state of the topic and its dynamics, b) the different perceptions of science and society, and c) the separation of the idealized context of science to produce knowledge practically relevant.	Federal Technological Institute, Switzerland
McGregor (2005) [150]	Participants in a TD research project could be: academics, civil society, government authorities, companies, artists, etc. They propose the TD as a process to achieve peace.	Universidad Mount Saint Vincent, Halifax, Canada
Vitória's statement (2005) (151)	"Transdisciplinary action articulates relationship with the world (ecoformation), the relationship with the other (hetero and co-formation), the relationship with ourselves (self-training) and the relationships with being (onto-formation)" (Cetrans, 2005; see, Casella, 2009) [151].	Victoria, Brazil

Table 1c. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	Description	Nationality and / or Universities
Wickson <i>et al.</i> (2006) [152]	Researchers who operate regularly in a TD manner would encourage the development of the integrative and collaborative required in research. Features: 1) The TD integrates various methodologies, it is not one, 2) collaboration with actors of the problem (affected people).	Wollongong University, and University of Sydney, Australia
Galvani (2006) [153]	Transdiscipline must be understood as an attitude of intellectual rigor, which allows the researcher to be aware of their own limits and the limits of their discipline. "Being transdisciplinary" for this author means being aware that everything cannot be explained through the lens of our profession or particular area, but we must accept that we need other professions and fields of knowledge, to gather all or the greatest possible number of perspectives that allow us to form a more complete idea of reality. Demanding openness not only to other disciplines, but also to classical and popular knowledge, and to the cross-cultural, including art, philosophy, spirituality, science, etc.	
Congress Barcelona (2007)	in Pineau points out contributions in ecological training, contemplating respect nature (ecology) and others (otherness) [154].	Barcelona, Spain Pineau of the Rabelais Tours University, France.
Hadom <i>et al.</i> (2008; 2010) [54, 155]	Research that addresses issues in the world of life. Phases: 1) problem identification and structuring phase, 2) problem investigation and 3) outcome phases. Transdisciplinary have three types of knowledge: systems, objective, of transformation, and reflects the mutual dependence.	ETH Zurich, Switzerland
Peón and Hernández (2009) [156]	The transdisciplinary research process is service oriented, useful to share with others or others. It always implies universal values and ethics. In addition to observing the object studied, it requires self-observation. We work for tolerance between different ideas of disciplined experts and even beyond, we work to understand the undisciplined, the empirical, the common citizen, etc. Constant awareness of unity. Focused not only on doing but also on being (Hernández-Aguilar).	National Polytechnic Institute Mexico
Casella <i>et al.</i> (2010) [157]	TD is a way of conceiving, thinking and analyzing the reality that surrounds, to relate knowledge with life. Born for to meet the need to deal with the unprecedented challenges of the problematic world in which we live and require a multi-referential treatment because they are complex.	Arkos University Studies Center, Puerto Vallarta, Mexico
Núñez (2012) [158]	TD is a transformative experience, self-transformation process, where there permanent questions and reflective dialogues within different levels of Reality.	Veracruzana University, Mexico
Basarab (2013) [159]	In his speech made a comparison between Disciplinary and Transdisciplinary Education held in Istanbul, Turkey	CIRET, Paris, Francia
Angelstam <i>et al.</i> (2013) [160]	Transdisciplinary research is based on: 1). integration of multiple disciplines and 2) of stakeholders- included levels of governance (representatives of different social sectors participate and have active inclusion in formulating problems, knowledge production and learning).	Swedish University of Agricultural Sciences Sweden and U.K.
Axelsson <i>et al.</i> (2013) [161]	Self-reflection, evaluation of the problem-solving process, multi-level collaboration.	Swedish University of Agricultural Sciences Sweden, Czech Republic, Austria, Canada,
Mausser <i>et al.</i> (2013) [162]	Stakeholders and academic, involment in co-design and co-production of knowledge. Co-design: 1) Joint framing (topic depend on societal emergence), 2) research definition (researc scale, research question), implementation (calling, proposals, review, etc.). Co-production: 1) scientific integration (interdisciplinary, consistency, uncertainly), 2) Relevance (transdisciplinarity, stakeholder, involvement), 3) Dissemination of results (translation, transparency dialogue, responsivity)	University Munich, Germany, Australia, Netherlands

Table 1d. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	DESCRIPTION	NATIONALITY AND / OR UNIVERSITIES
Augsburg Tanya (2014) [163]	Characteristics of a person who decides to do a TD job: moving from a traditional comfort zone, working outside one's own discipline, participating in different ways of thinking and acting, breaking the paradigm that science offers "the best solution", joy to see from another look, develop trust and mutual needs, be modest, build networks outside the family, etc.	San Francisco State University, California, USA
Benesh <i>et al.</i> (2014) [164]	TD research is a collaboration between investigators with several backgrounds, where their co-generate ideas.	Washington University School of Medicine
Darbellay (2015) [165]	Transdisciplinarity can be considered as a research method that brings together political, social and economic actors, as well as ordinary citizens, in the research process itself, in a perspective of "problem solving"	University of Geneva, Switzerland
Brenner (2015) [166]	Transdisciplinarity is a philosophical movement which can provide a new approach to current problems and paradoxes of human thought, science and philosophy.	Chemin du College Switzerland
Vilsmaier <i>et al.</i> (2015) [167]	TD research needs deep reflection, transformation of attitudes and capacity building by all participants; to overcome cultural differences that cause difficulties in the mutual learning process (Hirsch Hadorn <i>et al.</i>).	Lüneburg University, Germany
Mateescu <i>et al.</i> (2015) [168]	The TD leads to the change of man for access and participation in the socio-cultural and spiritual life.	University of Constanța Romania
Wiesmann <i>et al.</i> (2016) [169]	Proposals to strengthen TD research process: among which are: Definition, scope and relevance, recursive processes, forms of knowledge, contextuality and generality, specialization and innovation, participation and mutual learning, values and uncertainty, management and leadership, education and career building, evaluation and quality control, etc.	Bern University, Switzerland
Hurni Hadorn and Wiesmann <i>et al.</i> (2016) [170]	They suggest that a transdisciplinary approach requires that the investigated phenomena be considered from a perspective that goes beyond specific disciplines and is based on a broad-spectrum participation characterized by systematic cooperation with those involved.	Bern University, Switzerland
McGregor (2017) [171]	Individual and collective diversities profoundly affect communications and collaborations during transdisciplinary work.	Mount Saint Vincent University, Halifax, Canada
Pohl <i>et al.</i> (2017) [172]	They propose reflective levels to interpret socially relevant problems.	ETH Zurich, Switzerland
Jim Morin (2017) [173]	TD is characterized by a paradigm shift to produce knowledge, overcoming the division of academic work and segmented into separate departments.	Universidad católica del Maule, Chile
Morales (2017) [174]	Participants in research projects TD must employ traditional scientific methods, research skills, even employ research methods such as the used in an art or design study. She uses the term of an individual transdisciplinarity.	Boston College USA
Appel (2018) [175]	TD are the efforts carried out in research by academics from different disciplines who work together to create conceptual, theoretical, methodological innovations, etc. for go beyond disciplines addressing complex problems.	Tiffin University, USA
Carol Costley and Nicola Pizzolato (2018) [176]	Qualities to promote in PhDs students: Researching collaboratively with stakeholders, diversity of disciplinary and assessment criteria, Integration of methodologies, situating of the research in multiple contexts, Impact on 'situation' with procedures or products news, Ethics and trust.	Middlesex University London
Hernández-Aguilar (2018) [177]	Proposes four phases for transdisciplinary training and research: 1) Contextual and documentary research, focusing on the problem and taking scientific evidence of it, 2) Self-research, 3) Experimental research, in search of the solution and its demonstration, 4) impact investigation.	National Polytechnic Institute Mexico City, Mexico
Fam <i>et al.</i> (2018) [178]	'science for society' is modified to 'science with the society (Fam)	University of Technology, Sydney Australia

Table 2. Contributions to transdisciplinarity most cited in the last 50 years according to the literature review carried out.

2011-2020	2001-2010	1991-2000	1981-1990	1970-1980
¹ Jahn <i>et al.</i> (2012) [41] 675	Max-Neef (2005) [72] 1073	Gibbons <i>et al.</i> (1994) [5] 18630	Bertalanffy (1986) [29] 87	Jantsch (1970) [42] 353
Mauser <i>et al.</i> (2013) [122] 481	Hadorn <i>et al.</i> (2008) [54] 856	Klein (1996) [57] 1669		Kockelmans (1979a) [47] 158
Basarab (2014) [38] 378	Klein (2004) [108] 700	Gibbons <i>et al.</i> (1999) [6] 1028		
Pohl (2011) [53] 204	Klein (2001a) [8] 640	Brewer (1999) [52] 430		
Bernstein (2015) [11] 187	Wickson <i>et al.</i> (2006) [112] 585	Basarab (1996) [56] 347		
Scholz and Steiner (2015a) [39] 142	Pohl and Hadorn (2007) [73] 492	Basarab (1999) [98] 154		
	Miller <i>et al.</i> (2008) [33] 462			
	Lawrence and Després (2004) [103] 401			

Table 3. Some base methodologies in Transdisciplinary research processes

AUTHOR (S)	PHASES	APPLICATION
Scholz <i>et al.</i> (2000b; 2003; 2006) [136, 179, 180]	I. Preparation (choosing and knowing the case, including empathy) II. Realization III. Epilogue (synthesized group reports and case report presented to the public)	Groundwater management
Hadorn <i>et al.</i> (2008) [54]	I. Problem identification and structuring II. Problem analysis III. Provide results to a good end	Transdisciplinary research processes
Jahn, T. (2008), Jahn <i>et al.</i> , (2012) [76, 82]	I. Constitution of a common object of investigation II. New transferable knowledge III. Transdisciplinary integration	Mainstreaming and marginalization
Enengel <i>et al.</i> (2012) [125]	I. History of the problem II. Problem identification and structuring III. Research design, method selection IV. Data collection V. Analysis of data VI. Reflection / Interpretation, synthesis VII. Dissemination of results	Development—an analysis of actor roles and knowledge types in different research phases
Lang <i>et al.</i> (2012) [182]	I. Frame research problem and team building II. Co-creation of solution III. Reintegration and application of created knowledge	Transdisciplinary sustainable research
Enengel <i>et al.</i> (2014) [181]	I. Concept II. Analytical network III. Collection and selection of case studies IV. Questionnaires and guidelines V. Triangulation, case-sensitive and inter-case results VI. Conclusions and recommendations for action VII. Feedback all with Knowledge of literature review And exploratory interviews with experts.	Stakeholder's perspective on efforts, benefits and risks
Richter <i>et al.</i> (2015) [183]	I. Transdisciplinary II. Systemic III. Adaptive management	Ecosystem approaches to health
Miah <i>et al.</i> (2015) [184]	I. Problem specification II. Generation of ideas III. Solution development III. Application IV. Knowledge dissemination	Academy-industry
Berger <i>et al.</i> (2016) [185]	I. Knowledge of facets of variable to study II. System analysis III. Final Synthesis IV. Project goals (guiding question) V. Terminal focal variable	Cancer knowledge
Hernández <i>et al.</i> (2018) [177]	I. Contextual, field and documentary research - (Focus and evidence of oak in the real world (MR)) II. Investigation of the investigating subject- Self-research III. Experimental research, in search of the solution, its demonstration and new proposal design IV. Investigation of the impact of the proposal (Including impact research and communication of results (scientific and social level))	Training of transdisciplinary researchers
Gebhardt <i>et al.</i> (2019) [186]	I. Understand users in their everyday context, II. Describe and identify the various types of users III. Developing ideas and concepts, testing and evaluating in the Real World Laboratory	Sustainable mobility system