Advancing with Transdisciplinarity: Effective Responses for Coronavirus

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The term 'transdisciplinarity' was discussed 50 years ago at the International Seminar on Interdisciplinarity in Universities in Nice, France. Then, transdisciplinary contributions were defined as those establishing a common system of axioms for a set of disciplines using systemic logics and the synthesis of higher order disciplinary relationships that distinguish transdisciplinary from multidisciplinary and interdisciplinary contributions. These key principles are recalled because societal challenges and problems, such as the current coronavirus pandemic, highlight the difficulty of many scientists, public administrators and politicians to think systemically within and beyond the conceptual and methodological boundaries of their discipline and profession. Although discipline-based expertise is needed about coronavirus, alone, it cannot provide a comprehensive understanding necessary for effective responses to its multiple impacts within and beyond the public health sector. This article proposes that the coronavirus SARS-CoV-2 pandemic should be considered as an emergent, complex, contextual, and systemic societal challenge that requires concerted actions involving not only disciplinary and professional expertise but also other types of knowledge and know-how. The article includes a conceptual framework that represents this transdisciplinarity.

Keywords: Conceptual framework, coronavirus, disciplinary confinement, science-society relations, societal challenges, systemic thinking, transdisciplinarity.

1 Introduction

Six months ago, the World Health Organization declared the current coronavirus SARS-CoV-2 pandemic and underlined that the multiple impacts of COVID-19 disease are unknown, emergent, contextual and unpredictable [1]. Since then there is a growing concern about the rapid expansion of thousands of scientific publications that complement omnipresent mass media coverage about the coronavirus SARS-CoV-2 pandemic, and ongoing treatments for patients diagnosed with COVID-19 [2]. Many scientific articles published in peer review journals report ongoing biomedical or epidemiological research as well as testing treatments and cures of patients by medical practitioners and others [3]. Concurrently, the partisan claims of politicians and elected officials, whether at national, state, or local geo-political levels in some countries, have also been reported. They confirm the political instrumentalisation of emerging data and information about the pandemic and that we are living in a post-truth era.

In a recent commentary on research gaps about coronavirus, Trudie Lang (2020) [4] noted that over 2000 clinical trials had been registered around the world, mostly in hospital settings in countries with high gross domestic product (GDP). She also noted that these contributions repeat the custom of much medical research that benefits only about 10 per cent of the world population. This is one outcome of the increasing privatisation and commodification of medical and health care since the 1970s. It recalls a fundamental ethical principle about the societal impact of specialised research and teaching. It also raises the question about how societal challenges, including the current coronavirus pandemic and other infectious diseases, are interpreted as scientific problems that can be resolved by empirically validated knowledge produced for decision makers in the public and private sectors (see later).

The common ground and differences between scientific, political and public responses to the current coronavirus pandemic illustrate how divergent, sometimes conflicting interpretations of emergent situations and persistent problems are interpreted and confronted by societies at national, state and local geo-political levels [5]. These differences highlight the need to account for individual, social and cultural values that coexist in human societies. We underline that too little attention has been attributed to human beliefs, intentions, motives, preferences, and fundamental values that frame the societal responses to the current pandemic, as well as individual and collective behaviours. We regret that too few contributions from authors and institutions in the scientific, professional and public policy domains have addressed these subjects, and these omissions highlight the limits of scientific research and professional expertise to address the current complex and unpredictable global health challenge [5]. Based on real-world situations in cities and countries around the world, we argue and illustrate that interdisciplinary collaboration, cross-sector professional co-ordination, political commitment and leadership, and social adherence to behavioural norms and rules are all needed; they should be combined creatively to understand multiple meanings, perceptions and values in order to collectively define and implement effective transdisciplinary responses to the current pandemic.

In her contribution about research gaps on the current pandemic, Trudie Lang (2020) [4] included fundamental questions about the medicalisation of scientific research on COVID-19 that ignores behavioural, cultural and economic variables which influence individual and population health, especially infectious diseases including Ebola and Zika. These variables cannot be dissociated from human behaviour, perceptions and values. Accordingly, we have analysed, synthesised and explained the virtuous relations between three prerequisite conditions - multilevel governance; different types of knowledge and other kinds of resources; and community adherence to individual and collective behaviours - that should be combined and synthesised in transdisciplinary responses to the coronavirus pandemic at several geo-political levels [5].

This article highlights the advantages of these kinds of human-centred responses, because they confirm the pertinence of key principles about the societal impact of interdisciplinary scientific research discussed 50 years ago at the International Seminar on Interdisciplinarity in Universities held in Nice, France, in September 1970 [6]. A half century later, our reading of the seminar papers and other literature indicates that some of these key principles are sorely missed in research, policy making and interventions in countries and cities, whereas they have been implemented successively in others [5]. For this reason, this article is written to mark the 50th anniversary of the public use of the term transdisciplinarity; it presents a transdisciplinary conceptual framework that can facilitate shared understanding and responses to the current pandemic.

This article reports conceptual research that has examined plausible interrelations between specific concepts and principles proposed to define transdisciplinarity in 1970, and applications of these concepts and principles to study specific subjects, problems, or situations in the world. This approach recognises that a key concern among academics 50 years ago was the purpose of scientific research and education as well as their social purpose. We endorse the pertinence of foundation concepts of transdisciplinarity proposed by the first generation of scholars in the 1970s to deal with complex societal challenges, such as the current coronavirus pandemic, other infectious diseases, loss of biodiversity, climate change and mass migration, provided that fundamental human beliefs, meanings, perceptions, values, and worldviews are included.

The next section of this article briefly recalls some key concepts and core principles discussed at the at

the International Seminar on Interdisciplinarity in Universities in 1970, as well as in other publications about that time. We argue that these concepts and principles are pertinent for effective responses to the current coronavirus, whereas disciplinary confinement has meant that they have rarely been included explicitly in scientific publications, public policies, or general public media about the pandemic.

2 Sense of Purpose of Scientific Research for Societal Challenges

Participants at the International Seminar on Interdisciplinarity in Universities held in Nice, France, in 1970, discussed the academic and institutional organization of scientific research and higher education according to autonomous disciplines. This custom not only supported the segmentation and specialisation of research and teaching; it also endorsed a strong bias positioning scientific knowledge above all other types of knowledge and know-how (see later). During the seminar, Swiss psychologist Jean Piaget's (1896-1980) distinguished between multi-, inter- and trans- according to the properties of relations between several discipline-based components. Notably, extra-scientific knowledge was not included. Piaget posited that transdisciplinarity denotes a higher stage of interrelations that succeed interdisciplinary relationships to create a multi-level order [7]. Erich Jantsch (1929-1980), an Austrian astrophysicist, complemented Piaget and proposed principles of general systems theory applied to science. He explained that "... objectivity does not reside in facts, but in relationships to be found in reality" [8, p.98]. Then, the participants defined transdisciplinary contributions as those establishing a common system of axioms for a set of disciplines using systemic logics and the synthesis of higher order disciplinary relationships that distinguish transdisciplinary from multidisciplinary and interdisciplinary contributions.

We agree with Piaget and Jantsch that transdisciplinarity has multiple interpretations and it can denote a verb; notably it designates communication, collaboration, interactions and interrelations that may not lead to integration or fusion during specific projects (see later). This core principle has been forgotten by those researchers who have endorsed a unity of knowledge using 'the integration imperative' so aptly described by Nicole Klenk and Katie Meehan (2015) [9] in relation to research on climate change. We propose that conflicting beliefs, meanings and values attributed to societal challenges, illustrated by the current coronavirus pandemic, confirm that achieving consensus and integration or fusion should not be assumed (see later).

Jantsch's contribution in 1970 also proposed an ongoing debate about the fundamental contribution of a human-centred interpretation of the purpose of science and technology:

> "... the crucial question is whether science and its internal system, or "structures", of relationships is independent of human or social purpose, or whether there is a feedback link tying them together. We have learned part of the answer by recognizing that not only scientific facts, but also scientific structures can be grasped by the human mind only through what we may call anthropomorphic modes of organization ..." [8, p.98].

Jantsch asked his audience to consider whether "science is an autonomous cultural expression" which challenges the conventional interpretation of science founded on individual curiosity and creativity; or whether science "is a social overhead investment" assuming that science "underlies all the purposes of society, and is therefore to be carried out in an organisational structure which is patterned on the conceptual structure of knowledge" [8, p.98].

Similar ideas had already been published in 1939 by John Desmond Bernal (1901-1971) about the scope and purpose of science, technology and public policy [10]. Bernal was an Irish physicist who argued that science should not be an autonomous and protected field of intellectual inquiry; instead it should contribute to improving human livelihood, thus becoming an agent of change rather than isolated in institutions. In 1970, René Dubos (1901-1982), a well-known micro-biologist, expressed his concern about how scientific knowledge could be used to understand human problems [11]. We note that problem solving has been an important motivation for both interdisciplinary and transdisciplinary research, while underlining that specialised disciplinary research has also made important contributions to understanding societal problems.

Nonetheless, about 50 years ago the fundamental limitations of scientific analyses of social policy problems, including public health challenges, were discussed by Horst Rittel and Melvin Webber at a meeting of the American Association for the Advancement of Science in December 1969:

> "The search for scientific bases for confronting problems of social policy is bound to fail, because of the nature of these problems. They are 'wicked problems', whereas science has developed to deal with 'tame' problems" [12, p.155].

The distinction between tame and wicked problems proposed by Rittel and Webber in 1969 is pertinent for the debate about the limitations of science to respond effectively to complex ecological and societal challenges. However, we underscore that science should make specific and unique contributions by providing empirically validated data and information to the general public. This was well illustrated by the contribution of science to identifying and monitoring the depletion of the ozone layer before international organisations, national authorities and private enterprises formulated and implemented effective responses.

2.1 Lessons from Concerted Action on the Ozone Layer

In 1974, scientists discovered that chlorofluorocarbon (CFCs) gases were depleting the ozone in the stratosphere. These gases were common propellant in spray cans, and they were also used as refrigerants and solvents. In the 1980s, scientists observed a measurable thinning of the ozone layer over Antarctica. The scientific discovery that human-made CFCs were a major agent in the depletion of the ozone layer soon followed. On 16th September 1987, politicians from 24 countries signed the Montreal Protocol on Substances that Deplete the Ozone Layer which came into force on 1st January 1989. This Multilateral Agreement established legally binding measures for the national production and consumption of ozone depleting substances. These substances should be phased out of use by the mid-21st century [13,14].

The causes of the depletion of the ozone layer were clearly identified by researchers in disciplines of the natural/physical sciences. However, alone, access to scientific knowledge cannot resolve this global problem; the depletion of the ozone layer is not just a scientific problem (nor one requiring an innovative technical solution), because the know-how required to restore and sustain the constitution of the ozone layer already existed but had to be applied globally. Hence, this is a complex societal problem, comprising ten properties of wicked problems proposed by Rittel and Webber (1973) [12], that requires synergies between political recognition (rather than denial), and pertinent regulatory means and measures (rather than *laissez-faire*), the allocation of appropriate financial incentives, funds and other resources for implementation (for the public good), and broad public adherence based on effective communication. In order to implement these multiple measures, a coalition of scientists, policy-makers, politicians and representatives of the private sector is needed to reach an agreement on the causes before they negotiate how to proceed from empirical knowledge to policy definition and then effective measures prior to implementation. This is precisely what has been achieved by extensive transboundary communication and negotiation processes between scientists and a wide range of actors and institutions at international and national geo-political levels. This transdisciplinary achievement has rarely been repeated but it is sorely needed to respond effectively to the current coronavirus pandemic and other public health challenges.

2.2 Rethinking Human Values

Elsewhere, we have argued that an important barrier to societal change is not lack of data, information, and knowledge about persistent problems. Instead, inertia is grounded in human beliefs, intentionality, preferences, values, and worldviews that influence individual and collective behaviour [15]. We live in a value-laden world; therefore, it is the personal and shared beliefs, experience, perceptions, and values associated with societal problems and global challenges that count, not just the addition of the number of people concerned. Fundamental values should be identified and understood, whereas they are generally excluded from so-called 'objective' scientific research which is claimed to be 'value neutral' and a-political.

In contrast, Rittel and Webber (1973) [12] explained that human beliefs, values, and worldviews are embedded in interpretations of societal problems.

Values convey the relative importance of objects, events, situations, challenges and problems. They are guiding principles that influence human aspirations, choices, intentions, and goals that are embedded in human interpretations of these challenges and problems and responses to them [16]. Individual, societal and fundamental cultural values coexist in precise localities with respect to specific subjects and situations. Dyball and Newell (2015) [17] confirmed that human ecologists have accounted for values, but they have often used the term narrowly, referring to a numerical amount, magnitude or monetary values of objects, or a quantity of material things (e.g. the stocks of ecosystems). We enlarge common interpretations of value to include aesthetic, cultural, moral and spiritual values because these are embedded in people-society-environment-biosphere interrelations that are contextual and dynamic. All decision making involves choices and trade-offs between these different values [12].

Values are incorporated in the anthropo-logic of the human ecology framework we proposed 20 years ago [18]. In the fields of interdisciplinary and transdisciplinary research, whether theoretical or pragmatic, it is difficult to understand why much more attention has not been attributed to improved understanding of the diversity of human beliefs, intentions, priorities, and values that coexist in heterogenous societies. Notably, different, and especially conflicting experiences, intentions, perceptions, and values should be understood and dealt with more effectively than they are by conventional processes for consensus building which rarely confront incommensurability.

3 Core Principles of Transdisciplinary Contributions

From the 1970s, interdisciplinary curricula and research gathered momentum in the cognitive sciences, environmental sciences, gender studies and urban studies [19,20]. However, these contributions were often prescribed only by combinations of scientific knowledge produced by empirical research that applied methods and reasoning developed and validated in the natural/physical sciences, and to a lesser extent, the social/human sciences. The hegemony of scientific knowledge was rarely challenged before the 1990s even though authors including Michael Polanyi (1969) [21] - like Jean Piaget and Erich Jantsch - had challenged positivism and reductionism, and instrumental rationalism that excluded those types of knowledge and ways of knowing that were not scientific, objective, or validated empirically by research protocols.

Between 1970 and 1990, the field of transdisciplinarity did not develop as extensively as interdisciplinarity. In both cases, many project-based contributions in real world situations were defined and implemented by funding agencies for academic researchers who collaborated in increasingly large research consortiums to share knowledge collected, synthesised and validated by disciplinary concepts, methods and protocols in several scientific disciplines. Until the 1990s, extra-scientific types of knowledge were rarely included [22]. When other types of knowledge were introduced there were two dominant currents of thought that proposed how they should be included in theory and practice; the first proposed integration to create a fusion or unity of knowledge, whereas the second promoted joint problem solving by the co-production of knowledge in precise situations. These will be briefly summarised in the next two subsections.

3.1 Integration for Unity of Knowledge

At the International seminar in 1970, Jantsch explained that models of society influence the organization of sciences and disciplines, and this ordering confirmed the importance of human values. From the 1980s, one main current of thought about transdisciplinarity included the search for unity of knowledge which the Preface to the OECD publication described as "... a nostalgia of world unity" [8, p.1]. The theoretical contributions of Basarab Nicolescu and French speaking scholars at the International Centre for Transdisciplinary Research (CIRET), in Paris, founded in 1987, are examples of this current of thought [23,24]. These French language contributions raised important questions about the conventional production of scientific knowledge. Like Piaget and Jantsch, they challenged the fragmentation of discipline-based

knowledge, and they proposed the search for a unity of knowledge. Nicolescu proposed a fusion of different types of knowledge including objective scientific knowledge and subjective experiential knowledge in real-world situations:

> Transdisciplinarity "... concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines" and its aim is the unity of knowledge together with the unity of our being: "Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge" [23, p.44].

Nicolescu also proposed 'multiple levels of Reality' which are complex, dynamic, and emergent. Notably, transdisciplinary processes create shared values between the participants. We consider that these important contributions to the epistemology of transdisciplinary knowledge should acknowledge that human values are fundamental foundations of human agency and culture, and they influence transdisciplinary projects. They may be shared or conflicting, and perhaps incommensurable, as we noted in the case of the current coronavirus pandemic [5]. Although certain human values may be shared between participants during specific projects, others that are incommensurable cannot be integrated, such that fusion or unification is impossible.

3.2 Co-Producing Knowledge for Solving Problems

From the 1990s, a second current of thought about trandisciplinarity followed the issues raised by Jantsch in 1970 about the interrelations between science and society. This became a long and ongoing debate about the science-policy tandem and the science-practice tandem. This current of thought includes post-normal science, co-production of knowledge, and Mode 2. Following Gibbons et al. (1994), [25] debates about Mode 2 science and post-normal science have acknowledged the importance of accounting for the diversity of meanings attributed to real-world projects. In 2001, discussions about Mode 2 science were extended by Mode 2 knowledge and Mode 2 society (Nowotny et al. 2001) [26]. This enlarged discussion extended debates in the 1970s about mutual relations between knowledge creation and the society in which this occurs. Lawrence (2015) [22,27] emphasised that these contributions highlighted the need to explore the cultural and political contexts in which any subject or situation occurs, as well as the human beliefs, intentions, motives, perceptions, and values envisaged to change them, but such contributions are rare.

A German Speaking School, sometimes mislabelled the Zurich School, [28] received large funding in the 1990s from public authorities who sought responses to ecological challenges, such as reducing negative impacts on natural ecosystems, especially loss of biodiversity, whether in alpine, forest, or wetland ecosystems. These interdisciplinary projects in German speaking countries in Europe were dominated by natural/physical scientists who were meant to identify, understand, and propose solutions to specific problems. For example, in 1991, the Swiss National Science Foundation funded the Swiss Environmental Priority Programme which included transdisciplinary research projects [29]. According to explicit terms of reference, this meant that projects had to propose joint problem definition, involving researchers and professional practitioners, joint problem solving and also the joint evaluation of project outcomes by representatives of these two groups. These projects were founded on the assumption that scientific research is the main resource for solving environmental problems provided they included contributions from representatives of society. Many projects followed the custom of social research methods applied after 1945. This meant that many of these projects involved participatory research, or participatory action research. Based on the accumulation of research projects during the 1990s, an International Transdisciplinary Conference was held in Zurich at the Swiss Federal Institute of Technology (ETHZ) in 2000 [30].

The International Transdisciplinary Conference in Zurich included numerous presentations by international participants (not only German speaking), about collaborative projects that involve researchers and non-academic participants from society jointly concerned about resolving problematic situations [30]. These projects were examples of the shift from 'science for society' to 'science with and for society' that had expanded during the 1990 in tandem with research on sustainable development. Many of these projects were managed by scientific researchers in academic institutions who were committed to problem solving.

They were examples of participatory action research that adopted the term transdisciplinary and combined knowledge from different disciplines, sometimes including both the natural/physical sciences and the human/social sciences. However, the content of the post-conference book indicates that many projects rarely employed other core components of transdisciplinarity discussed from the 1970s, notably a common system of axioms using a logic of systemic relations between different types of scientific and extra-scientific knowledge that would be ordered creatively to provide a higher order of understanding than conventional multi- and inter-disciplinary contributions [31].

4 A Transdisciplinary Conceptual Framework

Conceptual frameworks are sets of assumptions, beliefs and concepts that are used implicitly or explicitly to represent real-world phenomena. The value of conceptual frameworks and models as aids to thinking about complex subjects gained importance with the development of systems theory from the 1960s [17]. These frameworks can be derived from literature reviews, observational studies, and other kinds of empirical research. They are representations of complex, real-world subjects. They are useful in order to represent diverse components of extant subjects and situations according to logical patterns and interrelationships. The crucial challenge is to ensure that all key variables are accounted for before the direct and indirect interrelations between them are deciphered.

Figure 1 is a conceptual framework that represents a transdisciplinary triad including three key sets of variables and the mutual interaction between them and other external variables. These three sets of contextual and dynamic variables are not fused or unified but retain their specific and unique characteristics as components of a complex and dynamic system [32]. The components and the mutual relations between them can facilitate our understanding of the incidence and propagation of the coronavirus pandemic in precise localities; for example, the differences between large cities such as Hong Kong, Melbourne, New York, Stockholm, and Taipei.

This framework represents an open system given that the emergence of the pandemic, and its impacts on population health, is influenced by both internal and external variables and dynamic relationships. The framework can be used to identify and monitor pertinent variables as well as the mutual interaction between them. We argue that this has rarely been done systematically to understand the complexity, emergence and diffusion of coronavirus SARS-CoV-2 and Covid-19 disease. One consequence of this conceptual framework is that disciplinary confinement is challenged and the need for intersectoral collaboration is highlighted. Different types of discipline-based research methods - both quantitative and qualitative - are required and should be co-ordinated. Another consequence is that a spectrum of interventions founded on scientific research, public policies, and communal and private initiatives need shared agreements and the allocation of resources prior to interventions. Moreover, these initiatives should be monitored to assess whether desired impacts are achieved; if they are not realized concerted action can facilitate adaptations. This capacity to adjust has been illustrated by evolving public policies and collective behaviors to contain the coronavirus in some cities [5].

This transdisciplinary conceptual framework is broader in content, scope and purpose than the two dominant interpretations of transdisciplinarity mentioned earlier. It acknowledges the relative importance of multiple types of knowledge, know-how and ways of knowing that are contextually embedded in specific localities and situations. It confirms that scientific knowledge can contribute to understanding and monitoring societal challenges and facilitate human well-being. Recalling the debate in 1970, this systemic framework also acknowledges that not only the key sets of variables but also the mutual relations between them should replace linear cause-effect relations. The framework also accommodates heterogenous sets of human beliefs, intentions, perceptions, meanings, and values. It confirms the fundamental role of human values that was recognised in the 1970s but have been devalued since then in much research, policy, and practice [27]. In the wake of the coronavirus pandemic, these distinctions are sorely missed, and many controversies based on false claims and partisan divisions have been published [33].

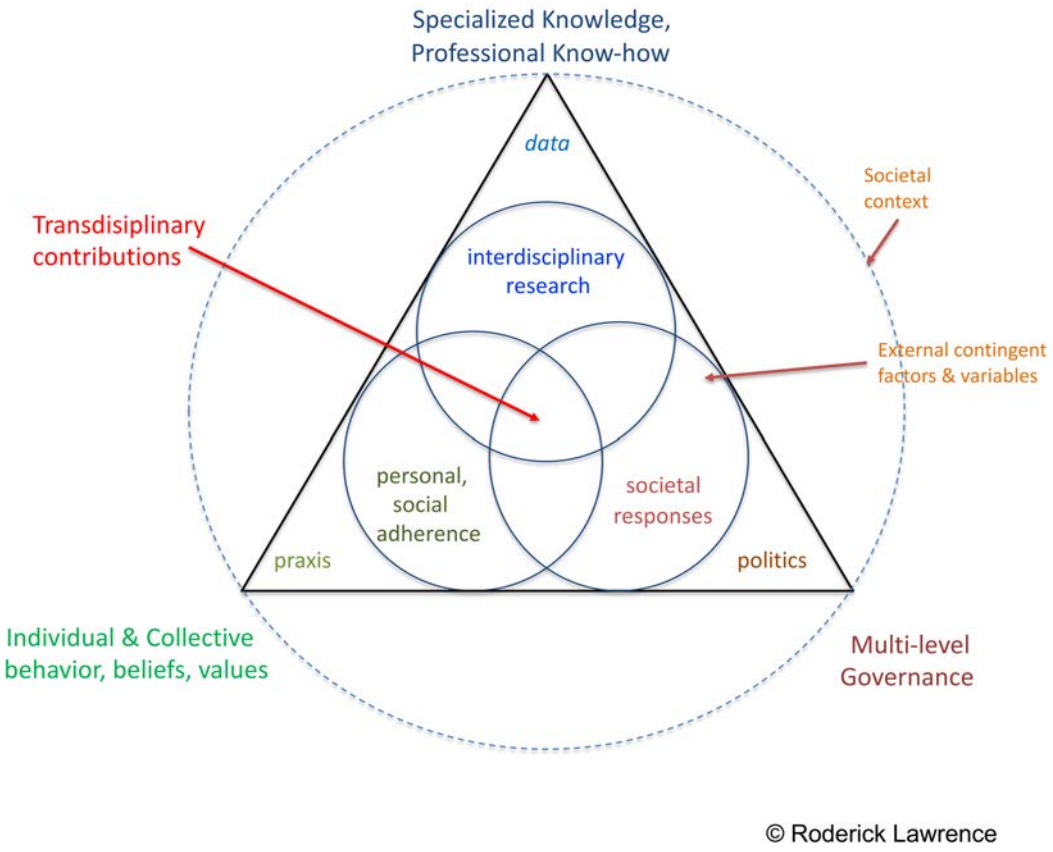

Figure 1: This transdisciplinary conceptual framework represents a complex and dynamic system in which each set of variables has unique properties that are influenced by mutual interactions with other sets of internal and external variables. Effective responses to the emergence, complexity and uncertainty of coronavirus SARS-CoV-2 and the compound health, economic and social impacts of Covid-19 disease, require collective understanding before implementing concerted action involving disciplinary knowledge and professional know-how, several types of resources, coordinated multi-level governance, and individual and collective behaviours, that should be combined in transdisciplinary contributions.

4.1 A Transdisciplinary Triad

In the 1970s, the distinction between societal problems and scientific problems was proposed but rarely adopted in academic research grounded in the science-policy interface. Notably, Rittel and Webber (1973) [12] explained that scientific problems are usually isolated from their extant situations before they are studied, and a solution is proposed using explicit rational knowledge derived from scientific research protocols. They emphasized that scientific problems are meant to be definable, objective, static and neutral. The development of a vaccine for COVID-19 is one example because it will prevent the symptoms of this disease but not eradicate multiple causes of coronavirus. In contrast, Rittel and Webber explained that societal problems of this kind should not be isolated from their cultural, political and temporal context, because they are emergent, systemic and unpredictable, and they have no definite resolution. This is clearly the case with the current coronavirus pandemic. We now have ample evidence that societal responses to the current coronavirus are not determined only by scientific data, information, or protocols as scientists have often assumed. The following paragraphs briefly present and illustrate the three core sets of variables

included in the transdisciplinary triad presented in Figure 1.

First, multi-level governance of this global pandemic, shown at the bottom right of Figure 1, is fundamental and explained in Lawrence (2020) [5]. Governance denotes the way that governments, public administrations, private enterprises, and community associations interpret the pandemic; whether and how they decide collectively to respond to it. In order to reduce known unknowns about this beta-type coronavirus with species jump, the coordinated synthesis of disciplinary expertise, interdisciplinary knowledge, professional know-how and social perceptions is necessary; then this improved understanding can be applied to define the appropriate public health policies and those interventions required to implement effective responses.

The second prerequisite condition, shown at the top of Figure 1, is the importance of specialized biological, epidemiological, medical and veterinary knowledge and professional know-how required to understand and counteract a new virus for which there is still no proven medical or pharmaceutical remedy. The known unknowns about this coronavirus can be identified and studied by applying key principles of One health, Ecological public health, and Planetary health during transdisciplinary research and practice in community settings to 'collect facts on the ground' beyond the walls of laboratories. Lawrence (2020) [5] explained that this pandemic confirms the crucial function and contribution of access to many types of resources when they are needed at the appropriate time; in particular, sufficient stocks of medical equipment; hospital wards with specialized infrastructure; replenished supplies of pharmaceutical products; adequate numbers of trained and qualified medical doctors, nursing staff and auxiliary personnel in hospitals, medical centers and nursing homes for elderly persons; and coordinated uses of all these resources when the virus is first diagnosed in specific localities.

The third prerequisite condition that influences effective national, city and communal responses to counteract the transmission of coronavirus is individual, household and community adherence to behavioural norms and new regulations introduced by national and local governments – see bottom left of Figure 1. Some interventions by governments and public administrations concern regulating personal behaviour and interpersonal contacts. For example, norms and rules include different degrees of confinement, controlled access to outdoor public spaces, markets and shops, social distancing, quarantine, wearing masks and washing hands. Lawrence (2020) [5] explained that public adherence to these norms and rules cannot be assumed owing to cultural, social, and psychological reasons including religious customs, spiritual beliefs, group identity and the notion of individual liberty.

5 Synthesis and Conclusion

The extraordinary situation of the current pandemic should be a catalyst for rethinking the foundations of science-society relationships. The organization and coordinated uses of different types of knowledge need to be reconsidered, while accounting for human beliefs, intentions, meanings, perceptions and values used implicitly and explicitly to fund and conduct scientific research about societal challenges within and beyond the domain of public health (e.g. housing, malnutrition, obesity etc.). We now have ample examples of the strengths and limits of scientific research to deal with the current SARS-CoV-2 pandemic knowing that the emergent, complex and unpredictable nature of this coronavirus cannot be prescribed by conventional scientific protocols. It should also be the occasion for sceptics of interdisciplinary research and transdisciplinary projects in and beyond the medical and health sectors to question their adherence to disciplinary confinement based on the limitations and strengths of uncoordinated sector-based approaches that have been implemented to tackle the current pandemic.

We underline that the capacity of scientific knowledge alone to provide a pertinent framework for understanding and responding to the current pandemic should not be taken for granted. There is an urgent need for more in-depth and wholistic understanding of the biological, cultural, medical, para-medical, and societal variables that influence health and quality of life in specific localities. This means that many types of knowledge and ways of knowing need to be understood. The transdisciplinary triad of multilevel governance; multiple types of knowledge, know-how and resources; and individual and community adherence

to behavioral norms and rules, should become the foundations of more coordinated, systemic and communal responses to public health risks and vulnerability in these and future extraordinary circumstances.

5.1 Conclusion

During the last 20 years, it has been increasingly realized that, alone, the accumulation of scientific knowledge, and professional expertise, will not automatically prescribe individual or collective responses to persistent problems and societal challenges [34]. The joint contribution and commitment of pertinent actors and institutions in both the public and private sectors is necessary to implement effective responses to societal challenges including the current coronavirus pandemic. It is crucial to identify and understand the multiple types of knowledge, know-how, and ways of knowing that coexist and are pertinent when defining and implementing societal responses.

Finally, since the 1970s, the ongoing quarrel about the advantages of collaborative research projects compared with conventional disciplinary contributions has focused on the breadth and depth of knowledge required to understand and respond to real-world challenges that surpass the boundaries of any single discipline. This narrow focus is founded on a common assumption that these societal challenges are inscribed within several (not one) disciplinary knowledge domain. Major interventions, such as the positive response to the current coronavirus pandemic in several cities and countries, confirm that the subject is more complex: In principle, scientific knowledge is only one component of collective thinking and action that are inscribed in a cultural context with a specific political agenda. Consequently, transdisciplinary contributions can make a crucial contribution in defining the contingent factors that enable or inhibit decision making to deal with societal challenges in our post-truth era. This has been well documented by a recent publication of the OECD [35]; it presents 28 transdisciplinary projects 50 years after the international seminar in Nice discussed the pertinence of such contributions.

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